

Scilab Textbook Companion for  
Internal Combustion Engines  
by R. K. Rajput<sup>1</sup>

Created by  
Kvnkc Sharma  
B tech  
Mechanical Engineering  
K L University  
College Teacher  
G L Narayana  
Cross-Checked by  
Chaitanya

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# **Book Description**

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Scilab numbering policy used in this document and the relation to the above book.

**Exa** Example (Solved example)

**Eqn** Equation (Particular equation of the above book)

**AP** Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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# Chapter 3

## Air Standard cycles

Scilab code Exa 3.1 Carnot engine

```
1 clc;funcprot(0); //EXAMPLE 3.1
2 // Initialisation of Variables
3 t1=673; ..... //Max temp in Kelvin
4 t3=313; ..... //Min temp in Kelvin
5 W=130; ..... //Work produced in kJ
6 //calculations
7 etath=(t1-t3)/t1; ..... // Engine thermal
   efficiency
8 disp(etath*100,"Engine thermal efficiency in %:")
9 ha=W/etath; ..... //Heat added in kJ
10 disp(ha,"Head added in kJ:")
11 dels=(ha-W)/t3; ..... //Change in entropy
12 disp(dels,"Change in entropy in kJ/K")
```

---

Scilab code Exa 3.2 Carnot power cycle

```

Scilab 5.4.1 Console
File Edit Control Applications ?
File Browser Scilab 5.4.1 Console
Name : C:\Users\Varashna\Documents\

Documents
.. 
Custom Office Templates
Inventor Server SDK ACAD 2014
My Games
My Received Files
Samsung
SolidWorks Downloads
UDC Output Files
ptcselab.bak
ptcselab.log
Recycling Composites in an Easy and Economical
std.out
trial.txt.1
trial.txt.2
trial.txt.3

Engine thermal efficiency in %:
53.491828
Head added in kJ:
243.02778
Change in entropy in kJ/K:
0.3611111
-->

```

The screenshot shows the Scilab 5.4.1 console window. The file browser sidebar lists various documents and log files. The main console area displays the calculation of the thermal efficiency of a Carnot engine, resulting in 53.491828% efficiency with a head of 243.02778 kJ and a change in entropy of 0.3611111 kJ/K.

Figure 3.1: Carnot engine

```

Scilab 5.4.1 Console
File Edit Control Applications ?
File Browser Scilab 5.4.1 Console
Name : C:\Users\Varashna\Documents\

Documents
.. 
Custom Office Templates
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ptcselab.bak
ptcselab.log
Recycling Composites in an Easy and Economical
std.out
trial.txt.1
trial.txt.2
trial.txt.3

The maximum temperature in Kelvin:
585.36585
The minimum temperature in Kelvin:
292.68293
Volume at the end of isothermal expansion in m^3:
0.1931916
Process Heat transfer
Isothermal expansion 40 kJ
Adiabatic reversible expansion 0 kJ
Isothermal compression -40 kJ
Adiabatic reversible compression 0 kJ
-->

```

The screenshot shows the Scilab 5.4.1 console window. The file browser sidebar lists various documents and log files. The main console area displays the maximum and minimum temperatures in Kelvin (585.36585 K and 292.68293 K), the volume at the end of isothermal expansion (0.1931916 m<sup>3</sup>), and a table of process heat transfers for a Carnot cycle. The processes listed are Isothermal expansion, Adiabatic reversible expansion, Isothermal compression, and Adiabatic reversible compression, with their respective heat transfer values in kJ.

Figure 3.2: Carnot power cycle

```

1 clc;funcprot(0); //EXAMPLE 3.2
2 // Initialisation of Variables
3 m=0.5;.....//Mass of air in kg
4 etath=0.5;.....//Thermal efficiency of
   engine
5 hie=40;.....//Heat transferred during
   isothermal expansion in kJ
6 p1=7;.....//Pressure in bar at the
   beginning of expansion
7 v1=0.12;.....//Volume in m^3 at the
   beginning of expansion
8 cv=0.721;.....// Specific heat at
   constant volume in kJ/kgK
9 cp=1.008;.....// Specific heat at
   constant pressure in kJ/kgK
10 R=287;.....//Gas constant in J/kgK
11 //Calculations
12 t1=(p1*10^5*v1)/(R*m);.....//Max temp
   in K
13 t2=t1*(1-etath);.....//Min temp in
   K
14 disp(t1,"The maximum temperature in Kelvin:")
15 disp(t2,"The minimum temperature in Kelvin:")
16 v2=(%e^((hie*1000)/(m*R*t1)))*v1;.....
   //Volume at the end of isothermal expansion in m
   ^3
17 disp(v2,"Volume at the end of isothermal expansion
   in m^3")
18 printf("\n\n")
19 printf("Process
   transfer\n")
20 printf("-----\n")
21 printf(" Isothermal expansion
   %d kJ\n",hie)
22 printf(" Adiabatic reversible expansion
   %d kJ\n",0)

```

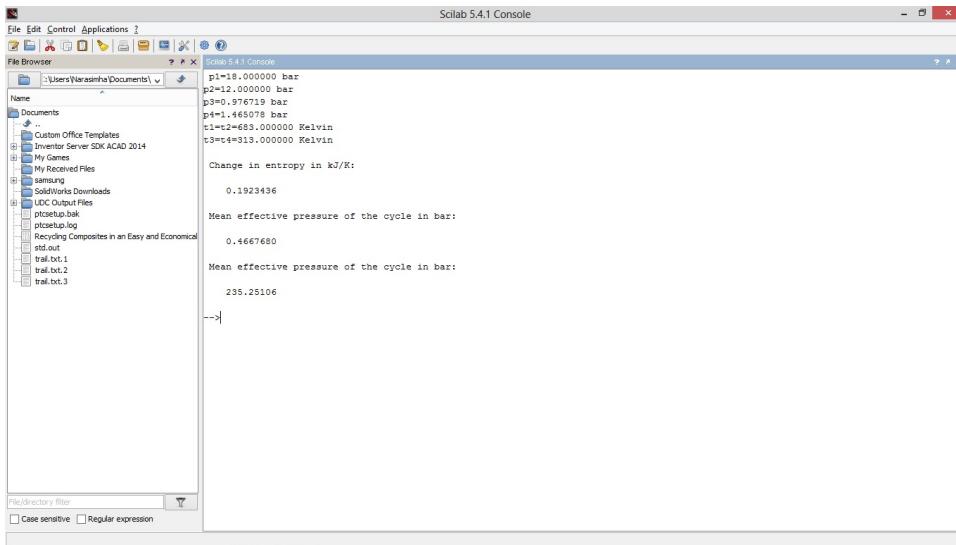


Figure 3.3: Efficiencies of carnot cycle

---

```

23 printf("Isothermal compression
           %d kJ\n",-hie)
24 printf("Adiabatic reversible compressions
           %d kJ",0)

```

---

### Scilab code Exa 3.3 Efficiencies of carnot cycle

```

1 clc;funcprot(0); //EXAMPLE 3.3
2 // Initialisation of Variables
3 p1=18;..... //Maximum pressure in bar
4 t1=410+273;..... //Maximum temperature in
   Kelvin
5 ric=6;..... //Ratio of isentropic
   compression
6 rie=1.5;..... //Ratio of isothermal
   expansion

```

```

7 v1=0.18;.....//Volume of air at the
beginning of expansion
8 ga=1.4;.....//Degree of freedom of gas
9 R=287;.....//Gas constant in J/kgK
10 nc=210;.....//no of working cycles
11 //Calculations
12
13 t4=t1/(ric^(ga-1));.....//Min temp in K
14 t3=t4;
15 p4=p1/(ric^ga);.....//Min pressure in
bar
16 p2=p1/rie;.....//pressure of gas
before isentropic expansion in bar
17 p3=p2*((1/6)^ga);.....//Pressure of gas
after isentropic expansion in bar
18 printf("p1=%f bar \n p2=%f bar \n p3=%f bar \n p4=%f
bar \n t1=t2=%f Kelvin \n t3=t4=%f Kelvin \n",p1,p2
,p3,p4,t1,t3)
19 dels=(p1*10^5*v1*log(rie))/(1000*t1)
;.....//Change in entropy
20 disp(dels,"Change in entropy in kJ/K:")
21 qs=t1*dels;.....//Heat supplied in
kJ
22 Qr=t4*dels;.....//Heat rejected in
kJ
23 eta=(qs-Qr)/qs;.....//Efficiency of the cycle
24 v3byv1=ric*rie;Vs=(v3byv1-1)*v1;.....//
Stroke volume
25 pm=((qs-Qr)*10^3)/(Vs*10^5);.....//Mean effective
pressure of the cycle in bar
26 disp(pm,"Mean effective pressure of the cycle in bar:
")
27 P=(qs-Qr)*(nc/60);.....//Power
of engine
28 disp(P,"Mean effective pressure of the cycle in bar:
")

```

---

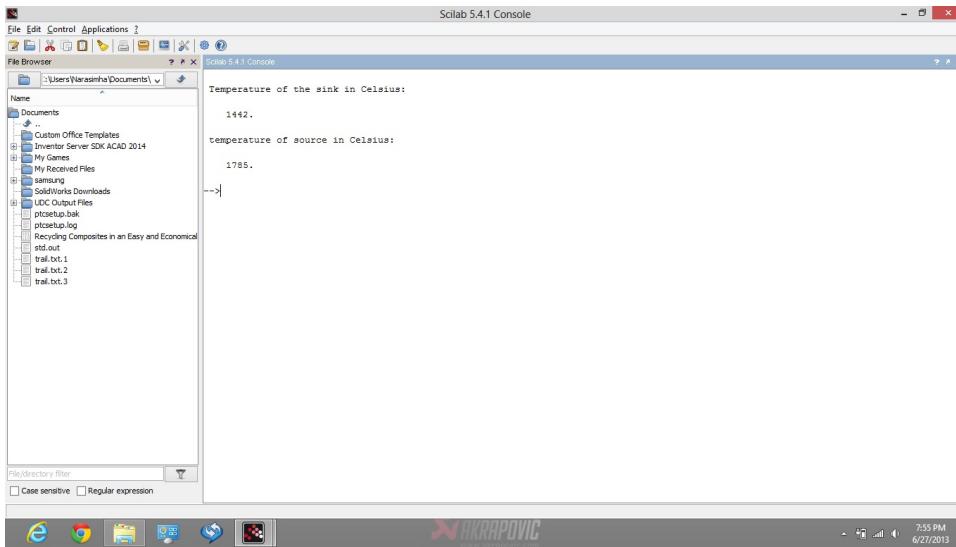


Figure 3.4: Carnot Engine

### Scilab code Exa 3.4 Carnot Engine

```

1 clc;funcprot(0); //EXAMPLE 3.4
2 // Initialisation of Variables
3 eta=1/6;.....// Efficiency of the
   engine
4 rts=70;.....//The amount of temp which
   is reduced in the sink in C
5 //Calculation
6 t1byt2=1/(1-eta);
7 t2=(rts+273)/((2*eta*t1byt2)-t1byt2+1);.....
   //Temperature of the sink in K
8 disp(t2-273,"Temperature of the sink in Celsius:")
9 t1=t1byt2*t2;.....//Temperature of source
   in K

```

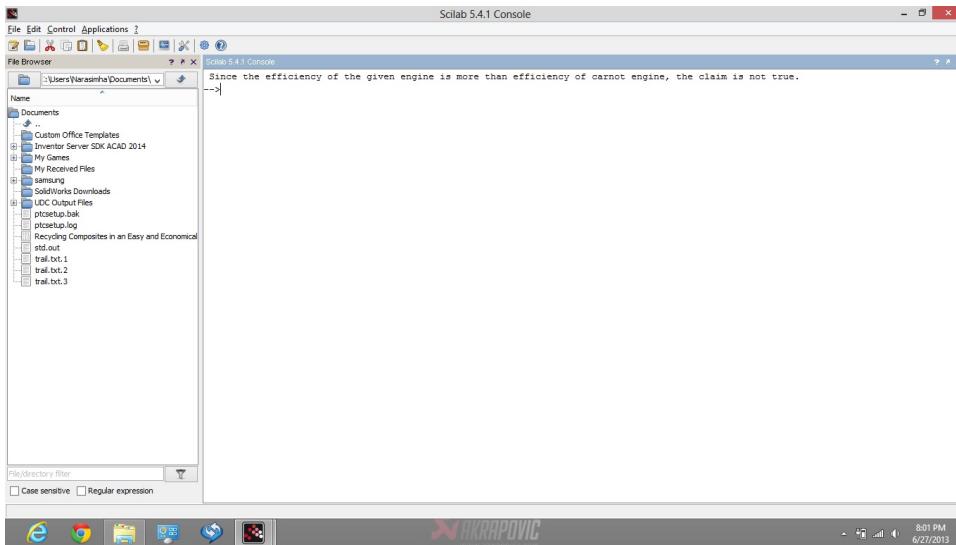


Figure 3.5: Carnot Engine

---

```
10 disp(t1-273,"temperature of source in Celsius:")
```

---

### Scilab code Exa 3.5 Carnot Engine

```

1 clc;funcprot(0); //EXAMPLE 3.5
2 // Initialisation of Variables
3 t1=1990; ..... //Temperature of the
      heat source in K
4 t2=850; ..... //Temperature of the sink
      in K
5 Q=32.5; ..... //Heat supplied in kJ/min
6 P=0.4; ..... //Power developed by the
      engine in kW
7 //Calculations
8 eta=1-(t2/t1); ..... //Efficiency of carnot
      engine

```

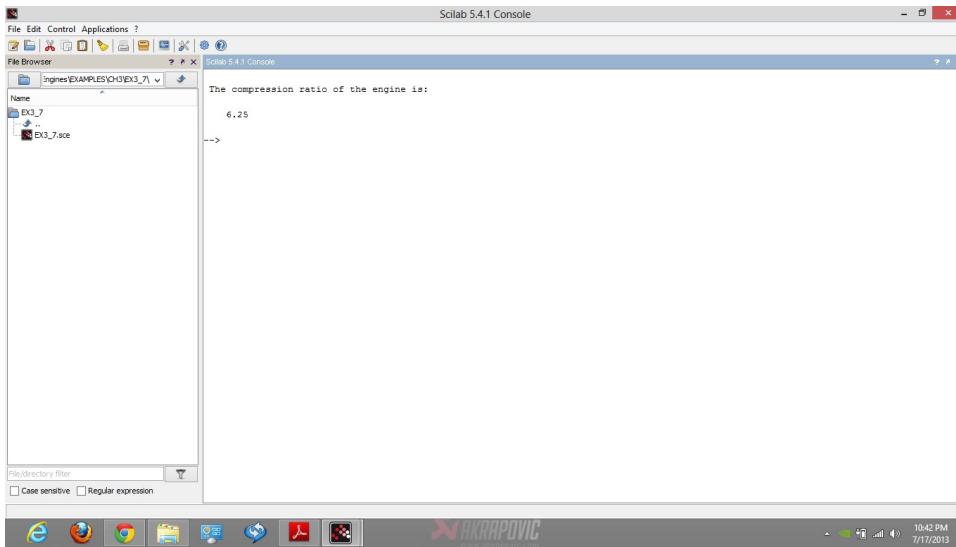


Figure 3.6: Otto cycle

```

9 etath=P/(Q/60);.....// Efficiency of the
   given engine
10 if (etath>eta) then printf("Since the efficiency of
      the given engine is more than efficiency of
      carnot engine , the claim is not true .")
11 end

```

---

### Scilab code Exa 3.7 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.7
2 // Initialisation of Variables
3 etaotto=0.6;.....// Efficiency of otto engine
4 ga=1.5;.....//Ratio of specific heats
5 //Calculations
6 r=(1/(1-etaotto))^(1/(ga-1));.....//Compression ratio

```



Figure 3.7: Otto cycle

---

```
7 disp(r,"The compression ratio of the engine is:")
```

---

### Scilab code Exa 3.8 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.8
2 // Initialisation of Variables
3 D=0.25;..... //Engine bore in m
4 L=0.375;..... //Engine stroke in m
5 Vc=0.00263;..... //Clearence volume in m^3
6 p1=1;..... //Initial pressure in bar
7 t1=323;..... //Initial temperature in K
8 p3=25;..... //Max pressure in bar
9 ga=1.4;..... //Ratio of specific heats
10 //Calculations
11 Vs=(%pi/4)*D*D*L;..... //Swept volume in m
^3
```

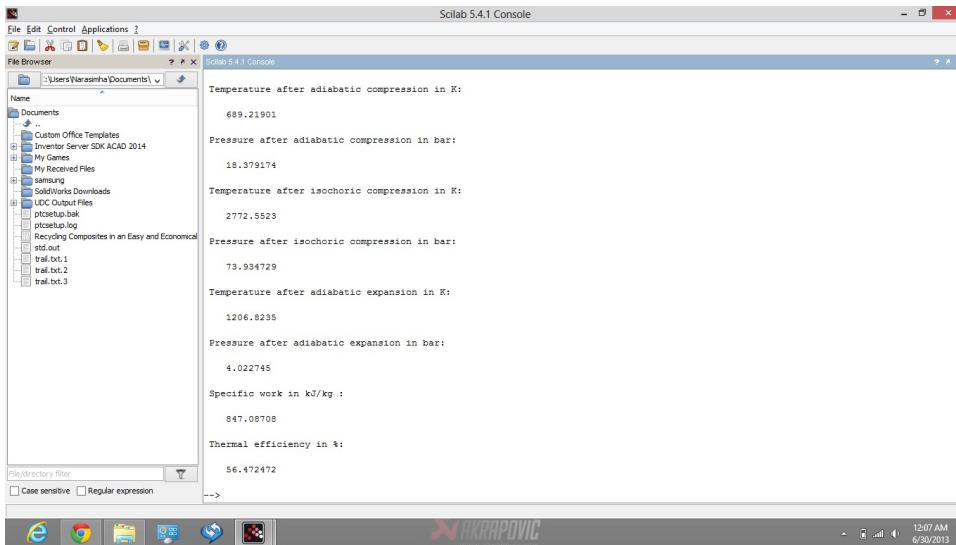


Figure 3.8: Otto Cycle

```

12 r=round((Vs+Vc)/Vc);.....//  

     Compression ratio  

13 etaotto=1-(1/(r^(ga-1)));.....//Air  

     standard efficiency of otto cycle  

14 disp(etaotto*100,"The air standard efficiency of  

     otto cycle in %:")  

15 p2=p1*((r)^ga);  

16 rp=p3/p2;.....//Pressure ratio  

17 pm=(p1*r*((r^(ga-1))-1)*(rp-1))/((ga-1)*(r-1))  

     ;.....//Mean effective pressure in bar  

18 disp(pm,"Mean effective pressure in bar:")

```

---

### Scilab code Exa 3.9 Otto Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.9  

2 // Initialisation of Variables

```

```

3 p1=1;.....//Pressure in bar
4 t1=300;.....//Temperature in K
5 Q=1500;.....//Heat added in kJ/kg
6 r=8;.....//Compression ratio
7 Cv=0.72;.....//Specific heat at
    constant volume
8 ga=1.4;.....//Ratio of specific
    heats
9 //Calculations
10 t2=t1*(r)^(ga-1);.....//Temperature after
    adiabatic compression in K
11 p2=p1*(r^ga);.....//Pressure after
    adiabatic compression in bar
12 t3=(Q/Cv)+t2;.....//Temperature after
    isochoric compression in K
13 p3=(p2*t3)/t2;.....//Pressure after
    isochoric compression in bar
14 t4=t3/(r^(ga-1));.....//Temperature after adiabatic expansion in K
15 p4=p3*(1/(r^(ga)));.....//Pressure after
    adiabatic expansion in bar
16 Ws=Cv*(t3-t2-t4+t1);.....//Specific work in kJ/
    kg
17 etath=1-(1/(r^(ga-1)));.....//Thermal
    efficiency
18 disp(t2,"Temperature after adiabatic compression in
    K:")
19 disp(p2,"Pressure after adiabatic compression in bar
    :")
20 disp(t3,"Temperature after isochoric compression in
    K:")
21 disp(p3,"Pressure after isochoric compression in bar
    :")
22 disp(t4,"Temperature after adiabatic expansion in K:
    ")
23 disp(p4,"Pressure after adiabatic expansion in bar:")
24 disp(Ws,"Specific work in kJ/kg :")

```

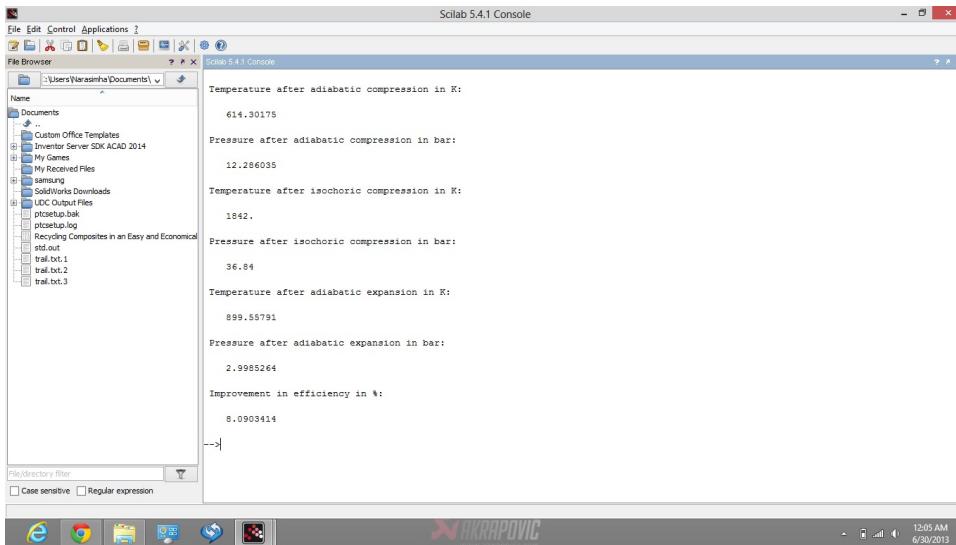


Figure 3.9: Otto cycle and Atkinson cycle

---

25 **disp**(*etath\*100*, "Thermal efficiency in %:")

---

### Scilab code Exa 3.10 Otto cycle and Atkinson cycle

```

1 clc;funcprot(0); //EXAMPLE 3.10
2 // Initialisation of Variables
3 r=6;..... //Compression ratio
4 p1=1;..... //Pressure after isochoric
   expansion in bar
5 t1=300;..... //Temperature after isochoric
   expansion in K
6 t3=1842;..... //Temperature after isochoric
   compression in K
7 ga=1.4;..... //Ratio of specific heats
8 //Calculations

```

```

9 p2=p1*(r^ga);.....// Pressure after
    adiabatic compression in bar
10 t2=t1*(r^(ga-1));.....//Temperature after
    adiabatic compression in K
11 p3=p2*(t3/t2);.....// pressure after
    isochoric compression in bar
12 t4=t3/(r^(ga-1));.....//Temperature after
    adiabatic expansion in K
13 p4=p3*(1/(r^(ga)));.....// Pressure after
    adiabatic expansion in bar
14 etaotto=1-(1/(r^(ga-1)));.....// Efficiency of
    otto cycle
15 p5=p1;
16 t5=((p5/p3)^((ga-1)/ga))*t3;.....// 
    Atkinson cycle temp after further adiabatic
    expansion in K
17 etatk=1-((ga*(t5-t1))/(t3-t2));.....//
    Efficiency of atkinson cycle
18 disp(t2,"Temperature after adiabatic compression in
    K:")
19 disp(p2,"Pressure after adiabatic compression in bar
    :")
20 disp(t3,"Temperature after isochoric compression in
    K:")
21 disp(p3,"Pressure after isochoric compression in bar
    :")
22 disp(t4,"Temperature after adiabatic expansion in K:
    ")
23 disp(p4,"Pressure after adiabatic expansion in bar:")
24 disp((etatk-etaotto)*100,"Improvement in efficiency
    in %:")

```

---

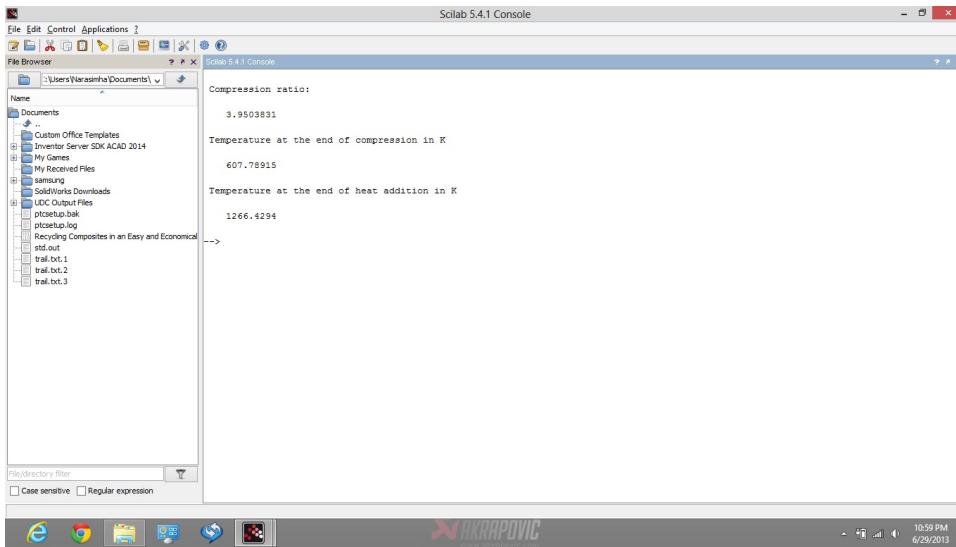


Figure 3.10: Otto cycle

### Scilab code Exa 3.11 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.11
2 // Initialisation of Variables
3 p1=1;.....//Initial pressure in bar
4 t1=343;.....//Initial temperature in K
5 p2=7;.....//Pressure after adiabatic
   compression
6 Qs=465;.....//Heat addition at constant
   volume in kJ/kg
7 cp=1;.....//Specific heat at
   constant pressure in kJ/kg
8 cv=0.706;.....//Specific heat at
   constant volume in kJ/kg
9 ga=cp/cv;.....//Ratio of specific heats
10 //Calculations
11 r=(p2/p1)^(1/ga);.....//Compression ratio
12 t2=t1*(r^(ga-1));.....//Temperature
   at the end of compression in K
13 t3=t2+(Qs/cv);.....//Temperature at the end

```

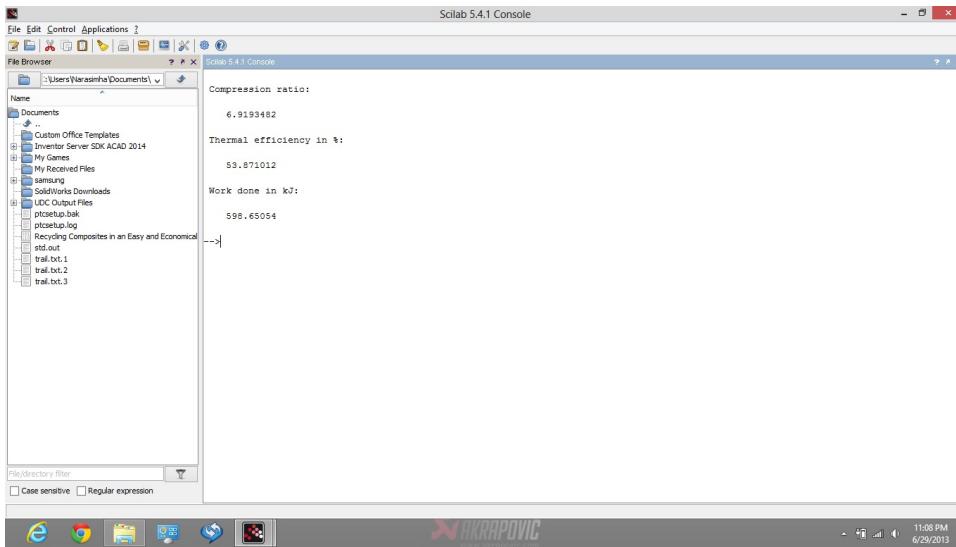


Figure 3.11: Otto cycle

```

          of heat addition in K
14 disp(r,"Compression ratio:")
15 disp(t2,"Temperature at the end of compression in K"
      )
16 disp(t3,"Temperature at the end of heat addition in
      K")

```

---

### Scilab code Exa 3.12 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.12
2 // Initialisation of Variables
3 ga=1.4;.....//Ratio of specific heats
4 p2byp1=15;.....//Ratio pressure at the end
      of compression to that of pressure at the start
5 t1=311;.....//Initial temperature in K
6 t3=2223;.....//Maximum temperature in K

```

```

7 R=0.287;.....//Gas constant in kJ/kg K
8 //Calculations
9 r=p2byp1^(1/ga);.....//Compression ratio
10 etath=1-(1/(r^(ga-1)));.....//Thermal
    efficiency
11 t2=t1*(r^(ga-1));.....//Temperature at the
    end of compression in K
12 t4=t3/(r^(ga-1));.....//Temperature at the end
    of isothermal expansion in K
13 cv=R/(ga-1);.....//Specific heat at
    constant volume in kJ/kg
14 Q=cv*(t3-t2);.....//Heat supplied in kJ/kg
    of air
15 Qr=cv*(t4-t1);.....//Heat rejected in kJ
    /kg of air
16 W=Q-Qr;.....//Work done
17 disp(r,"Compression ratio:")
18 disp(etath*100,"Thermal efficiency in %:")
19 disp(W,"Work done in kJ:")

```

---

### Scilab code Exa 3.13 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.13
2 // Initialisation of Variables
3 v1=0.45;.....//Initial volume in m^3
4 p1=1;.....//Initial pressure in bar
5 t1=303;.....//Initial temperature in K
6 p2=11;.....//Pressure at the end of
    compression stroke in bar
7 Q=210;.....//heat added at constant
    volume in kJ
8 N=210;.....//No of working cycles per
    min

```

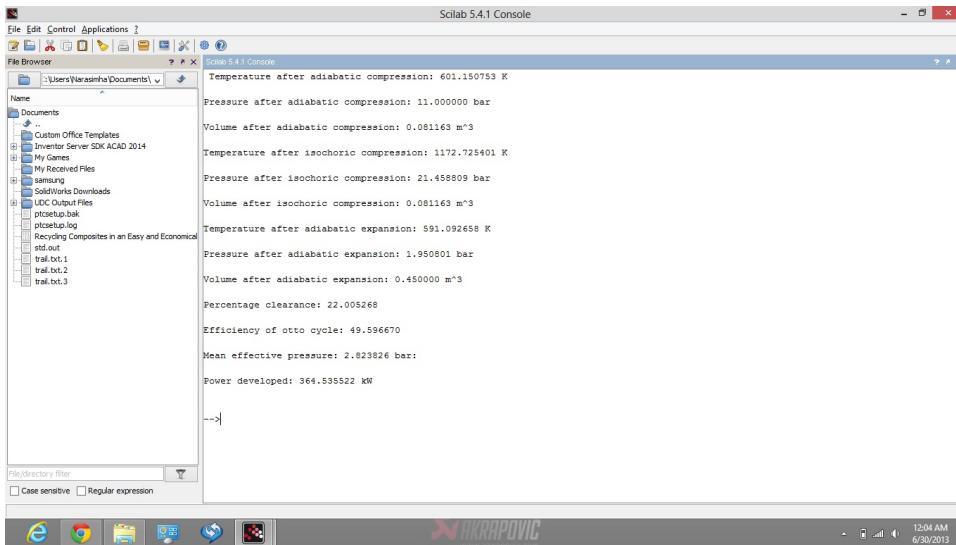


Figure 3.12: Otto cycle

```

9 ga=1.4;..... //Ratio of specific heats
10 R=287;..... //Gas constant in kJ/kgK
11 cv=0.71;..... //Specific heat at constant
    volume in kJ/kg
12 //Calculations
13 r=(p2/p1)^(1/ga);..... //Compression
    ratio
14 t2=t1*(r^(ga-1));..... //Temperature at
    the end of adiabatic compression
15 v2=(t2*p1*v1)/(t1*p2);..... //Volume at
    the end of adiabatic compression in m^3
16 m=(p1*v1*10^5)/(R*t1);..... //Mass of
    engine fluid in kg
17 t3=(Q/(m*cv))+t2;..... //Temperature at
    the end of isochoric compression in K
18 p3=(t3/t2)*p2;..... //Pressure at the end
    of isochoric compression in bar
19 v3=v2;
20 t4=t3*(1/r)^(ga-1);..... //Temperature
    at the end of adiabatic expansion in K

```

```

21 p4=p3*(1/r)^ga;.....// Pressure at
    the end of adiabatic expansion in bar
22 v4=v1;
23 pc=(v2*100)/(v1-v2);.....// Percentage
    clearance
24 etaotto=1-(1/(r^(ga-1)));.....//
    Efficiency of otto cycle
25 Qr=m*cv*(t4-t1);.....//
    Heat rejected in kJ/kg
26 pm=((Q-Qr)*1000)/((v1-v2)*100000);....//Mean
    effective pressure in bar
27 P=(Q-Qr)*(N/60);.....//Power
    developed in kW
28 printf("Temperature after adiabatic compression: %f
    K\n\n",t2)
29 printf("Pressure after adiabatic compression: %f bar
    \n\n",p2)
30 printf("Volume after adiabatic compression: %f m^3\n
    \n",v2)
31 printf("Temperature after isochoric compression: %f
    K\n\n",t3)
32 printf("Pressure after isochoric compression: %f bar
    \n\n",p3)
33 printf("Volume after isochoric compression: %f m^3\n
    \n",v3)
34 printf("Temperature after adiabatic expansion: %f K\
    n\n",t4)
35 printf("Pressure after adiabatic expansion: %f bar\n
    \n",p4)
36 printf("Volume after adiabatic expansion: %f m^3\n\n
    ",v4)
37 printf("Percentage clearance: %f\n\n",pc)
38 printf("Efficiency of otto cycle: %f\n\n",etaotto
    *100)
39 printf("Mean effective pressure: %f bar:\n\n",pm)
40 printf("Power developed: %f kW\n\n",P)

```

---



Figure 3.13: Otto cycle

### Scilab code Exa 3.14 Otto cycle

```

1 clc;funcprot(0); //EXAMPLE 3.14
2 // Initialisation of Variables
3 t1=310; ..... //Min temperature in K
4 t3=1220; ..... //Max temperature in K
5 ga=1.4; ..... //Ratio of specific heats for
air
6 cph=5.22; ..... // Specific heat at constant
volume for helium in kJ/kg
7 cvh=3.13; ..... // Specific heat at constant
pressure for helium in kJ/kg
8 //Calculations
9 r=(t3/t1)^(1/((ga-1)*2)); ..... //Compression
ratio

```

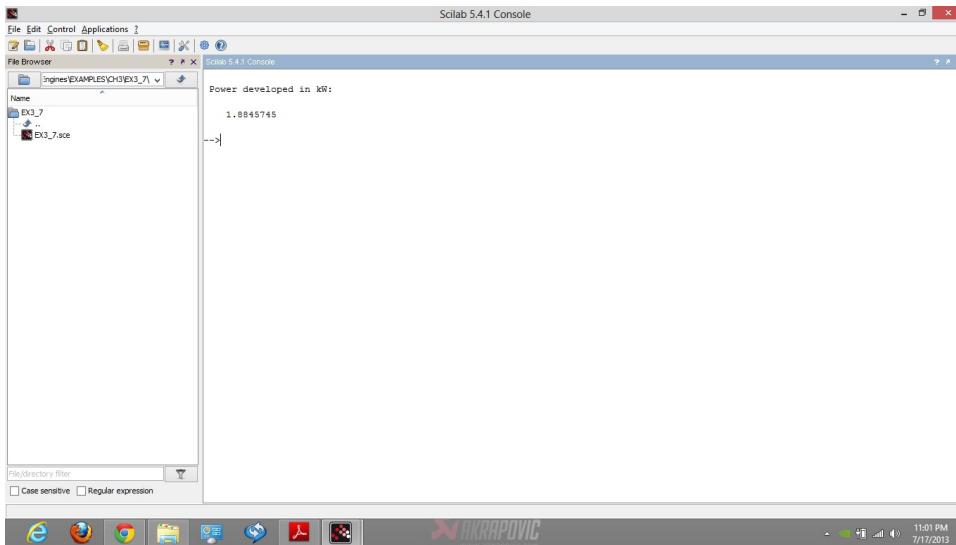


Figure 3.14: Otto cycle

```

10 etaotto=1-(1/(r^(ga-1)));..... // Air
    standard efficiency
11 gah=cph/cvh;..... // Ratio of specific
    heats for Helium
12 rh=(t3/t1)^(1/((gah-1)*2));..... // 
    Compression ratio when Helium is used
13 etaottoh=1-(1/(rh^(gah-1)));..... // Air
    standard efficiency when Helium is used
14 disp(etaotto*100,"Air standard efficiency of the
    engine in %:")
15 if ((round (etaotto)- round (etaottoh)) == 0) then
    disp("There is no change in efficiency when
        Helium is used as working fluid instead of air")
16 end

```

---

### Scilab code Exa 3.15 Otto cycle

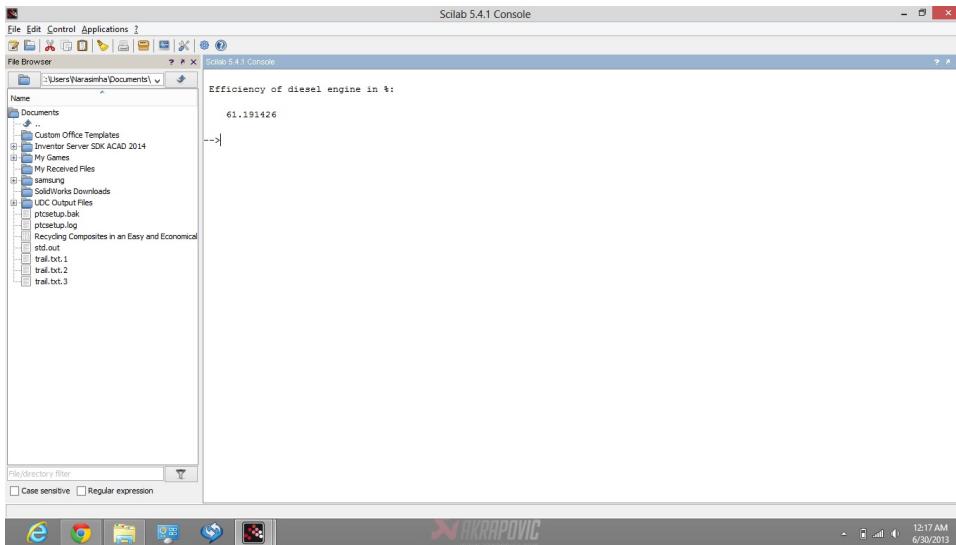


Figure 3.15: Diesel Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.15
2 // Initialisation of Variables
3 t1=310;.....//Minimum temperature in K
4 t3=1450;.....//maximum temperature in K
5 m=0.38;.....//Mass of working fluid in kg
6 cv=0.71;.....// Specific heat at constant
    volume in kJ/kg
7 // Calculations
8 t4=sqrt(t1*t3);.....//Temperature at the end
    of adiabatic expansion in K
9 t2=t4;
10 W=cv*(t3-t2-t4+t1);.....//Work done in
    kJ/kg
11 P=W*(m/60);.....//Power developed in kW
12 disp (P,"Power developed in kW:")

```

---

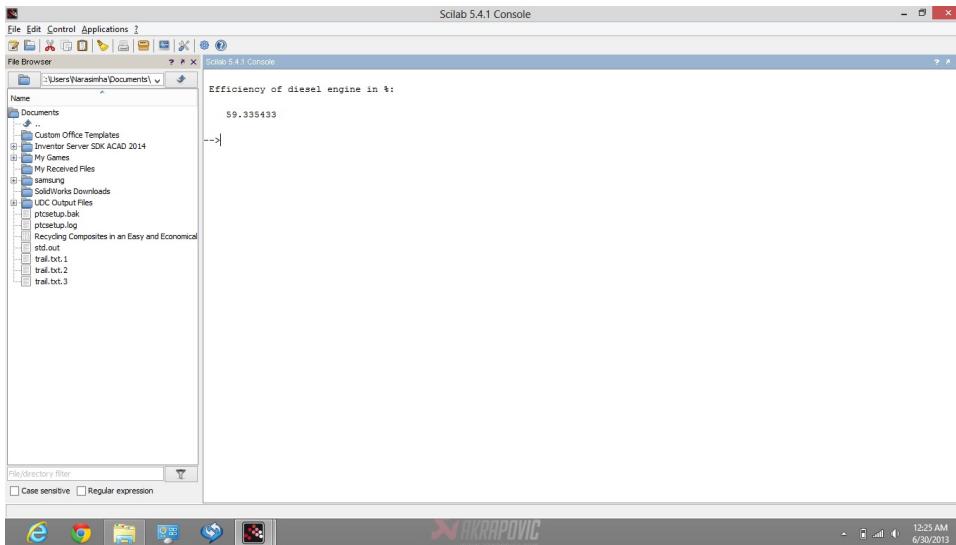


Figure 3.16: Diesel Cycle

### Scilab code Exa 3.17 Diesel Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.17
2 // Initialisation of Variables
3 r=15;.....//Compression ratio
4 ga=1.4;.....//Ratio os specific heats for
   air
5 perQ=6;.....//Heat addition at constant
   pressure takes place at 6% of stroke
6 //Calculations
7 rho=1+((perQ/100)*(r-1));.....//Cut off
   ratio
8 etad=1-(((rho^ga)-1)/(rho-1))*(1/(ga*(r^(ga-1))));.....//Efficiency of diesel engine
9 disp(etad*100," Efficiency of diesel engine in %:")

```

---

### Scilab code Exa 3.18 Diesel Cycle

```
1 clc;funcprot(0); //EXAMPLE 3.18
2 // Initialisation of Variables
3 L=0.25;.....//Engine stroke in m
4 D=0.15;.....//Engine bore in m
5 v2=0.0004;.....//Clearance volume in m^3
6 pers=5;.....//Percentage of stroke when
    fuel injection occurs
7 ga=1.4;.....//Ratio of specific heats
8 //Calculations
9 Vs=(%pi/4)*D*D*L;.....//Swept volume in m^3
10 Vt=Vs+v2;.....//Total cylinder volume
    in m^3
11 v3=v2+((pers/100)*Vs);.....//Volume at
    point of cut off
12 rho=v3/v2;.....//Cut off ratio
13 r=1+(Vs/v2);.....//Compression ratio
14 etad=1-(((rho^ga)-1)/(rho-1))*(1/(ga*(r^(ga-1))))*
    .....//Efficiency of diesel engine
15 disp(etad*100,"Efficiency of diesel engine in %:")
```

---

### Scilab code Exa 3.19 Diesel Cycle

```
1 clc;funcprot(0); //EXAMPLE 3.19
2 // Initialisation of Variables
3 r=14;.....//Compression ratio
4 pers1=5;.....//Percentage of stroke when
    fuel cut off occurs
5 pers2=8;.....//Percentage of stroke when
    delayed fuel cut off occurs
6 v2=1;.....//Clearance volume in m^3
7 ga=1.4;.....//Ratio of specific heats
```

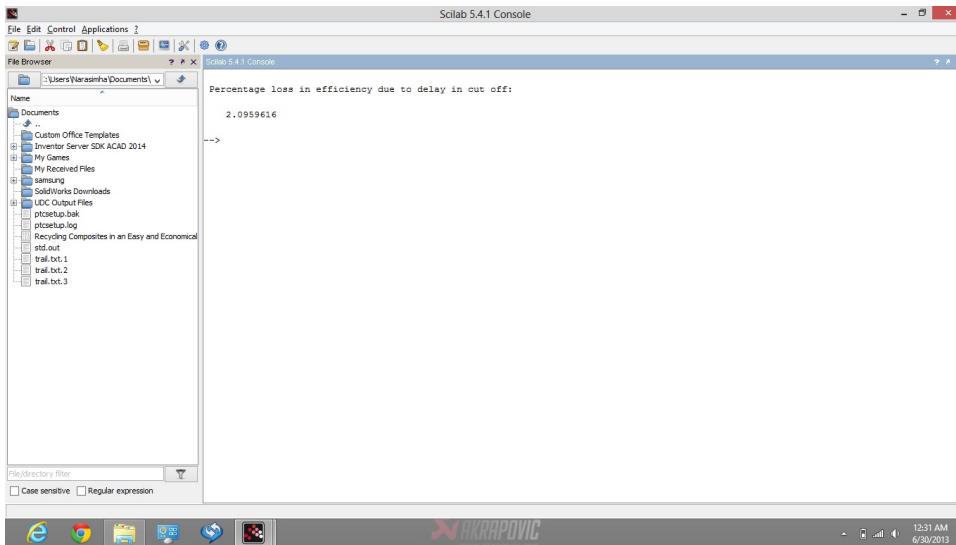


Figure 3.17: Diesel Cycle

```

8 // Calculations
9 // When the fuel is cut off at 5 %
10 rho1=((pers1/100)*(r-1))+1;.....//Cut off
    ratio
11 etad1=1-(((rho1^ga)-1)/(rho1-1))*(1/(ga*(r^(ga-1))))
    );.....//Efficiency of diesel
    engine
12 // When the fuel is cut off at 8 %
13 rho2=((pers2/100)*(r-1))+1;.....// Delayed
    Cut off ratio
14 etad2=1-(((rho2^ga)-1)/(rho2-1))*(1/(ga*(r^(ga-1))))
    );.....//Efficiency of diesel
    engine when cut off ratio is delayed
15 disp((etad1-etad2)*100,"Percentage loss in
    efficiency due to delay in cut off:")

```

---

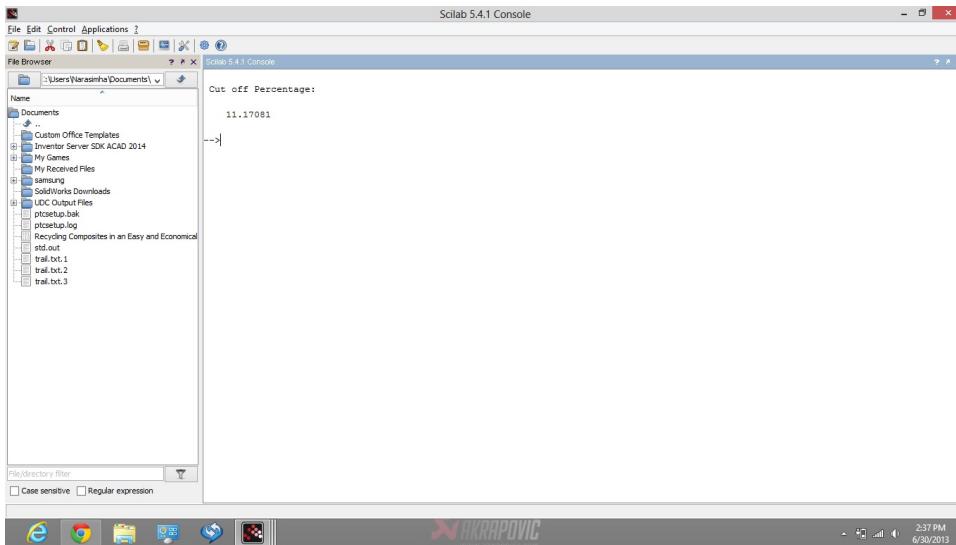


Figure 3.18: Diesel Cycle

### Scilab code Exa 3.20 Diesel Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.20
2 // Initialisation of Variables
3 pm=7.5;.....//Mean effective pressure in
   bar
4 r=12.5;.....//Compression ratio
5 p1=1;.....//Initial pressure in bar
6 ga=1.4;.....//Ratio of specific heats
7 //Calculations
8 k=(pm*(ga-1)*(r-1))/(p1*(r^ga));
9 c1=(r^(1-ga))/k;c2=(-ga)/k;c=1+(ga/k)-((r^(1-ga))/k)
   ;
10 function [f]=F(rho)
11     f=c1*(rho^ga)+c2*rho+c;
12 endfunction
13 //Initial guess
14 rho=2;
15 //Derivative
16 function [z]=D(rho)

```

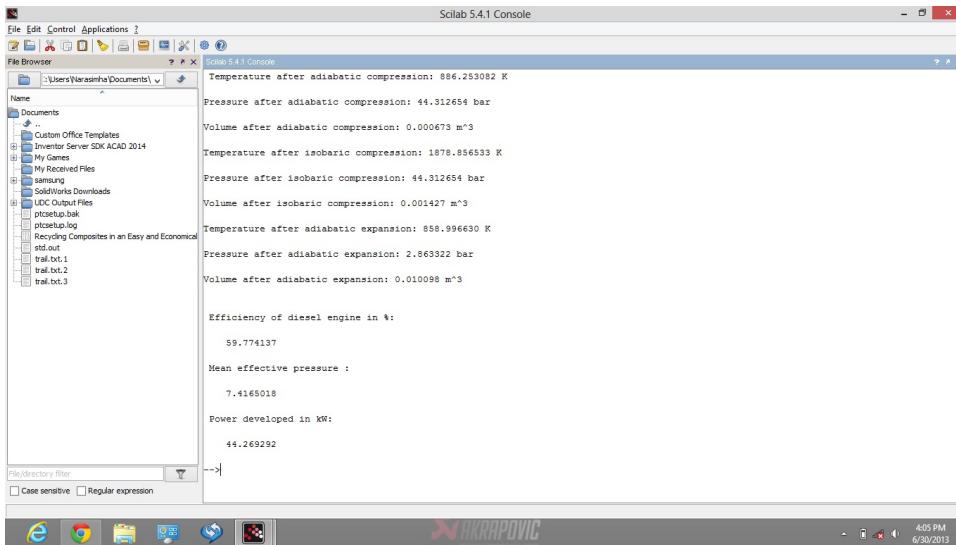


Figure 3.19: Diesel cycle

```

17 z=c1*ga*(rho^(ga-1))+c2;
18 endfunction
19 y=fsolve(rho,F,D)
20 perc=((y-1)/(r-1))*100;.....// Percentage of cutoff
21 disp(perc,"Cut off Percentage:")

```

---

### Scilab code Exa 3.21 Diesel cycle

```

1 clc;funcprot(0); //EXAMPLE 3.21
2 // Initialisation of Variables
3 D=0.2;.....//Engine bore in m
4 L=0.3;.....//Engine stroke in m
5 p1=1;.....//Initial pressure in bar
6 N=380;.....//No of working cycles per min

```

```

7 t1=300;.....//Initial temperature in K
8 co=8;.....//Cut off percentage
9 r=15;.....//Compression ratio
10 R=287;.....//gas constant in J/kg
11 ga=1.4;.....//Ratio of specific heats
12 //Calculations
13 Vs=(%pi/4)*D*D*L;.....//Stroke volume in m
14 v1=(r/(r-1))*Vs;.....//Volume at the end
    of isochoric compression in m^3
15 m=(p1*v1*10^5)/(R*t1);.....//Mass of air
    in cylinder in kg/cycle
16 p2=p1*(r^ga);.....//Pressure at
    the end of isentropic compression in bar
17 t2=t1*(r^(ga-1));.....//Temperature
    at the end of isentropic compression in K
18 v2=Vs/(r-1);.....//Volume at the end of
    isentropic compressionin m^3
19 p3=p2;
20 rho=((r-1)*(co/100))+1;.....//Cut off
    ratio
21 v3=rho*v2;.....//Volume at the end
    of isobaric expansion in m^3
22 t3=t2*(v3/v2);.....//Temperature at the
    end of isobaric expansion in K
23 p4=((rho/r)^ga)*p3;.....//Pressure at the
    end of adiabatic expansion in bar
24 t4=((rho/r)^(ga-1))*t3;.....//Temperature
    at the end of adiabatic expansion in K
25 v4=v1;
26 printf("Temperature after adiabatic compression: %f
    K\n\n",t2)
27 printf("Pressure after adiabatic compression: %f bar
    \n\n",p2)
28 printf("Volume after adiabatic compression: %f m^3\n
    \n",v2)
29 printf("Temperature after isobaric compression: %f K
    \n\n",t3)
30 printf("Pressure after isobaric compression: %f bar\

```

```

n\n",p3)
31 printf("Volume after isobaric compression: %f m^3\n\
n",v3)
32 printf("Temperature after adiabatic expansion: %f K\
n",t4)
33 printf("Pressure after adiabatic expansion: %f bar\n\
n",p4)
34 printf("Volume after adiabatic expansion: %f m^3\n\n\
",v4)
35 etad=1-(((rho^ga)-1)/(rho-1))*(1/(ga*(r^(ga-1))))
;.....//Efficiency of diesel engine
36 disp(etad*100," Efficiency of diesel engine in %:")
37 pm=p1*(r^ga)*[ga*(rho-1)-((r^(1-ga))*((rho^ga)-1))
]*((1/(ga-1))/1/(r-1));.....//Mean effective
pressure
38 disp(pm,"Mean effective pressure :")
39 Wdc=(pm*Vs*10^5)/1000;.....//Work done
per cycle in kJ/cycle
40 P=(Wdc*N)/60;.....//Power
developed in kW
41 disp(P,"Power developed in kW:")

```

---

### Scilab code Exa 3.22 Diesel Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.22
2 // Initialisation of Variables
3 rc=15.3;.....//Compression ratio
4 re=7.5;.....//Expansion ratio
5 cp=1.005;.....//Specific heat at
constant pressure in kJ/kg K
6 cv=0.718;.....//Specific heat at
constant volume in kJ/kgK
7 ga=1.4;.....//Ratio of specific heats

```

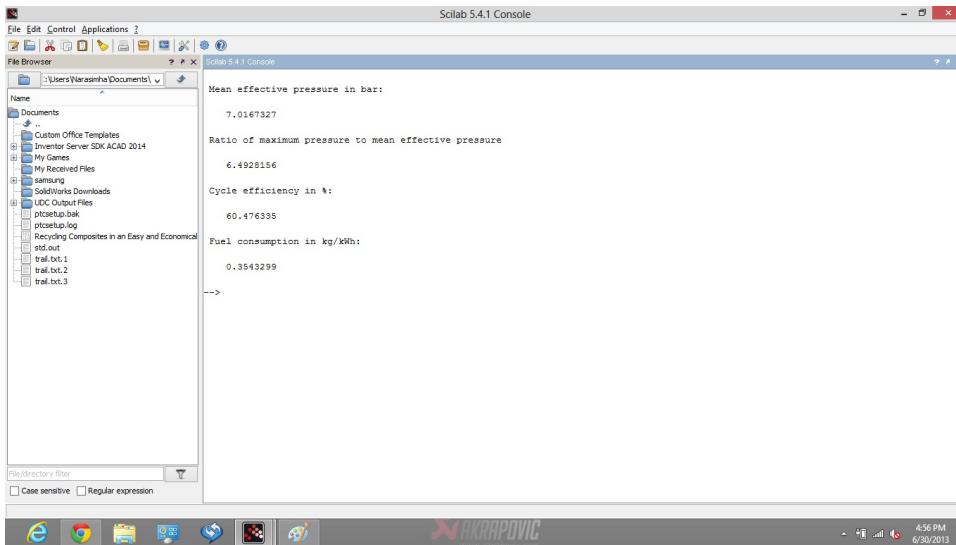


Figure 3.20: Diesel Cycle

```

8 p1=1;.....//Initial pressure in bar
9 t1=300;.....//Initial temperature in K
10 etamech=0.8;.....//Mechanical
    efficiency
11 C=42000;.....//Calorific value
    of fuel in kJ/kg
12 rita=0.5;.....//Ratio of
    indicated thermal efficiency to air standard
    efficiency
13 R=287;.....//Gas constant in kJ
    /kgK
14 //Calculations
15 t2=t1*(rc^(ga-1));.....//Temperature at
    the end of adiabatic compression in K
16 p2=p1*(rc^ga);.....//Pressure at the
    end of adiabatic compression in bar
17 t3=(rc*t2)/re;.....//Temperature at
    the end of constant pressure process in K
18 v2=1;.....//Volume at the end of
    adiabatic process in m^3

```

```

19 m=(p2*v2*10^5)/(R*t2);.....//Mass of
   working fluid in kg
20 t4=t3*((1/re)^(ga-1));.....//Temperature at the end of adiabatic expansion in K
21 W=[m*(cp*(t3-t2))]-[m*(cv*(t4-t1))];....//Work done in kJ
22 pm=W/(rc-1);.....//Mean effective pressure in kN/m^2
23 disp(pm/100,"Mean effective pressure in bar:")
24 disp((p2*100)/(pm),"Ratio of maximum pressure to mean effective pressure")
25 etacy=W/(m*cp*(t3-t2));.....//Cycle efficiency
26 disp(etacy*100,"Cycle efficiency in %:")
27 etaith=rita*etacy;.....//Indicated thermal efficiency
28 etabth=etaith*etamech;.....//Brake thermal efficiency
29 mf=3600/(etabth*C);.....//Fuel consumption per kWh
30 disp(mf,"Fuel consumption in kg/kWh:")

```

---

### Scilab code Exa 3.23 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.23
2 // Initialisation of Variables
3 Vs=0.0053;.....//Swept volume in m^3
4 Vc=0.00035;.....//Clearance volume in m^3
5 v3=Vc;
6 v2=Vc;
7 p3=65;.....//Max pressure in bar
8 co=5;.....//Cut off percentage

```

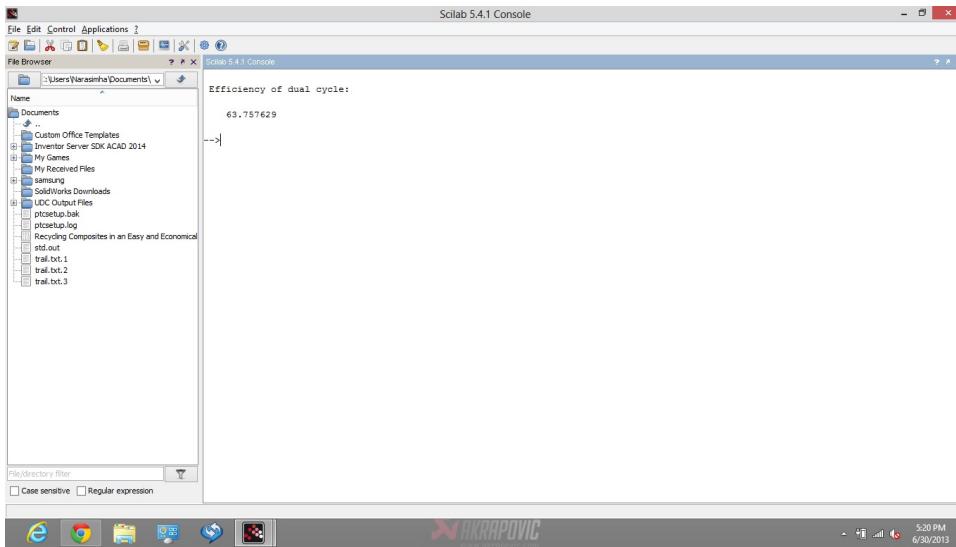


Figure 3.21: Dual Combustion Cycle

```

9 p4=p3;ga=1.4;.....//Ratio of specific
heats
10 t1=353;.....//Temperature at the
start of compression in K
11 p1=0.9;.....//Pressure at the start of
compression in bar
12 //Calculations
13 r=1+(Vs/Vc);.....//Compression ratio
14 rho=(((co/100)*Vs)/Vc)+1;.....//Cut
off ratio
15 p2=p1*(r^ga);
16 Beta=p3/p2;.....//Explosion
ratio
17 etadual=1-[(1/(r^(ga-1)))*((Beta*(rho^ga))-1)*(1/(
Beta-1)+(Beta*ga*(rho-1))))];.....//Efficiency of dual cycle
18 disp(etadual*100,"Efficiency of dual cycle:")

```

---

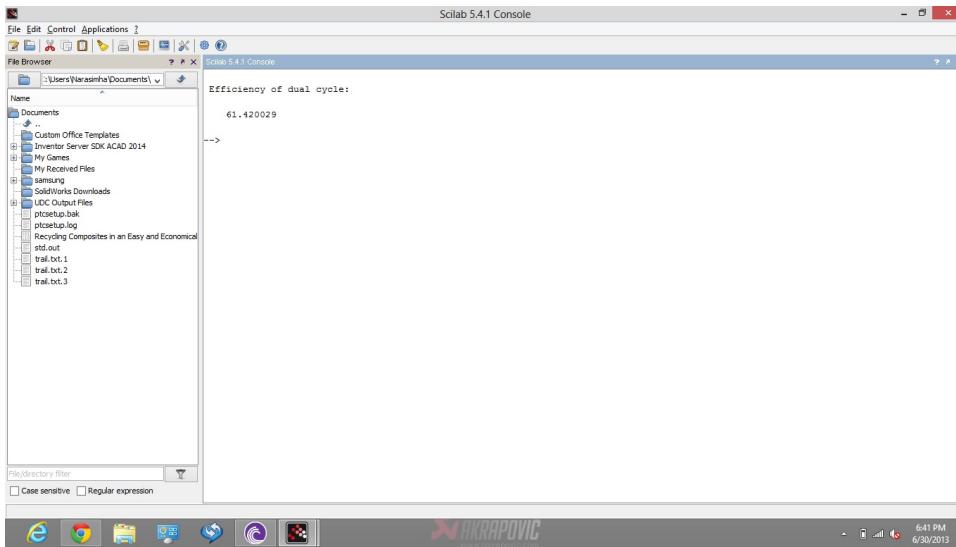


Figure 3.22: Dual Combustion Cycle

### Scilab code Exa 3.24 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.24
2 // Initialisation of Variables
3 r=14;.....//Compression ratio
4 Beta=1.4;.....//Explosion ratio
5 co=6;.....//Cut off percentage
6 ga=1.4;.....//Ratio of specific heats
7 //Calculation
8 rho=((co/100)*(r-1))+1;.....//Cut off
ratio
9 etadual=1-[(1/(r^(ga-1)))*((Beta*(rho^ga))-1)*(1/(
Beta-1)+(Beta*ga*(rho-1)))];.....// 
Efficiency of dual cycle
10 disp(etadual*100,"Efficiency of dual cycle:")

```

---

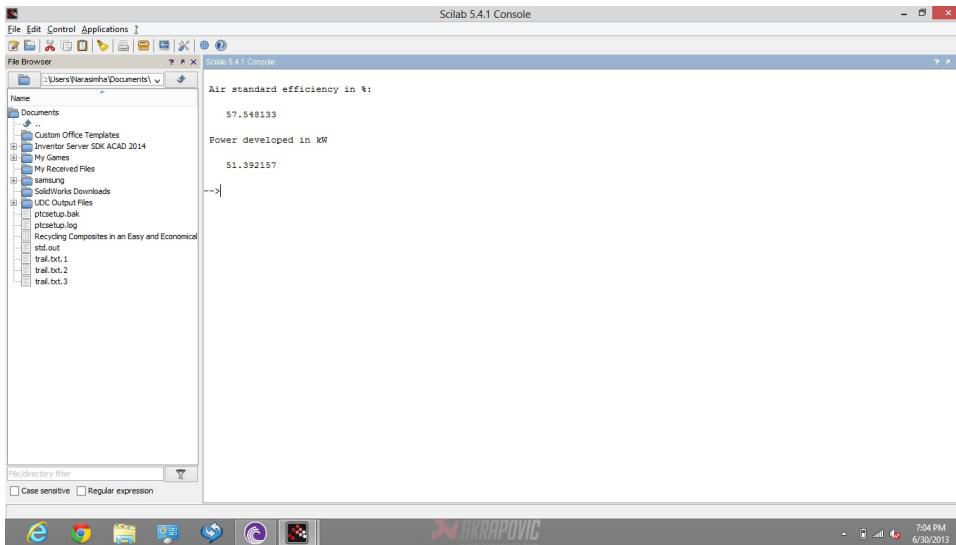


Figure 3.23: Dual Combustion Cycle

### Scilab code Exa 3.25 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.25
2 // Initialisation of Variables
3 D=0.25;.....//Engine bore in m
4 L=0.3;.....//Engine stroke in m
5 p1=1;.....//Initial pressure in bar
6 N=3;.....//No of cycles per second
7 p3=60;.....//Maximum pressure in bar
8 t1=303;.....//Initial temperature in K
9 co=4;.....//Cut off percentage
10 r=9;.....//Compression ratio
11 R=287;.....//gas constant in J/kg
12 cv=0.71;.....//Specific heat at constant
volume in kJ/kgK

```

```

13 cp=1.0;.....// Specific heat at constant
   pressure in kJ/kgK
14 ga=1.4;.....//Ratio of specific heats
15 //Calculations
16 p4=p3;
17 Vs=(%pi/4)*D*D*L;.....//Stroke volume in m^3
18 Vc=Vs/(r-1);.....//Clearance volume in
   m^3
19 rho=((r-1)*(co/100))+1;.....//Cut off
   ratio
20 v1=Vc+Vs;.....//Volume after isochoric
   compression in m^3
21 p2=p1*(r^ga);.....//Pressure after
   adiabatic compression in bar
22 t2=t1*(r^(ga-1));.....//Temperature after
   adiabatic expansion in K
23 t3=(p3*t2)/p2;.....//Temperature after
   isochoric compression in K
24 t4=t3*rho;.....//Temperature after
   isobaric expansion in K
25 t5=t4*((rho/r)^(ga-1));.....//Temperature after
   adiabatic expansion in K
26 p5=p4*(rho/r)^ga;.....//Pressure after
   adiabatic expansion in bar
27 Qs=(cv*(t3-t2)+cp*(t4-t3));....//Heat supplied in
   kJ/kg
28 Qr=cv*(t5-t1);.....//Heat rejected in
   kJ/kg
29 etast=1-(Qr/Qs);.....//Air standard
   efficiency
30 disp(etast*100,"Air standard efficiency in %:")
31 m=(p1*v1*10^5)/(R*t1);.....//Mass of air
   in cycle
32 W=m*(Qs-Qr);.....//Work done per
   cycle in kJ
33 P=W*N;.....//Power developed
   in kW
34 disp(P,"Power developed in kW")

```

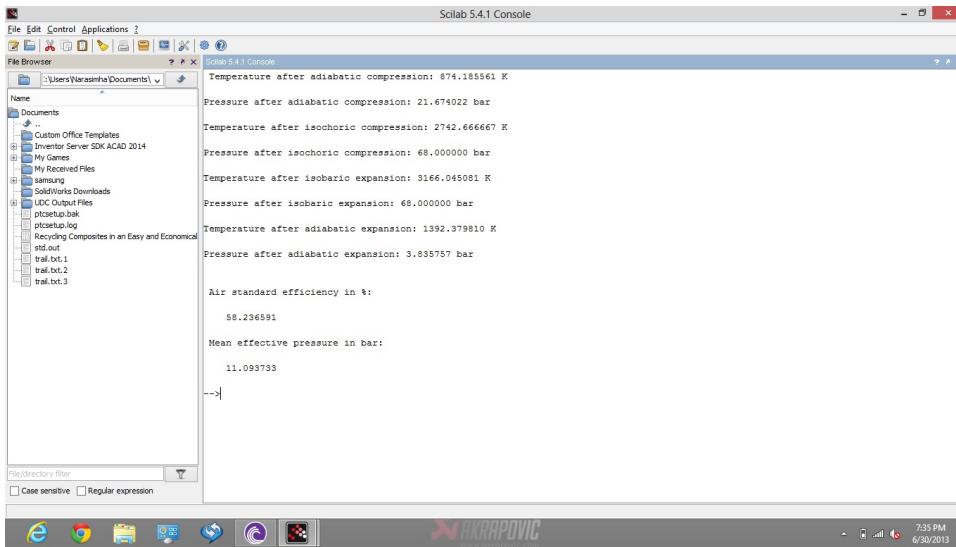


Figure 3.24: Dual Combustion Cycle

### Scilab code Exa 3.26 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.26
2 // Initialisation of Variables
3 p1=1;.....//Initial pressure in bar
4 t1=363;.....//Initial temperature in K
5 r=9;.....//Compression ratio
6 p3=68;.....//Max pressure
7 p4=p3;
8 Qs=1750;.....//Total heat supplied
9 ga=1.4;.....//Ratio of specific heats
10 R=287;.....//Gas constant in kJ/kgK
11 cv=0.71;.....//Specific heat at constant
volume in kJ/kgK

```

```

12 cp=1;.....// Specific heat at constant
   pressure in kJ/kgK
13 //Calculations
14 p2=p1*((r)^ga);.....//Pressure at the end of
   adiabatic compression in bar
15 t2=t1*((r)^(ga-1));.....//Temperature at the
   end of adiabatic compression in K
16 t3=t2*(p3/p2);.....//Temperature at the end
   of isochoric compression in K
17 Qv=cv*(t3-t2);.....//Heat added at constant
   volume in kJ/kg
18 Qp=Qs-Qv;.....//Heat added at
   constant pressure in kJ/kg
19 t4=(Qp/cp)+t3;.....//Temperature at the
   end of isobaric expansion in kJ/kg
20 rho=t4/t3;.....//Cut off ratio
21 p5=p4*((rho/r)^ga);.....//Pressure at the
   end of adiabatic expansion in kJ/kg
22 t5=t4*((rho/r)^(ga-1));.....//Temperature at
   the end of adiabatic expansion in kJ/kg
23 printf("Temperature after adiabatic compression: %f
   K\n\n",t2)
24 printf("Pressure after adiabatic compression: %f bar
   \n\n",p2)
25 printf("Temperature after isochoric compression: %f
   K\n\n",t3)
26 printf("Pressure after isochoric compression: %f bar
   \n\n",p3)
27 printf("Temperature after isobaric expansion: %f K\n
   \n",t4)
28 printf("Pressure after isobaric expansion: %f bar\n\
   n",p4)
29 printf("Temperature after adiabatic expansion: %f K\
   n\n",t5)
30 printf("Pressure after adiabatic expansion: %f bar\n\
   n",p5)
31 Qr=cv*(t5-t1);.....//Heat rejected in
   kJ

```

The screenshot shows a SciNotes window with the following code:

```

EX3_27.sce (C:\Users\Narasimha\Desktop\Scilab\Internal Combusion Engines\EXAMPLES\CH3\EX3_27\EX3_27.sce) - SciNotes
File Edit Format Options Window Execute ?
EX3_27.sce (C:\Users\Narasimha\Desktop\Scilab\Internal Combusion Engines\EXAMPLES\CH3\EX3_27\EX3_27.sce) - SciNotes
Save and execute EX3_27.sce
EX3_23.sce | EX3_24.sce | EX3_21.sce | EX3_25.sce | EX3_26.sce | EX3_27.sce
1 clc;funcprot(0); //EXAMPLE 3.27
2 // Initialisation of Variables
3 t1=300; ..... //Initial temperature
4 rmami=70; ..... //Ratio of max pressure and min pressure
5 r=15; ..... //Compression ratio
6 ga=1.4; ..... //Ratio of specific heats
7 R=287; ..... //Gas constant in kJ/kgK
8 t2=t1*(r^(ga-1)); ..... //Temperature at the end of adiabatic compression in K
9 t3=t2*(rmami/(r^ga)); ..... //Temperature at the end of isochoric compression in K
10 t4=t3*((t3-t2)/(ga)); ..... //Temperature at the end of isobaric process in K
11 t5=t4*((1/(t4/(t3*r)))^(ga-1)); ..... //Temperature at the end of adiabatic expansion in K
12 etast=1-[(t5-t1)/((t5-t2)+ga*(4-ga))]; ..... //Air standard efficiency
13 disp(etast*100,"Air standard efficiency in %:")
14

```

Figure 3.25: Dual Combustion Cycle

---

```

32 etast=1-(Qr/Qs); ..... // Air standard
    efficiency
33 disp(etast*100," Air standard efficiency in %:")
34 pm=(1/(r-1))*[(68*(rho-1))+(((p4*rho)-(p5*r))/(ga-1)
    )-((p2-r)/(ga-1))]; ..... //Mean
    effective pressure in bar
35 disp(pm," Mean effective pressure in bar:")

```

---

### Scilab code Exa 3.27 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.27
2 // Initialisation of Variables
3 t1=300; ..... //Initial temperature
4 rmami=70; ..... //Ratio of max pressure
    and min pressure
5 r=15; ..... //Compression ratio

```

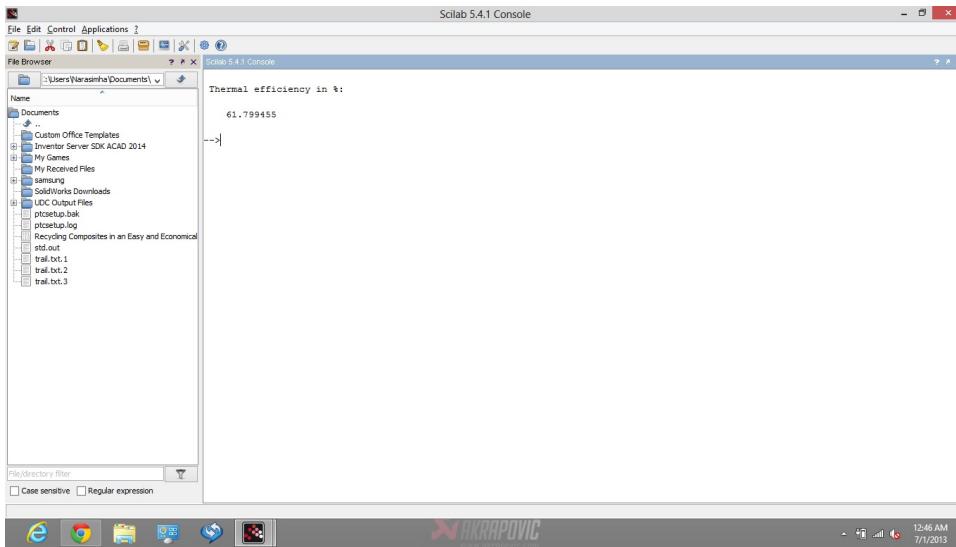


Figure 3.26: Dual Combustion Cycle

```

6 ga=1.4;..... //Ratio of specific heats
7 R=287;..... //Gas constant in kJ/kgK
8 t2=t1*(r^(ga-1));..... //Temperature at
    the end of adiabatic compression in K
9 t3=t2*(rmami/(r^ga));..... //Temperature at
    the end of isochoric compression in K
10 t4=t3+((t3-t2)/ga);..... //Temperature at
    the end of isobaric process in K
11 t5=t4/((1/(t4/(t3*r)))^(ga-1));..... //
    Temperature at the end of adiabatic expansion in
    K
12 etast=1-[(t5-t1)/((t3-t2)+ga*(t4-t3))
    ];..... //Air standard efficiency
13 disp(etast*100,"Air standard efficiency in %:")

```

---

### Scilab code Exa 3.28 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.28
2 // Initialisation of Variables
3 t1=373;..... // Initial temperature in K
4 p1=1;..... // Initial pressure in bar
5 p3=65;..... //Maximum pressure in bar
6 R=287;..... //Gas constant in kJ/kg
7 p4=p3;
8 ga=1.41;..... //Ratio of specific heats
9 Vs=0.0085;..... //Swept volume in m^3
10 afr=21;..... //Air fuel ratio
11 r=15;..... //Compression ratio
12 C=43890;..... //Calorific value of fuel in
    kJ/kg
13 cp=1;..... // Specific heat at constant
    pressure in kJ/kgK
14 cv=0.71;..... // Specific heat at constant
    volume in kJ/kgK
15 //Calculations
16 Vc=Vs/(r-1);..... //Clearance volume in m^3
17 v2=Vc;v1=Vs+v2;
18 v3=Vc;v5=v1;
19 p2=p1*(r^ga);..... //Pressure at the
    end of adiabatic compression in bar
20 t2=t1*(r^(ga-1));..... //Temperature at
    the end of adiabatic compression in K
21 t3=(t2*p3)/p2;..... //Temperature at
    the end of isochoric compression in K
22 m=(p1*v1*10^5)/(R*t1);..... //Mass of air in
    the cycle in kg
23 Qv=m*cv*(t3-t2);..... //Heat added
    during constant volume process in kJ
24 fv=Qv/C;..... //Fuel added
    during constant volume process in kg
25 mf=m/afr;..... //Total amount of fuel
    added in kg
26 mfib=mf-fv;..... //Total amount of
    fuel added in isobaric process in kg
27 Qib=mfib*C;..... //Total amount of

```

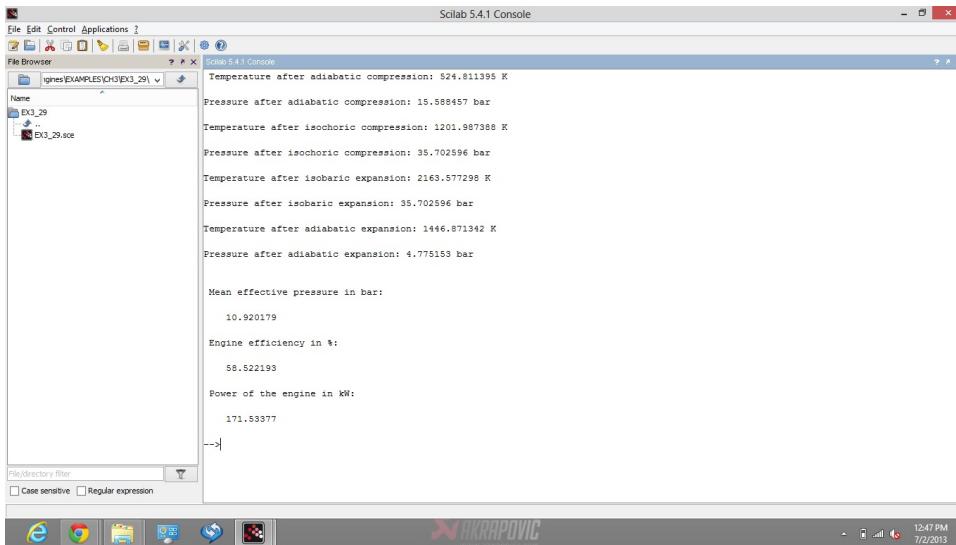


Figure 3.27: Dual Combustion Cycle

```

heat added in isobaric process in kJ
28 t4=(Qib/((m+mf)*cp))+t3;.....//Temperature at the
    end of isobaric process in K
29 v4=(v3*t4)/t3;.....//Volume at the end
    of isobaric process in m^3
30 t5=t4/((v5/v4)^(ga-1));.....//Temperature at the
    end of isochoric expansion in K
31 Qrv=(m+mf)*cv*(t5-t1);.....//Heat rejected
    during constant volume process in kJ
32 W=(Qib+Qv)-Qrv;.....//Work done in kJ
33 etath=W/(Qib+Qv);.....//Thermal
    efficiency
34 disp(etath*100,"Thermal efficiency in %:")

```

---

### Scilab code Exa 3.29 Dual Combustion Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.29
2 // Initialisation of Variables
3 D=0.25;.....//Engine bore in m
4 L=0.4;.....//Engine stroke in m
5 t1=303;.....//Initial temperature in K
6 R=287;.....//Gas constant in kJ/kgK
7 p1=1;.....//Initial pressure in bar
8 N=8;.....//No of working cycles per sec
9 cv=0.71;.....//Specific heat at constant
    volume in kJ/kgK
10 cp=1;.....//Specific heat at constant
    pressure in kJ/kgK
11 n=1.25;.....//Adiabatic index
12 rc=9;.....//Compression ratio
13 re=5;.....//Expansion ratio
14 rqptqe=2;.....//Ratio of heat liberated at
    constant pressure to heat liberated at constant
    volume
15 //Calculations
16 p2=p1*(rc^n);.....//Pressure at
    the end of adiabatic compression in bar
17 t2=t1*(rc^(n-1));.....//Temperature at
    the end of adiabatic compression in K
18 rho=rc/re;.....//Cut off ratio
19 t3=(2*cv*t2)/((2*cv)-(cp*(rho-1)));.....//
    Temperature at the end of isochoric compression
    in K
20 p3=p2*(t3/t2);.....// 
    Pressure at the end of isochoric compression in
    bar
21 p4=p3;t4=rho*t3;.....// 
    Temperature and pressure at the end of isobaric
    process
22 p5=p4*(1/(re^n));.....// 
    Pressure at the end of adiabatic expansion in bar
23 t5=t4*(1/(re^(n-1)));.....// 
    Temperature at the end of adiabatic expansion in
    K

```

```

24 pm=(1/(rc-1))*[(p3*(rho-1))+(((p4*rho)-(p5*rc))/(n
    -1))-((p2-(p1*rc))/(n-1))];.....//Mean
        effective pressure
25 printf("Temperature after adiabatic compression: %f
    K\n\n",t2)
26 printf("Pressure after adiabatic compression: %f bar
    \n\n",p2)
27 printf("Temperature after isochoric compression: %f
    K\n\n",t3)
28 printf("Pressure after isochoric compression: %f bar
    \n\n",p3)
29 printf("Temperature after isobaric expansion: %f K\n
    \n",t4)
30 printf("Pressure after isobaric expansion: %f bar\n\
    n",p4)
31 printf("Temperature after adiabatic expansion: %f K\
    n\n",t5)
32 printf("Pressure after adiabatic expansion: %f bar\n\
    \n",p5)
33 disp(pm,"Mean effective pressure in bar:")
34 Vs=(%pi/4)*D*D*L;.....//Swept volume
    in m^3
35 W=(pm*(10^5)*Vs)/1000;.....//Work done
    per cycle in kJ
36 m=(p1*(10^5)*(rc/(rc-1))*Vs)/(R*t1)
    ;.....//Mass of air per cycle in
    kg
37 Qs=m*[cv*(t3-t2)+cp*(t4-t3)];.....///
        Heat supplied per cycle in kJ
38 eta=W/Qs;.....//Engine efficiency
39 disp(eta*100,"Engine efficiency in %:")
40 P=W*N;.....//Power of the engine in kW
41 disp(P,"Power of the engine in kW:")

```

---

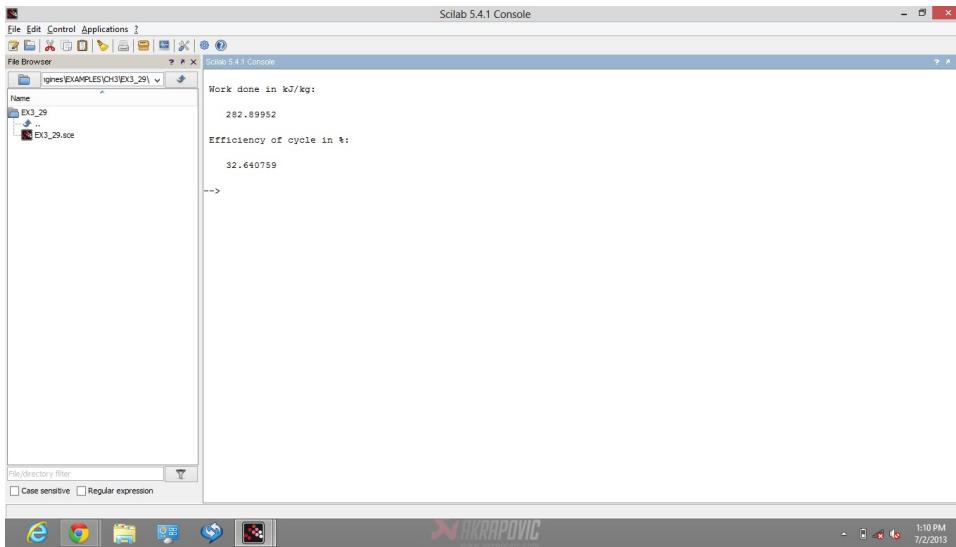


Figure 3.28: Atkinson Cycle

### Scilab code Exa 3.31 Atkinson Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.31
2 // Initialisation of Variables
3 cp=0.92;.....// Specific heat at
   constant pressure in kJ/kgK
4 cv=0.75;.....// Specific heat at
   constant volume in kJ/kgK
5 p1=1;.....//Pressure at the end of
   adiabatic expansion in bar
6 p2=p1;.....//Pressure at the end of
   isobaric compression in bar
7 p3=4;.....//Pressure at the end of
   isobaric compression in bar
8 p4=16;.....//Final pressure after heat
   addition in bar
9 t2=300;.....//Temperature at the end
   of isobaric compression in K
10 ga=1.22;.....//Ratio of specific heats
11 // Calculations

```

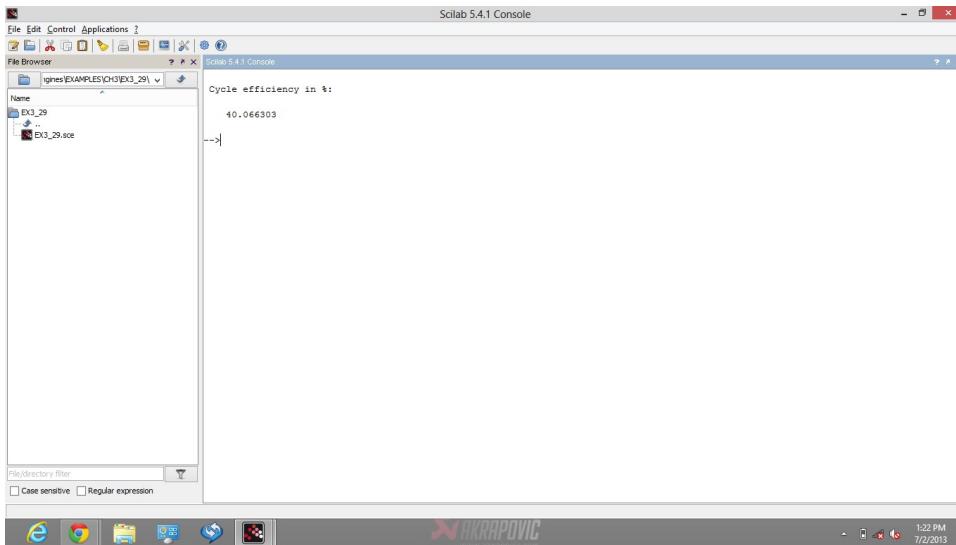


Figure 3.29: Brayton Cycle

```

12 t3=t2*((p3/p2)^((ga-1)/ga));.....//  

    Temperature at the end of isobaric compression in  

    K  

13 t4=(p4*t3)/p3;.....//Final  

    temperature after heat addition in K  

14 t1=t4/((p4/p1)^((ga-1)/ga));.....//  

    Temperature at the end of adiabatic compression  

    in K  

15 Qs=cv*(t4-t3);.....//Heat  

    supplied in kJ/kg  

16 Qr=cp*(t1-t2);.....//Heat  

    rejected in kJ/kg  

17 W=Qs-Qr;.....//Work done per kg of  

    gas in kJ  

18 disp(W,"Work done in kJ/kg:")  

19 eta=W/Qs;.....//Efficiency of cycle  

20 disp(eta*100,"Efficiency of cycle in %:")

```

---

### Scilab code Exa 3.32 Brayton Cycle

```
1 clc;funcprot(0); //EXAMPLE 3.32
2 // Initialisation of Variables
3 p1=101.325;.....// Pressure of intake
air in kPa
4 t1=300;.....//Temperature of
intake air in kPa
5 rp=6;.....//Pressure ratio in
the cycle
6 ga=1.4;.....//Ratio of specific
heats
7 rtc=2.5;.....//Ratio of
turbine work and compressor work
8 //Calculations
9 t2=t1*(rp^((ga-1)/ga));.....//
Temperature at the end of isentropic expansion in
K
10 t3=(rtc*(t2-t1))/(1-(1/(rp^((ga-1)/ga))));.....//
Temperature at the end of isobaric expansion in K
11 t4=t3/(rp^((ga-1)/ga));.....//
Temperature at the end of isentropic compression
in K
12 eta=(t3-t4-t2+t1)/(t3-t2);.....//Cycle
efficiency
13 disp(eta*100,"Cycle efficiency in %:")
```

---

### Scilab code Exa 3.33 Brayton Cycle

```
1 clc;funcprot(0); //EXAMPLE 3.33
```

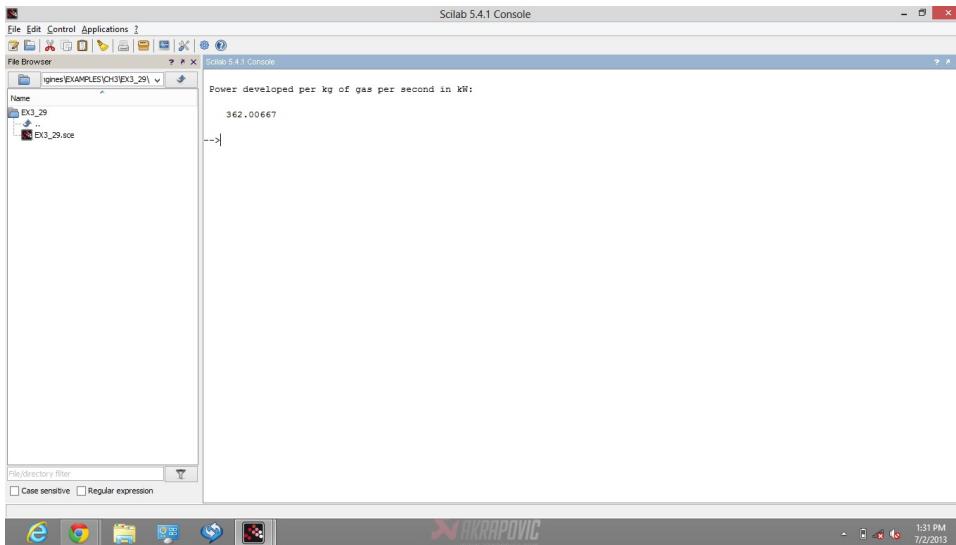


Figure 3.30: Brayton Cycle

```

2 // Initialisation of Variables
3 p1=1;.....//Intake pressure in bar
4 p2=5;.....//Supply pressure in bar
5 t3=1000;.....//Supply temperature in
   Kelvin
6 cp=1.0425;.....// Specific heat at
   constant pressure in kJ/kgK
7 cv=0.7662;.....// Specific heat at
   constant volume in kJ/kgK
8 ga=cp/cv;.....//Ratio of specific heats
9 //Calculations
10 t4=t3*((p1/p2)^((ga-1)/ga));
11 P=cp*(t3-t4);.....//Power developed
   per kg of gas per second in kW
12 disp(P,"Power developed per kg of gas per second in
   kW:")

```

---

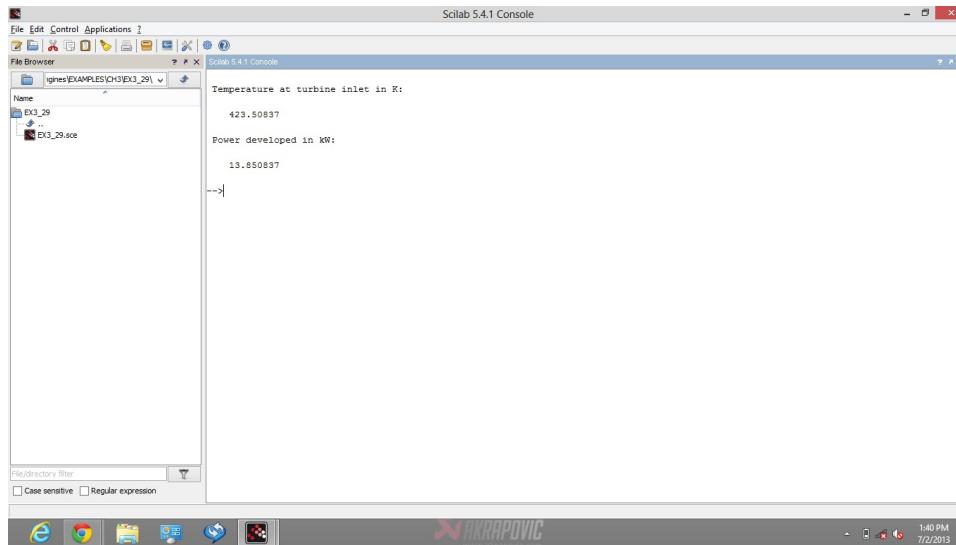


Figure 3.31: Brayton Cycle

### Scilab code Exa 3.34 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.34
2 // Initialisation of Variables
3 ma=0.1; ..... //Air supplied in kg/s
4 p1=1; ..... //Supply pressure in bar
5 t4=285; ..... //Temperature of air when
    supplied to cabin in K
6 p2=4; ..... //Pressure at inlet to
    turbine in bar
7 cp=1.0; ..... //Specific heat at constant
    pressure in kJ/kgK
8 ga=1.4; ..... //Ratio of specific heats
9 //Calculations
10 t3=t4*((p2/p1)^((ga-1)/ga)); ..... //
    Temperature at turbine inlet in K
11 disp(t3,"Temperature at turbine inlet in K:")

```

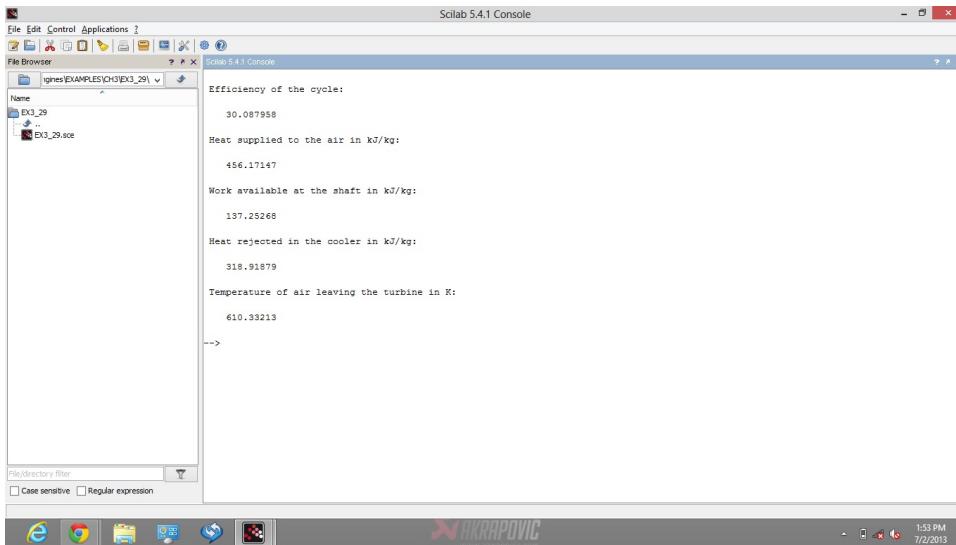


Figure 3.32: Brayton Cycle

---

```

12 P=ma*cp*(t3-t4); ..... //Power developed in kW
13 disp(P,"Power developed in kW:")

```

---

### Scilab code Exa 3.35 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.35
2 // Initialisation of Variables
3 p1=1; ..... //Pressure of air entering the compressor in bar
4 p2=3.5; ..... //Pressure of air while leaving the compressor in bar
5 t1=293; ..... //Temperature of air at the onset of the compressor in K
6 t3=873; ..... //Temperature of air at the turbine inlet in K

```

```

7 cp=1.005;.....// Specific heat at constant
    pressure in kJ/kgK
8 ga=1.4;.....// Ratio of specific heats
9 // Calculations
10 rp=p2/p1;.....// Pressure ratio of the
    cycle
11 eta=1-(1/(rp^((ga-1)/ga)));.....// 
    Efficiency of the cycle
12 disp(eta*100,"Efficiency of the cycle:")
13 t2=t1*((rp^((ga-1)/ga)));.....//
    Temperature of air while leaving the compressor
    in K
14 q1=cp*(t3-t2);.....//Heat supplied to the
    air in kJ/kg
15 disp(q1,"Heat supplied to the air in kJ/kg:")
16 W=eta*q1;.....//Work available at
    the shaft in kJ/kg
17 disp(W,"Work available at the shaft in kJ/kg:")
18 q2=q1-W;.....//Heat rejected in the
    cooler in kJ/kg
19 disp(q2,"Heat rejected in the cooler in kJ/kg:")
20 t4=t3/(rp^((ga-1)/ga));.....//
    Temperature of air leaving the turbine in K
21 disp(t4,"Temperature of air leaving the turbine in K
    :")

```

---

### Scilab code Exa 3.36 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.36
2 // Initialisation of Variables
3 p1=1;.....// Pressure of air entering
    the compressor in bar
4 t1=300;.....// Temperature of air

```

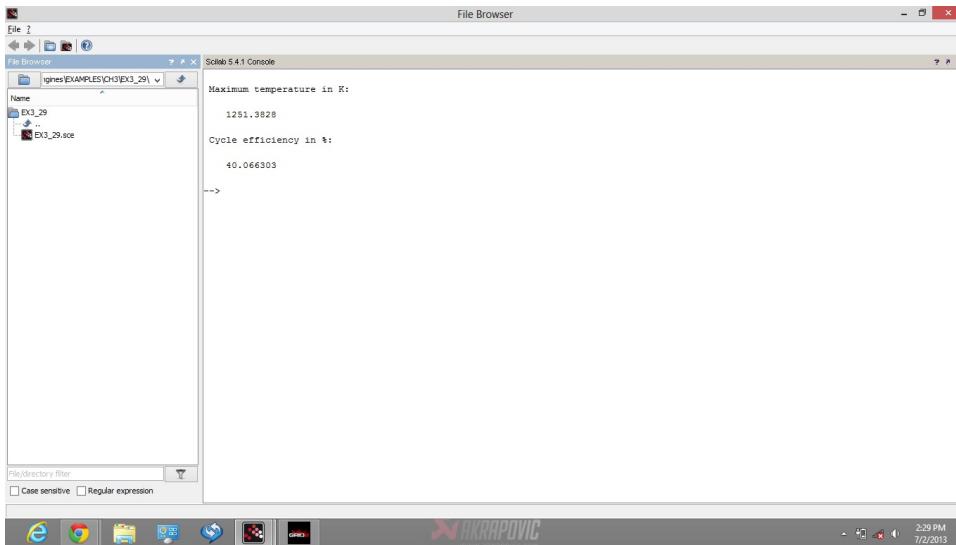


Figure 3.33: Brayton Cycle

```

        entering the compressor in bar
5 rp=6;.....//Pressure ratio
6 rtc=2.5;.....//Ratio of turbine work to
    compressor work
7 ga=1.4;.....//Ratio of specific heats
8 //calculations
9 t2=t1*(rp^((ga-1)/ga));.....//
    Temperature at the end of isentropic expansion in
    K
10 t3=(rtc*(t2-t1))/(1-(1/(rp^((ga-1)/ga))));.....//
    Temperature at the end of isobaric expansion in K
11 t4=t3/(rp^((ga-1)/ga));.....//
    Temperature at the end of isentropic compression
    in K
12 eta=(t3-t4-t2+t1)/(t3-t2);.....//Cycle
    efficiency
13 disp(t3,"Maximum temperature in K:")
14 disp(eta*100,"Cycle efficiency in %:")

```

---

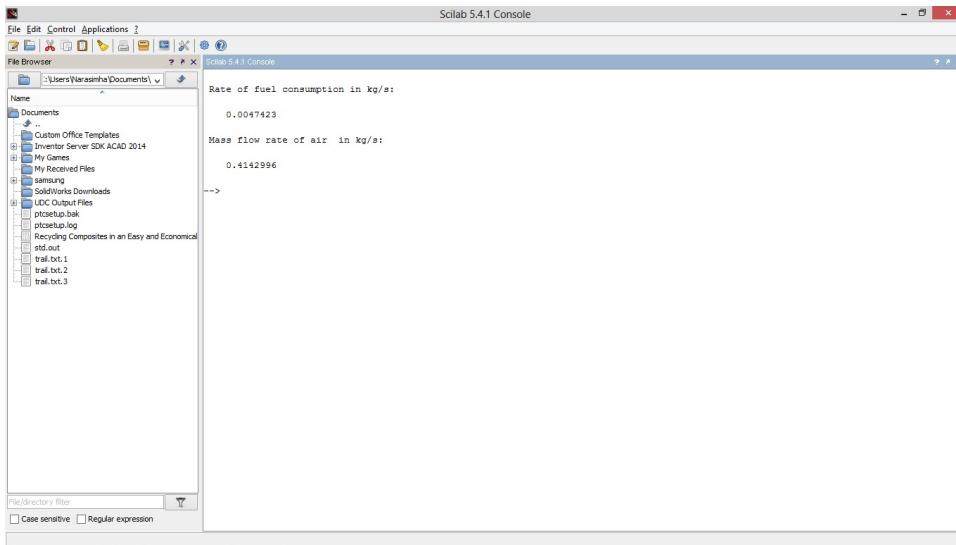


Figure 3.34: Brayton Cycle

### Scilab code Exa 3.37 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.37
2 // Initialisation of Variables
3 t1=303; ..... //Min temperature in
   K
4 t3=1073; ..... //Max temperature in
   K
5 C=45000; ..... //Calorific value of
   fuel in kJ/kg
6 cp=1; ..... // Specific heat at constant
   pressure in kJ/kgK
7 ga=1.4; ..... //Ratio os specific
   heats
8 diftc=100; ..... // Difference between

```

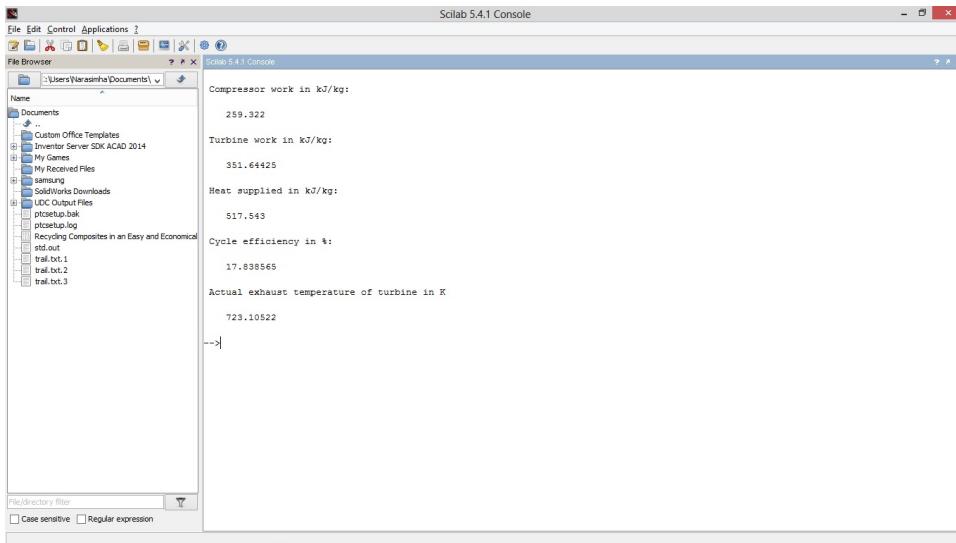


Figure 3.35: Brayton Cycle

```

work done by turbine and compressor in kW
9 // Calculations
10 t2=sqrt(t1*t3); t4 = t2;.....//Assumed
11 mf=diftc/[C*(1-((t4-t1)/(t3-t2)))]......
    //Fuel used in kg per second
12 disp(mf,"Rate of fuel consumption in kg/s:")
13 ma=[diftc-[mf*(t3-t4)]]/[(t3-t4-cp*(t2-t1))
    ];.....//Rate of air consumption in kg/s
14 disp(ma,"Mass flow rate of air in kg/s:")

```

---

### Scilab code Exa 3.38 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.38
2 // Initialisation of Variables
3 t1=300;.....//Inlet temperature in K
4 p1=1;.....//Inlet pressure in bar

```

```

5 ma=1;..... //Mass of air in kg
6 rp=6.25;..... //Pressure ratio
7 t3=1073;..... //Maximum temperature in K
8 etac=0.8;..... //Efficiency of compressor
9 etat=0.8;..... //Efficiency of turbine
10 ga=1.4;..... //Ratio of specific heats
11 cp=1.005;..... //Specific heat at constant
    pressure in kJ/kgK
12 //Calculations
13 t2=t1*(rp^((ga-1)/ga));..... //Ideal
    Temperature of air while leaving the compressor
    in K
14 t21=((t2-t1)/etac)+t1;..... //Actual
    Temperature of air while leaving the compressor
    in K
15 Wcomp=ma*cp*(t21-t1);..... //Compressor work
    in kJ/kg
16 t4=t3/(rp^((ga-1)/ga));..... //Ideal temperature
    of air while leaving the turbine in K
17 t41=t3-(etat*(t3-t4));..... //Actual temperature
    of air while leaving the turbine in K
18 Wtur=ma*cp*(t3-t41);..... //Turbine work in
    kJ/kg
19 Wnet=Wtur-Wcomp;..... //Net work produced
    in kJ/kg
20 Qs=ma*cp*(t3-t21);..... //Heat supplied
    in kJ/kg
21 disp(Wcomp,"Compressor work in kJ/kg:")
22 disp(Wtur,"Turbine work in kJ/kg:")
23 disp(Qs,"Heat supplied in kJ/kg:")
24 disp((Wnet/Qs)*100,"Cycle efficiency in %:")
25 disp(t41,"Actual exhaust temperature of turbine in K
    ")

```

---

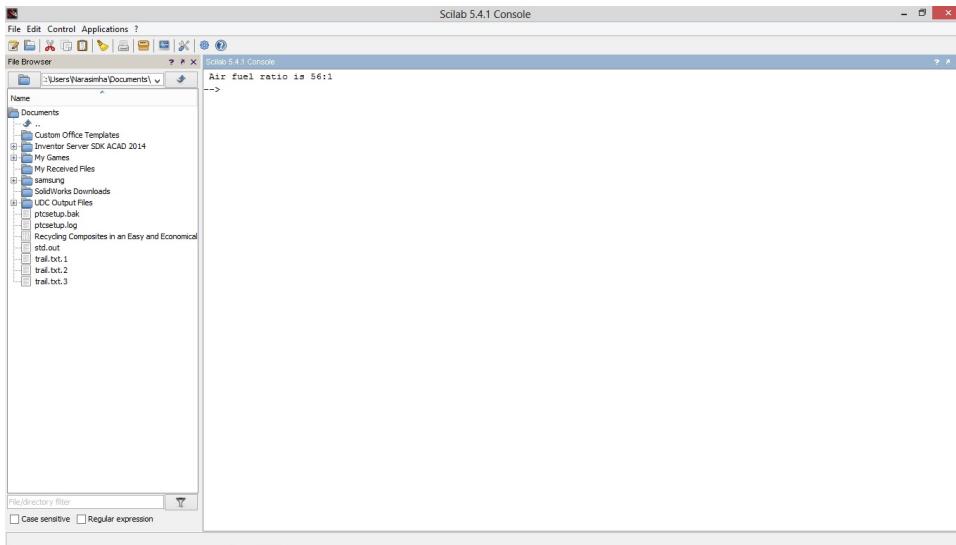


Figure 3.36: Brayton Cycle

### Scilab code Exa 3.39 Brayton Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.39
2 // Initialisation of Variables
3 etat=0.85;.....//Turbine efficiency
4 etac=0.8;.....//Compressor efficiency
5 t3=1148;.....//Max temperature in K
6 t1=300;.....//Temperature of working
    fluid when entering the compressor in Kelvin
7 cp=1;.....// specific heat at constant
    pressure in kJ/kgK
8 ga=1.4;.....//ratio of specific heats
9 p1=1;.....//Pressure of working fluid
    while entering the compressor in bar
10 rp=4;.....//Pressure ratio
11 C=42000;.....//Calorific value of fuel
    used in kJ/kgK
12 perlcc=10;.....//Percentage loss of
    calorific value in combustion chamber
13 //calculations

```



Figure 3.37: Stirling Cycle

```

14 p2=p1*rp;.....//pressure of air while
leaving the compressor in bar
15 etacc=1-(perlcc/100);.....//efficiency of
combustion chamber
16 t2=t1*(rp^((ga-1)/ga));.....//Ideal
Temperature of air while leaviing the compressor
in K
17 t21=((t2-t1)/etac)+t1;.....//Actual
Temperature of air while leaviing the compressor
in K
18 afr=((C*etacc)/(cp*(t3-t21)))-1;.....//Air
fuel ratio
19 printf("Air fuel ratio is %d:1",round(afr))

```

---

### Scilab code Exa 3.40 Stirling Cycle

```

1 clc;funcprot(0); //EXAMPLE 3.40
2 // Initialisation of Variables
3 p1=1;.....//pressure before isothermal
    compression in bar
4 t1=310;.....//temperature before isothermal
    compression in K
5 p3=16;.....//pressure before isothermal
    expansion in bar
6 t3=930;.....//temperature before isothermal
    expansion in K
7 R=287;.....//Gas constant in kJ/kgK
8 //Calculations
9 v1=(R*t1)/(p1*10^5);.....//Volume before
    isothermal compression in m^3
10 v3=(R*t3)/(p3*10^5);.....//Volume before
    isothermal expansion in m^3
11 v2=v3;v4=v1;.....//2-3 and 1-4 are
    isochoric processes
12 r=v1/v2;.....//Compression ratio
13 q12=R*t1*log(r);.....//Work done and heat
    rejected in process 1-2
14 w12=q12;
15 disp(q12/1000,"Work done in process 1-2 in kJ/kg:")
16 disp(w12/1000,"Heat rejected in process 1-2 in kJ/kg
    :")
17 q23=0;w23=q23;.....//COnstant volume
    process and hence work done is zero
18 disp(q23/1000,"Work done in process 2-3 in kJ/kg:")
19 disp(q23/1000,"Heat rejected in process 2-3 in kJ/kg
    :")
20 q34=R*t3*log(r);.....//Work done and heat
    rejected in process 1-2
21 w34=q34;
22 disp(q34/1000,"Work done in process 3-4 in kJ/kg:")
23 disp(w34/1000,"Heat rejected in process 3-4 in kJ/kg
    :")
24 q41=q34-q12;w41=q41;
25 disp(q41/1000,"Work done in process 4-1 in kJ/kg:")

```

```
26 disp(w41/1000,"Heat rejected in process 4-1 in kJ/kg  
:")  
27 etath=w41/q34;.....//Thermal  
efficiency  
28 disp(etath*100,"Thermal efficiency of the cycle in %  
:")
```

---

# Chapter 4

## Fuel Air and Actual Cycles

Scilab code Exa 4.2 Percentage change in otto cycle efficiency

```
1 clc;funcprot(0); //EXAMPLE 4.2
2 // Initialisation of Variables
3 r=8; ..... //Compression Ratio
4 ga=1.4; ..... //Degree of freedom
   for the gas
5 Cvinc=1.1; ..... //Increase of specific
   heat at constant volume in percentage
6 //Calculations
7 eta=1-1/(r^(ga-1)); ..... //efficiency of otto
   cycle
8 deta=(1-eta)*(ga-1)*log(r)*(Cvinc/100); .....
   //Change in efficiency
9 etach=-deta/eta; ..... //
   Percentage change in efficiency of change in
   efficiency
10 disp(etach*100,"The percentage change in the
   efficiency of otto cycle (in %):")
```

---

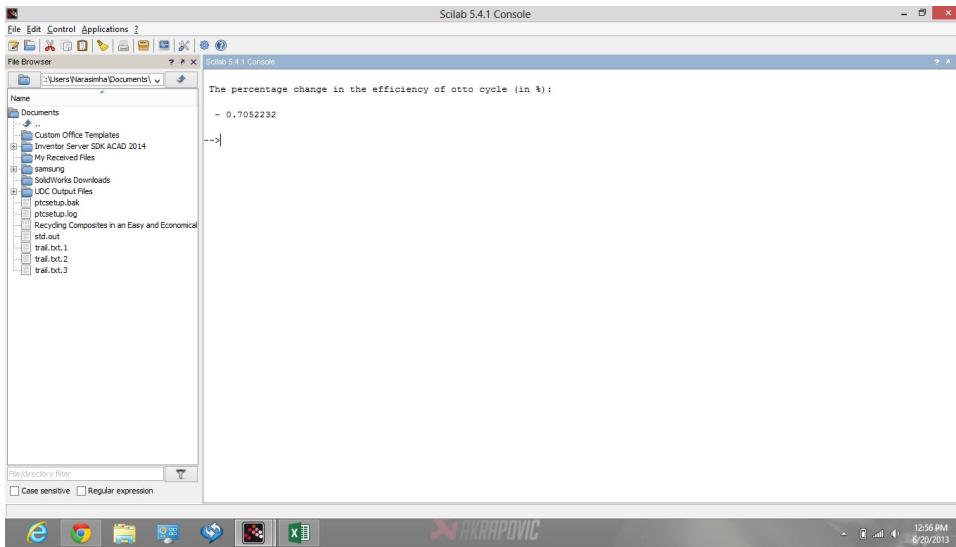


Figure 4.1: Percentage change in otto cycle efficiency

### Scilab code Exa 4.3 Percentage change in otto cycle efficiency

```

1 clc;funcprot(0); //EXAMPLE 4.3
2 // Initialisation of Variables
3 r=7; ..... //Compression Ratio
4 ga=1.4; ..... //Degree of freedom
   for the gas
5 Cvinc=3; ..... //Increase of specific
   heat at constant volume in percentage
6 //Calculations
7 eta=1-1/(r^(ga-1)); ..... //efficiency of otto
   cycle
8 deta=(1-eta)*(ga-1)*log(r)*(Cvinc/100); .....
   //Change in efficiency
9 etach=-deta/eta; ..... //

```

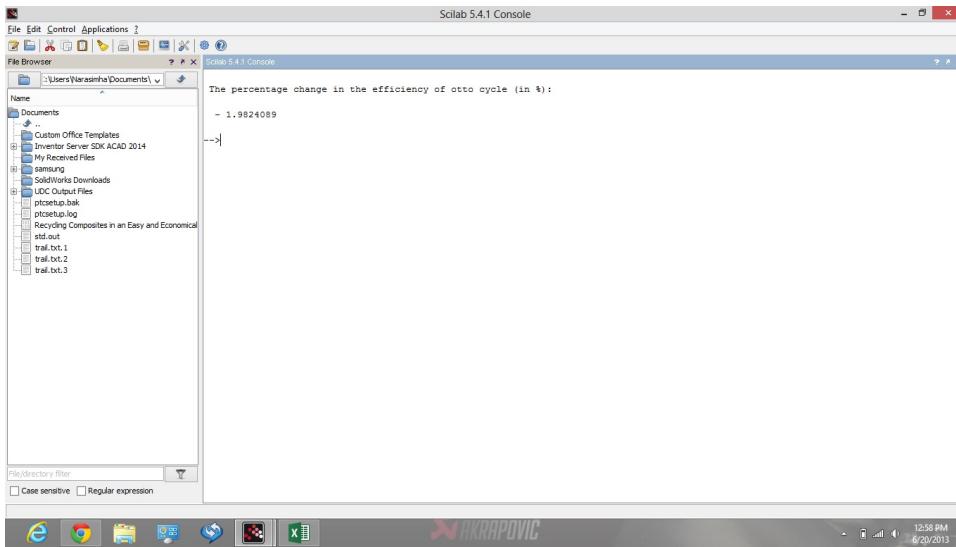


Figure 4.2: Percentage change in otto cycle efficiency

Percentage change in efficiency of change in efficiency

10 **disp(etach\*100,"The percentage change in the efficiency of otto cycle (in %):")**

---

#### Scilab code Exa 4.4 Change in air standard efficiency

```

1 clc;funcprot(0); //EXAMPLE 4.4
2 // Initialisation of Variables
3 r=18; ..... //Compression Ratio
4 co=5; ..... //Cut off percent of stroke
5 cv=0.71; ..... //Mean specific heat for cycle in kJ/kg K
6 R=0.285; ..... //Characteristic gas constant in kJ/kh K

```

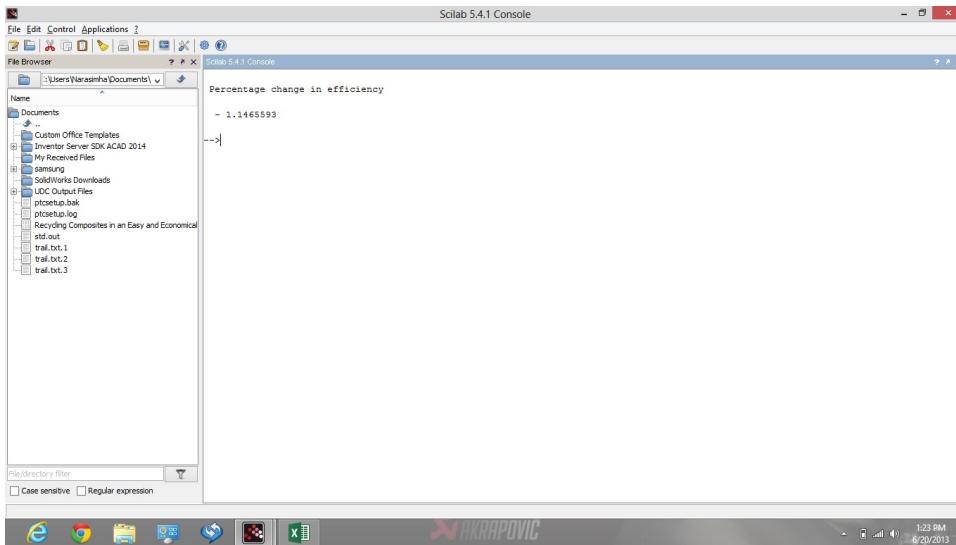


Figure 4.3: Change in air standard efficiency

```

7 cvinc=2;.....// Percentage increase
      in mean specific heat of the cycle
8 //Calculation
9 rho=(co/100)*(r-1)+1;
10 ga=1+(R/cv);
11 eta=1-(1/(ga*(r^(ga-1))))*((rho^ga)-1)/(rho-1)
      ;.....//Efficiency of diesel
      cycle
12 etach=-((1-eta)/eta)*(ga-1)*log(r)-(((rho^ga)*log(
      rho))/((rho^ga)-1))+(1/ga)*(cvinc/100);...// 
      Variation in the air standard efficiency
13 disp(etach*100,"Percentage change in efficiency ")

```

---

#### Scilab code Exa 4.5 Maximum pressure in cylinder

```
1 clc;funcprot(0); //EXAMPLE 4.5
```

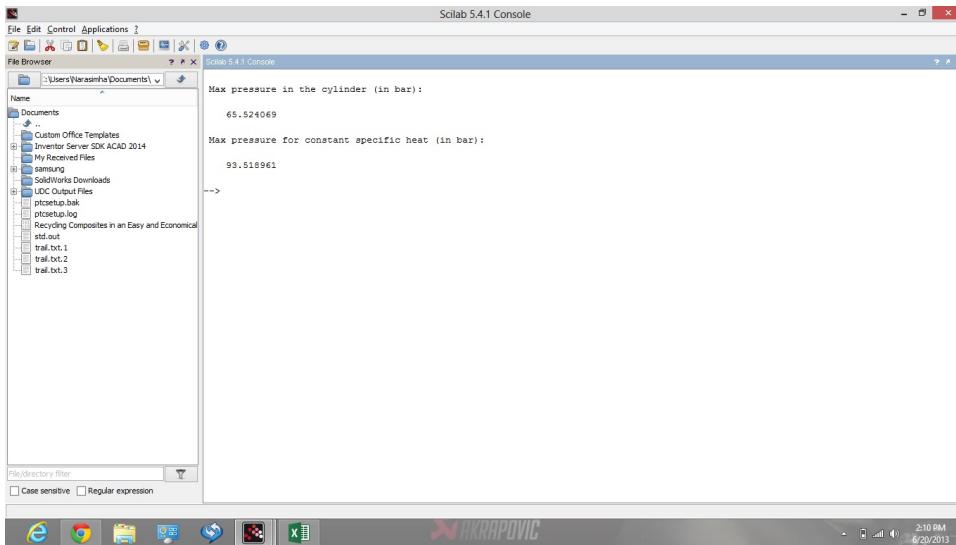


Figure 4.4: Maximum pressure in cylinder

```

2 // Initialisation of Variables
3 r=7; ..... //Compression ratio
4 C=44000; ..... //Calorific value of fuel
     used in kJ/kg
5 afr=15; ..... //Air fuel ratio
6 t1=338; ..... //Temperature of the
     charge at the end of the stroke in Kelvin
7 p1=1; ..... //Pressure of the charge
     at the end of the stroke in bar
8 n=1.33; ..... //Index of compression
9 cv=0.71; ..... //Specific heat constant at constant
     volume in kJ/kgK
10 k=20*10^(-5);
11 //Calculations
12 p2=p1*(r)^n;
13 t2=(t1*p2)/(p1*r);
14 ha=C/(afr+1); ..... //Heat added per
     kg of charge in kJ
15 t3=(((-2*cv)+sqrt((4*cv*cv)+(4*k*((2*cv*t2)+(k*t2*t2)
     +(2*ha))))))/(2*k);
```

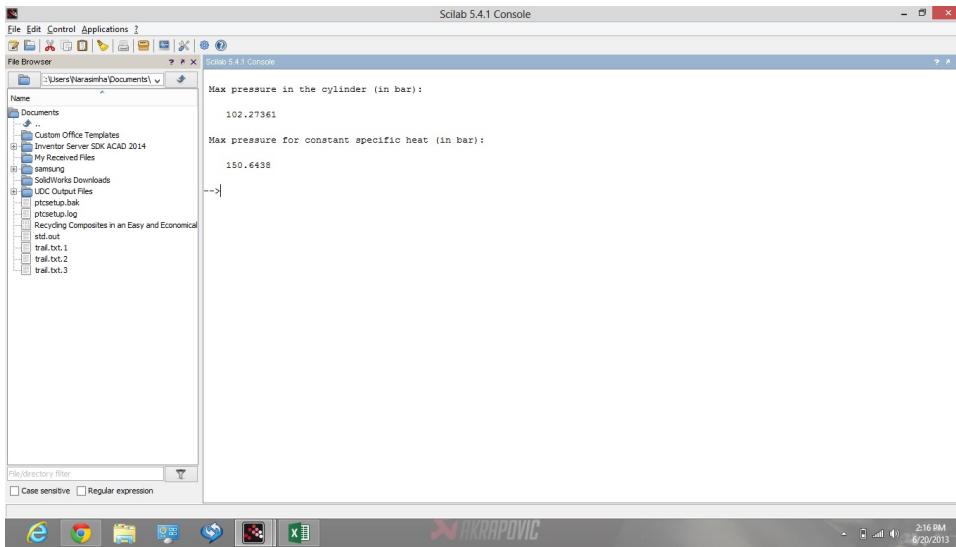


Figure 4.5: Maximum pressure in cylinder

---

```

16 p3=(p2*t3)/t2;.....//Max
    pressure for constant volume process in bar
17 P3=p2*((ha/cv)+t2)/t2;.....//Max
    pressure for constant specific heat in bar
18 disp(p3,"Max pressure in the cylinder (in bar):")
19 disp(P3,"Max pressure for constant specific heat (in
    bar):")
```

---

### Scilab code Exa 4.6 Maximum pressure in cylinder

```

1 clc;funcprot(0); //EXAMPLE 4.6
2 // Initialisation of Variables
3 r=10;.....//Compression ratio
4 C=48000;.....//Calorific value of fuel
    used in kJ/kg
5 afr=15;.....//Air fuel ratio
```

```

6 t1=330;.....//Temperature of the
    charge at the end of the stroke in Kelvin
7 p1=1;.....//Pressure of the charge
    at the end of the stroke in bar
8 n=1.36;.....//Index of compression
9 cv=0.7117;....//Specific heat constant at constant
    volume in kJ/kgK
10 k=2.1*10^(-4);
11 //Calculations
12 p2=p1*(r)^n;
13 t2=t1*((p2/p1)^((n-1)/n));
14 ha=C/(afr+1);.....//Heat added per
    kg of charge in kJ
15 t3=(((-2*cv)+sqrt((4*cv*cv)+(4*k*((2*cv*t2)+(k*t2*t2)
    +(2*ha)))))/(2*k));
16 p3=(p2*t3)/t2;.....//Max
    pressure for constant volume process in bar
17 P3=p2*((ha/cv)+t2)/t2;.....//Max
    pressure for constant specific heat in bar
18 disp(p3,"Max pressure in the cylinder (in bar):")
19 disp(P3,"Max pressure for constant specific heat (in
    bar):")

```

---

**Scilab code Exa 4.7** Percentage of the stroke when the combustion is completed

```

1 clc;funcprot(0); //EXAMPLE 4.7
2 // Initialisation of Variables
3 r=15;.....//Compression ratio
4 C=43000;.....//Calorific value of fuel
    used in kJ/kg
5 afr=27;.....//Air fuel ratio
6 t2=870;.....//Temperature of the

```

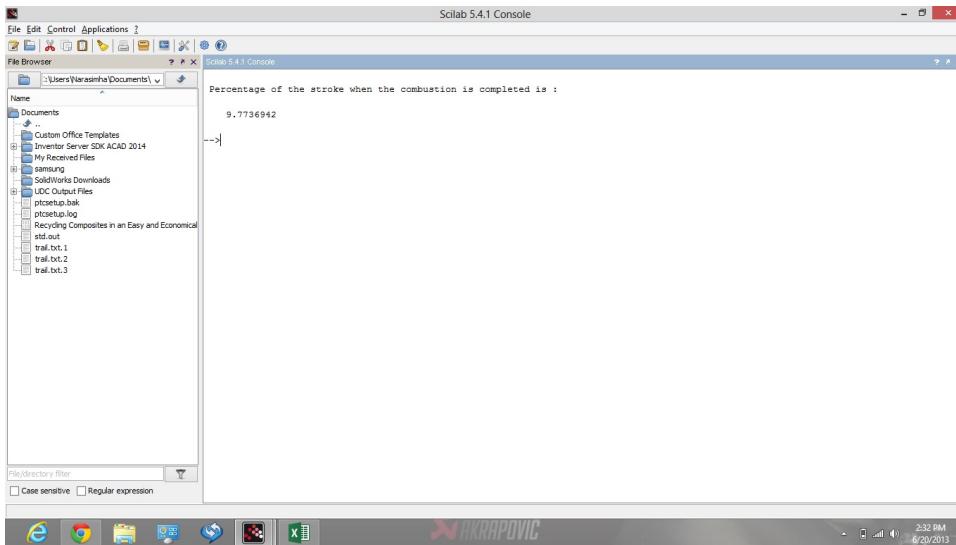


Figure 4.6: Percentage of the stroke when the combustion is completed

```

charge at the end of the stroke in Kelvin
7 cv=0.71;.....// Specific heat constant at constant
volume in kJ/kgK
8 R=0.287;.....//Gas constant in
kJ/kgK
9 k=20*10^(-5);
10 // Calculations
11 cp=cv+R;.....// Specific heat
at constant pressure
12 ha=C/(afr+1);.....//Heat added per
kg of charge in kJ
13 t3=(((-2*cp)+sqrt((4*cp*cp)+(4*k*((2*cp*t2)+(k*t2*t2)
+(2*ha))))))/(2*k);
14 co=((t3/t2)-1)/(r-1);.....//combustion
occupies this amt of stroke
15 disp(co*100,"Percentage of the stroke when the
combustion is completed is :")

```

---

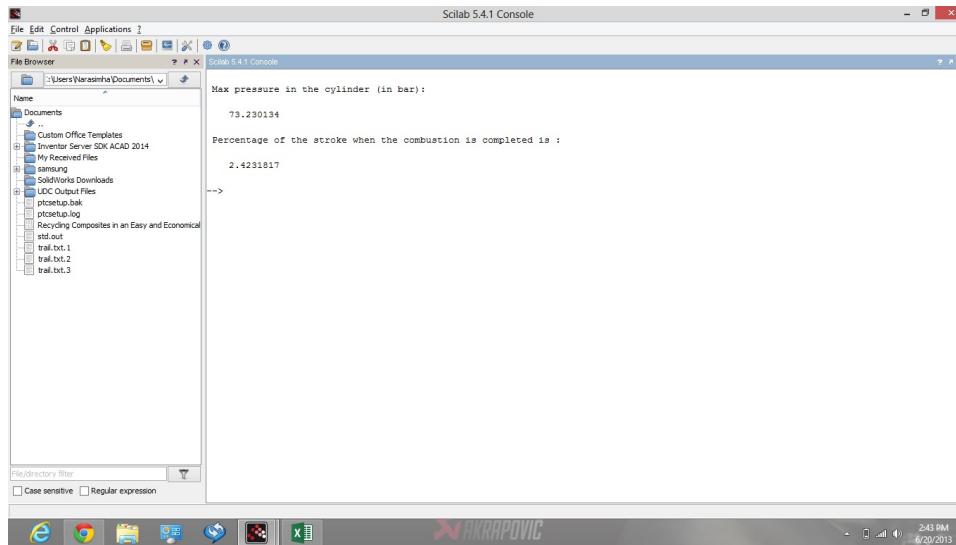


Figure 4.7: Percentage of the stroke when the combustion is completed

**Scilab code Exa 4.8** Percentage of the stroke when the combustion is completed

```

1 clc;funcprot(0); //EXAMPLE 4.8
2 // Initialisation of Variables
3 r=14;.....//Compression ratio
4 t1=87+273;.....//Temperature of the
   charge at the end of the stroke in Kelvin
5 p1=1;.....//Pressure of the charge
   at the end of the stroke in bar
6 hsupa=1700;.....//heat
   supplied per kg of air in kJ
7 cv=0.71;.....// Specific heat constant at constant
   volume in kJ/kgK
8 k=20*10^(-5);
9 ga=1.4;.....// Degree of freedom
10 R=0.287;.....//Gas constant in kJ/

```

```

        kgK
11 // Calculations
12 p2=p1*(r)^ga;
13 t2=t1*(r^(ga-1));
14 ha=hsupa/2;.....//Heat added per kg
    of charge in kJ
15 t3=(((-2*cv)+sqrt((4*cv*cv)+(4*k*((2*cv*t2)+(k*t2*t2)
    +(2*ha)))))/(2*k));
16 p3=(p2*t3)/t2;.....//Max
    pressure for constant volume process in bar
17 P3=p2*((ha/cv)+t2)/t2;.....//Max
    pressure for constant specific heat in bar
18 disp(p3,"Max pressure in the cylinder (in bar):")
19 cp=cv+R;.....//Heat
    capacity at constant pressure in kJ/kgK
20 t4=(((-2*cp)+sqrt((4*cp*cp)+(4*k*((2*cp*t3)+(k*t3*t3)
    +(2*ha)))))/(2*k));
21 co=((t4/t3)-1)/(r-1);.....//combustion
    occupies this amt of stroke
22 disp(co*100,"Percentage of the stroke when the
    combustion is completed is :")

```

---

**Scilab code Exa 4.9** Maximum pressure and temperature ignoring and considering fuel expansion

```

1 clc;funcprot(0); //EXAMPLE 4.9
2 // Initialisation of Variables
3 r=8;.....//Compression ratio
4 C=44000;.....//Calorific value of fuel in kJ/
    kg
5 afr=13.8;.....//Air fuel ratio
6 t1=343;.....//Temperature of
    the mixture at the beginning of the compression

```

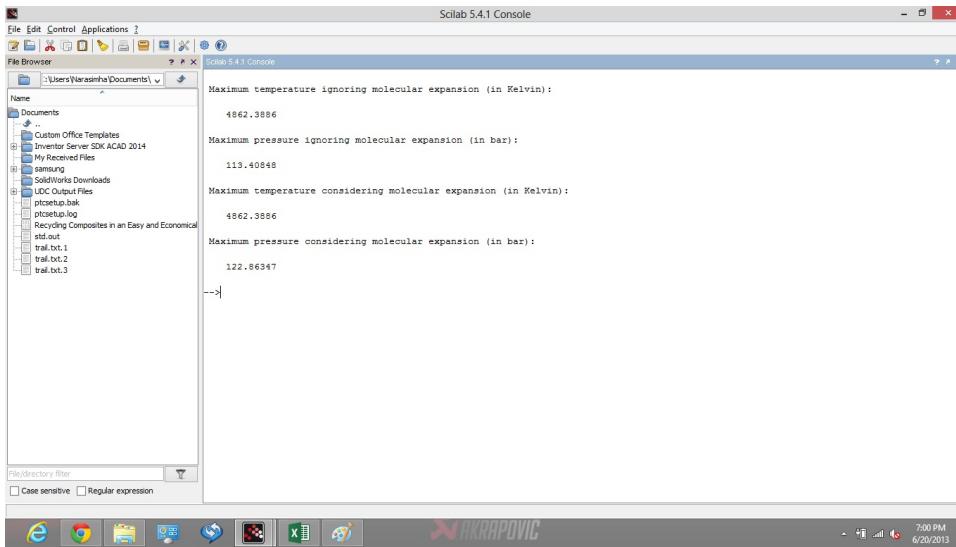


Figure 4.8: Maximum pressure and temperature ignoring and considering fuel expansion

```

    in Kelvin
7 p1=1;.....//Pressure of the
      mixture at the beginning of the compression in
      bar
8 cv=0.716;.....// Specific heat at
      constant volume in kJ/kgK
9 in=1.35;.....// Index of
      compression
10 nc=6;.....//No of carbon
      elements in the given fuel
11 nh=14;.....//No of hydrogen
      elements in the given fuel
12 mc=12;.....//Atomic mass of
      carbon in amu
13 mh=2;.....//atomic mass of
      hydrogen molecule in amu
14 mo=32;.....//Atomic mass of
      oxygen molecule in amu
15 // Calculations

```

```

16 //The chemical equation is C6H14 + xO2 ==> yCO2 +
   zH2O
17 //x is the no of oxygen molecules required for
   complete combustion
18 //y is the no of carbon dioxide molecules produced
   in complete combustion
19 //z is the no of Water molecules produced in
   complete combustion
20 y=nc; ..... //As no of CO2
   molecules is equal to no of C atoms in the fuel
21 z=nh/2; ..... //No of H2O
   molecules is equal to half the no of H atoms in
   the fuel
22 x=(z/2)+y; ..... //No of oxygen
   molecules required for combustion is half the no
   of water molecules plus the no of oxygen
   molecules
23 gafr=((x*32)*(100/23))/((mc*y)+(mh*z))
   ; ..... //Gravimetric air fuel ratio
24 ms=(gafr/afr)*100; ..... //Actual
   mixture strength
25 //Since the mixture strength is greater than 100 %
26 //The mixture is rich in fuel. The combustion is
   therefore incomplete and hence CO will be formed
27 d=ms/100; ..... //No of fuel
   molecules required for combustion
28 //The chemical equation is d(C6H14) + 9.5(O2) ==> a(
   CO2) + b(CO) + c(H2O)
29 c=(d*nh)/2; ..... //No of
   H2O molecules is equal to half the no of H atoms
   in the fuel
30 a=(x*2)-(d*nc)-c; ..... //Equating
   atoms of the same element on both sides of
   equation
31 b=(d*nc)-a;
32 //By adding nitrogen on both sides , we are adding
   the same molecular weight on both sides .
33 //Air is 79 % nitrogen and 21 % oxygen

```

```

34 //Both N2 and O2 are diatomic molecules
35 n=x*(79/21);.....//No of
    nitrogen molecules
36 mbc=d+x+n;.....//Moles
    before combustion
37 mac=a+b+c+n;.....//Moles
    after expansion
38 me=(mac-mbc)/mbc;.....//Molecular
    expansion
39 t2=(t1*(r^(in-1)));
40 t3=(t2+(C/((afr+1)*cv)));.....//Maximum
    temperature ignoring molecular expansion in
    Kelvin
41 p3=p1*r*(t3/t1);.....//Maximum
    pressure ignoring molecular expansion in bar
42 t3me=t3;.....//Maximum
    temperature considering molecular expansion in
    Kelvin
43 p3me=p3*(mac/mbc);.....//Maximum
    pressure considering molecular expansion in bar
44 disp(t3,"Maximum temperature ignoring molecular
    expansion (in Kelvin):")
45 disp(p3,"Maximum pressure ignoring molecular
    expansion (in bar):")
46 disp(t3me,"Maximum temperature considering molecular
    expansion (in Kelvin):")
47 disp(p3me,"Maximum pressure considering molecular
    expansion (in bar):")

```

---

### Scilab code Exa 4.10 Otto cycle work done and efficiency

```

1 clc;funcprot(0); //EXAMPLE 4.10
2 // Initialisation of Variables

```

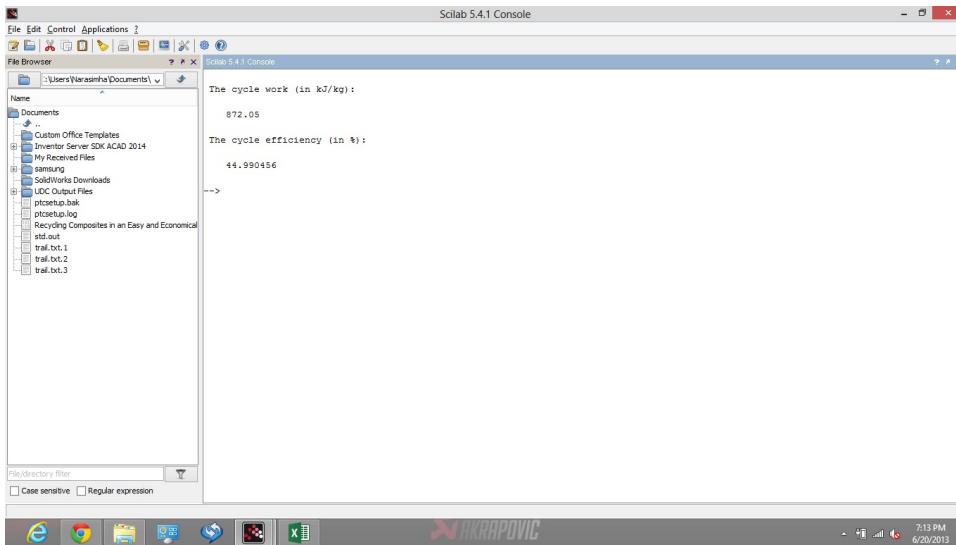


Figure 4.9: Otto cycle work done and efficiency

```

3 r=7;..... //Compression Ratio
4 t2=715;..... //Temperature at the end of
   isentropic compression in Kelvin
5 t4=1610;..... //Temperature at the end of
   expansion in Kelvin
6 //Calculations
7 vr2=65.8;..... //From steam table
8 u2=524.2;..... //From steam table
9 vr4=5.69;..... //From steam table
10 u4=1307.63;..... //From steam table
11 vr1=r*vr2;
12 t1=338;..... //From steam table
13 u1=241.38;..... //From steam table
14 vr3=vr4/r;
15 t3=2800;..... //From steam table
16 u3=2462.5;..... //From steam table
17 W=(u3-u2)-(u4-u1);..... //Work done
18 Qa=(u3-u2);..... //Heat added
19 eta=W/Qa;..... //Cycle
   efficiency

```

```
20 disp(W,"The cycle work (in kJ/kg):")
21 disp(eta*100,"The cycle efficiency (in %):")
```

---

# Chapter 5

## Combustion in SI engines

**Scilab code Exa 5.1** Time for combustion process and total crank rotation

```
1 clc;funcprot(0); //EXAMPLE 5.1
2 // Initialisation of Variables
3 d=10.2;..... //Engine bore in cm
4 spo=0.6;..... //Spark plug offset in cm
5 vf=15.8;..... //Average flame speed in m/s
6 thetas=20;..... //The angle of the crank when
    spark plug is fired
7 theta=6.5;..... //Angle by which the Engine
    rotates for combustion to develop (degree)
8 N=1200;..... //Engine rpm
9 //calculations
10 dmax=(0.5*d)+spo;..... //Max distance of flame
    travel in cm
11 tf=(dmax)/(vf*100);..... //Time of flame
    travel in seconds
12 degs=(N/60)*360;..... //Conversion of
    engine rpm into degree/second
13 ctheta=tf*degs;..... //Crank angle for
    flame travel in degree
```

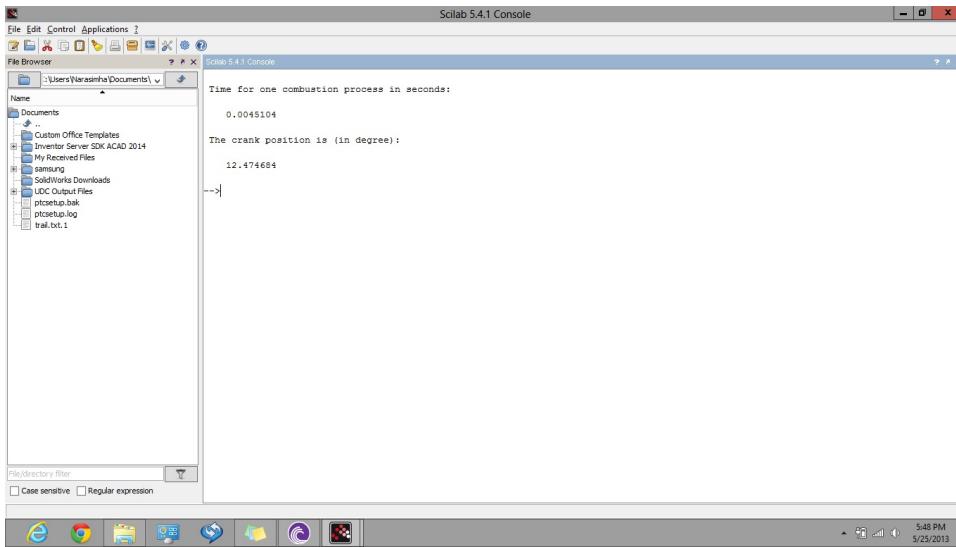


Figure 5.1: Time for combustion process and total crank rotation

```

14 tc=theta/degs;.....//time for
    combustion to develop in seconds
15 top=tf+tc;.....//Time for one
    combustion process in seconds
16 thetatot=theta+ctheta;.....//Total crank
    rotation in degree
17 thetacp = thetatot-thetas;.....//Crank position
18 disp(top,"Time for one combustion process in seconds
    :")
19 disp(thetacp,"The crank position is (in degree):")

```

---

### Scilab code Exa 5.2 Time of spark

```

1 clc;funcprot(0); //EXAMPLE 5.2
2 // Initialisation of Variables
3 dp=22;.....//Delay period in degree

```

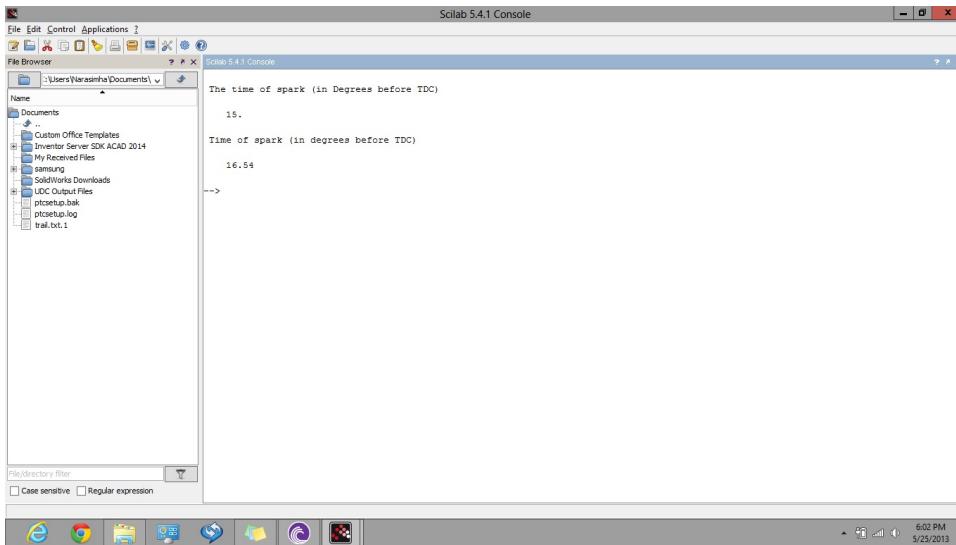


Figure 5.2: Time of spark

```

4 cp=17;.....//Combustion period in degree
5 dper=14;.....//Delay Percentage
6 //Calculations
7 thetad=dper/2;.....//Full throttle half speed will
    result in delay angle being reduced for the same
    time
8 //Thus ignition timing should be arranged so that
    the total of thetad+cp ends 13 degree after TDC
9 tsp=(thetad+cp)-13;.....//Time of spark in
    degree
10 disp(tsp,"The time of spark (in Degrees before TDC)"
    )
11 //Half throttle half speed will result in an
    increase of 14% in delay time over that at full
    throttle half speed
12 theta=(dper*thetad)/100;
13 dtheta=thetad+theta;.....//Delay angle
14 tp=dtheta+cp;.....//Total period
15 tsp=tp-13;.....//
16 disp(tsp,"Time of spark (in degrees before TDC)")
```

---

# Chapter 7

## Air Capacity of Four Stroke Engines

Scilab code Exa 7.1 Volume of Gas

```
1 clc;funcprot(0); //EXAMPLE 7.1
2 // Initialisation of Variables
3 D=20.3;.....//Diameter in cm
4 L=30.5;.....//Length in cm
5 N=300;.....//Engine rpm
6 eta=78;.....//Efficiency in percentage
7 afr=4/1;.....//Air Fuel Ratio
8
9 //Calculations
10 StV = ((%pi)/4)*((D/100)^2)*(L/100);.....//
   Calculating the stroke volume
11 Vinh= (eta/100)*StV;.....//Volume
   Inhaled
12 Gainh= (Vinh/(4+1));.....//Gas Inhaled
13 Gainhpm = Gainh*(N/2);
14 disp (Gainhpm , "Gas Inhaled per minute : (m^3/min)")
```

---

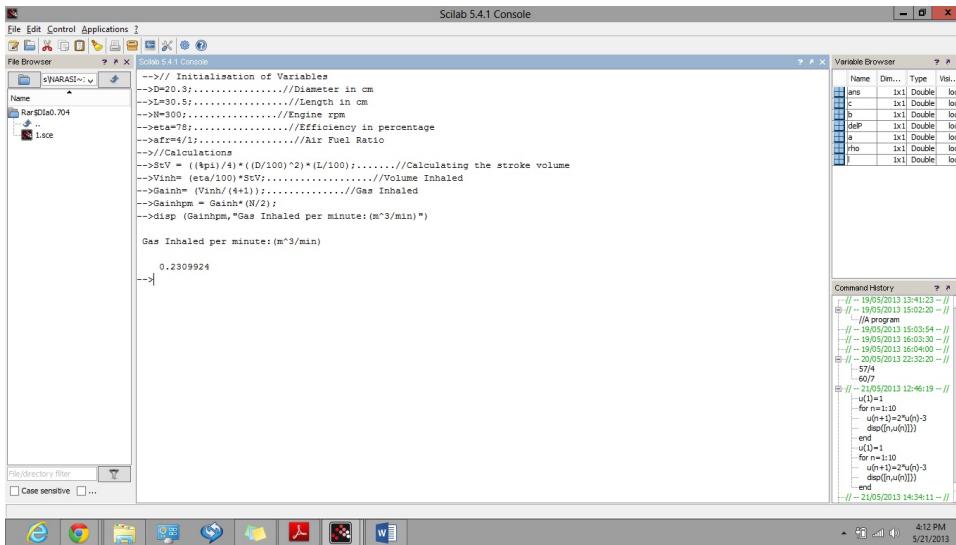


Figure 7.1: Volume of Gas

### Scilab code Exa 7.2 Volumetric Efficiency

```

1 clc;funcprot(0)//EXAMPLE 7.2
2 // Initializing the variables
3
4 N=3600;.....//engine rpm
5 T=15;.....//Inlet temperature in degree
   Celsius
6 Tk = T+273;.....//Inlet temperature in
   Kelvin
7 p=760;.....//Inlet pressure in mm of Hg i
   .e. 1.013 x 10^5 Pa
8 ppa=1.013*(10^5);.....// Inlet pressure in
   Pascals
9 pdv=4066;.....//Total piston displacement

```

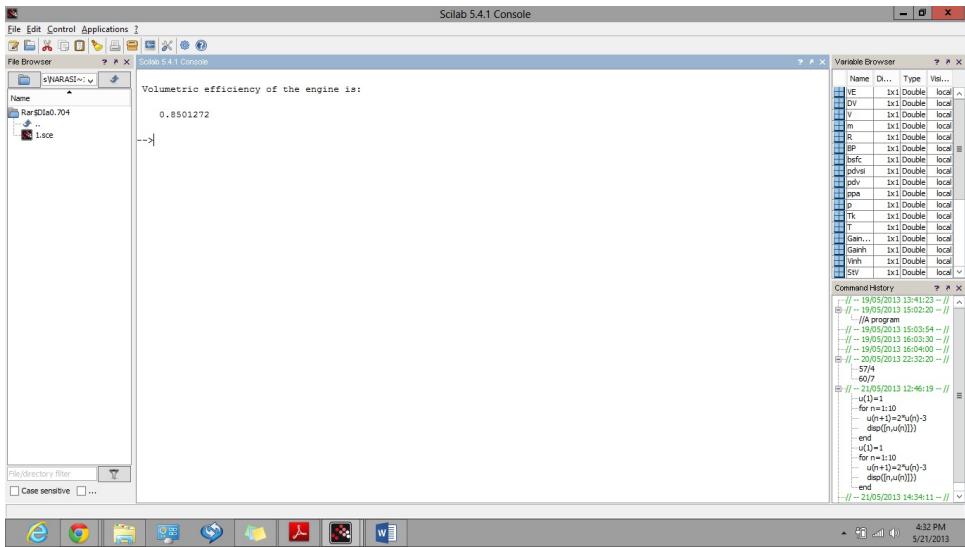


Figure 7.2: Volumetric Efficiency

```
volume in cm^3
10 pdvsi=pdv*(10^(-6));.....//Total piston
displacement volume in m^3
11 afr=14/1;.....//Air fuel ratio is 14:1
12 bsfc=0.38;.....// b.s.f.c in kg/kWh
13 BP=86;.....//power output in kW
14 R=287;.....//Gas constant for air in J/kg
.K
15 //Calculations
16 m = (BP*bsfc*afr)/60;.....//Air
consumption
17 V = (m*R*Tk)/ppa;
18 DV= pdvsi*(N/2);.....//Displacement Volume
19 VE=V/DV;.....//Volumetric Efficiency
20 disp (VE," Volumetric efficiency of the engine is:")
```

---

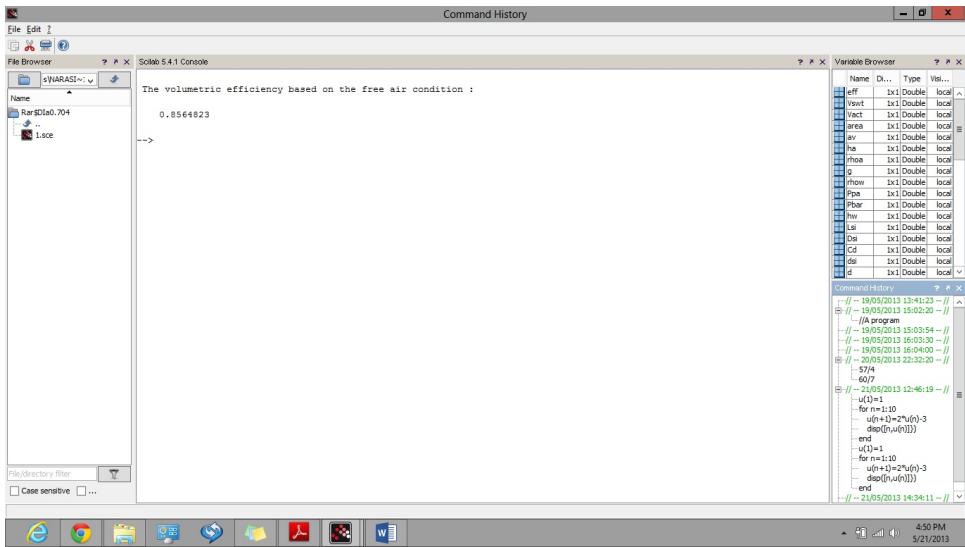


Figure 7.3: Volumetric Efficiency

### Scilab code Exa 7.3 Volumetric Efficiency

```

1 clc;funcprot(0)//EXAMPLE 7.3
2
3 // Initializing the variables
4 n=4;.....//No of cylinders
5 d=5;.....//diameter of orifice in cm
6 ds=d/100;.....// diameter in m
7 Cd=0.6;.....//Co-efficient of discharge
8 D=10;.....//Engine bore in cm
9 Ds=d/100;.....//Engine bore in m
10 L=12;.....//Engine stroke in cm
11 Ls=L/100;.....//Engine stroke in m
12 N=1200;.....//Engine rpm
13 hw=0.046;.....//Pressure drop across orifice
    in m of water
14 T = 17;.....//Ambient Temperature in Degree
    Celsius
15 Tk = T+273;.....// Ambient Temperature in
    Kelvin

```

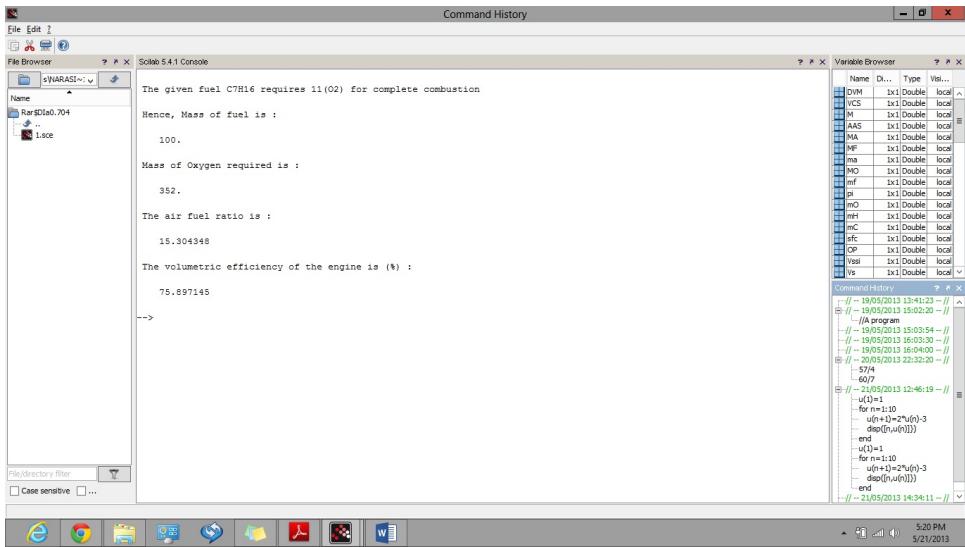


Figure 7.4: Volumetric Efficiency

```

16 Pbar = 1;.....// Ambient pressure in bar
17 Ppa = 1 * (10^5);.....//Ambient pressure in Pascal
18 R = 287;.....// Gas constant in J/kg.K
19 rho_w = 1000;.....//Density of water in kg/m^3
20 g=9.81;.....//Acceleration due to gravity
21 //Calculations
22
23 rho_a= Ppa/(R*T_k);.....//Density of air
24 ha= (h_w*rho_w)/rho_a;
25 av= sqrt(2*g*ha);.....//Air velocity
26 area = (%pi/4)*(dsi^2);
27 Vact = Cd*area*av;.....// V actual
28 Vswt = n*(%pi/4)*(Dsi^2)*Lsi*(N/60*2);
29 eff = Vact/Vswt;.....//Volumetric
    efficiency
30 disp (eff,"The volumetric efficiency based on the
    free air condition : ")

```

### Scilab code Exa 7.4 Volumetric Efficiency

```
1 clc;funcprot(0)//EXAMPLE 7.4
2
3 // Initializing the variables
4 n=1;.....//No of cylinders
5 k=0.5;
6 Vs=7000;.....//displacement volume in cm^3
7 Vssi= Vs*(10^(-6));.....//displacement volume in
     m^3
8 OP=14.7;.....//Power developed in kW
9 N=450;.....//Engine rpm
10 sfc=0.272;.....// Specific fuel
    consumption in kg/kWh
11 //Fuel used is C7H16
12 mC=12;.....//mass of carbon in amu
13 mH=1;.....//mass of hydrogen in amu
14 mO=16;.....//mass of oxygen in amu
15 pi=1.013 * (10^5);.....//initial pressure
    in pascal
16 T=30;.....//initial temperature in
    degree celsius
17 Tk=30+273;.....// initial temperature in
    degree kelvin
18 R=287;.....//Gas constant for air in J/
    kg.K
19 //calculations
20 disp("The given fuel C7H16 requires 11(O2) for
    complete combustion")
21 mf=(7*mC)+(16*mH);
22 disp (mf," Hence , Mass of fuel is :")
23 M0=11* 2 * mO;
24 disp (M0," Mass of Oxygen required is :")
25 ma = M0/0.23;.....//mass of air
```

```

26 // Air contains 23% of oxygen by weight
27 afr = ma/mf;.....// air fuel ratio is the
      ratio of mass of air to mass of fuel
28 disp(afr,"The air fuel ratio is :")
29 MF = sfc * OP;.....//actual fuel consumed in
      kg/h
30 MA = afr*MF;
31 AAS = MA * (1+0.3);.....// actual air
      supplied in kg/h
32 M = AAS + MF;.....//mass of charge in kg/
      h
33 VCS = ((M/60)*R*Tk)/pi;.....//Volume of
      charge sucked in m^3/min
34 DVM = Vssi * (N/2);.....// Displacement
      volume/min
35 eta = VCS/DVM;
36 disp (eta*100,"The volumetric efficiency of the
      engine is (%) :")

```

---

### Scilab code Exa 7.5 Brake Torque

```

1 clc;funcprot(0)//EXAMPLE 7.5
2
3 // Initializing the variables
4 n=6;.....//No of cylinders
5 vsi=730*(10^(-6));.....// Piston displacement
      per cylinder in m^3
6 BP=80;.....//Power produced per cylinder in
      kW
7 N=3100;.....//Engine rpm
8 C=44*(10^6);.....//Calorific value of petrol
      in J/kg
9 Pc=28;.....//Petrol consumed per hour in kg

```

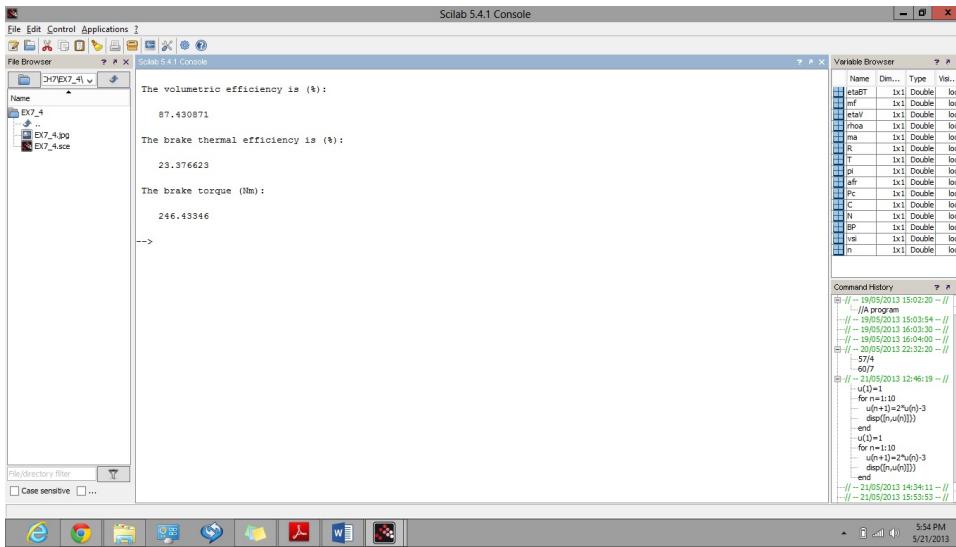


Figure 7.5: Brake Torque

```

10 afr = 13/1;.....//air fuel ratio
11 pi=0.88*(10^5);.....//Intake pressure in pa
12 T=300;.....//Intake temperature in Kelvin
13 R = 287;.....//gas constant in J/kg.K
14 //calculations
15 ma = (Pc*afr)/60;.....// air consumed
16 rhoa = pi/(R*T);.....//Density of air
17 etaV=ma/(rhoa*vsi*n*(N/2));
18 disp(etaV*100,"The volumetric efficiency is (%) :")
19 mf = Pc/3600;.....//Fuel consumed per sec
20 etaBT = (BP*1000)/(mf*C);
21 disp (etaBT*100,"The brake thermal efficiency is (%) :")
22 T=(BP*60*1000)/(2*(%pi)*N);
23 disp (T,"The brake torque (Nm) :")

```

---

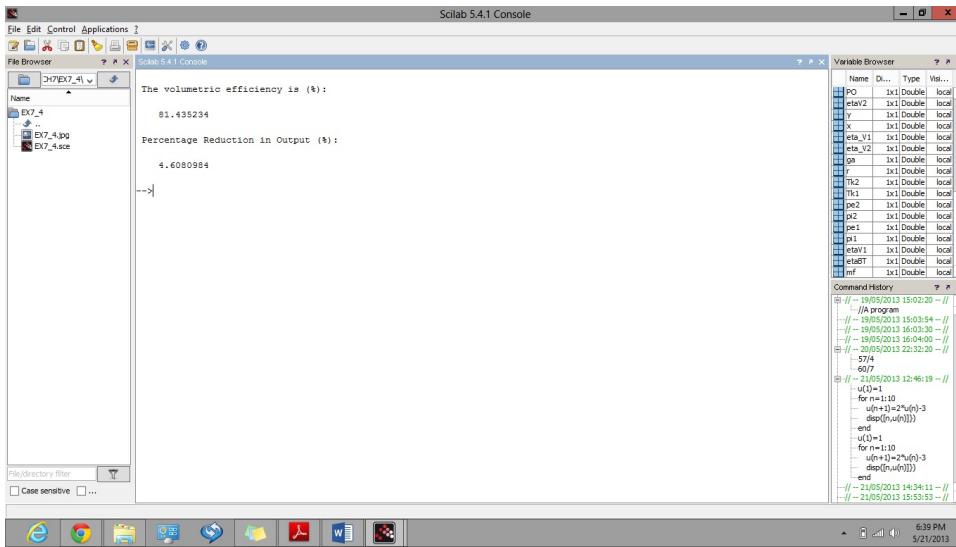


Figure 7.6: Percentage change in output

### Scilab code Exa 7.6 Percentage change in output

```

1 clc;funcprot(0)//EXAMPLE 7.6
2
3 // Initializing the variables
4 etaV1 = 0.8;.....//Volumetric efficiency
5 pi1 = 1.013;.....//Inlet pressure
6 pe1= 1.013;pi2= 1.013;
7 pe2 = 1.15;.....//Exhaust pressure
8 Tk1 = 298;.....//Temperature in Kelvin
9 Tk2 = 318;.....//Temperature in Kelvin
10 r = 7.5;.....//compression ratio
11 ga=1.4;.....//degree of freedom for gas
12 //calculations
13 //For pressure change
14 eta_V2 = r - (pe2/pi2)^(1/ga);
15 eta_V1 = r - (pe1/pi1)^(1/ga);
16 x=eta_V2/eta_V1;
17 //For inlet temperature change
18 y = sqrt(Tk2/Tk1);

```

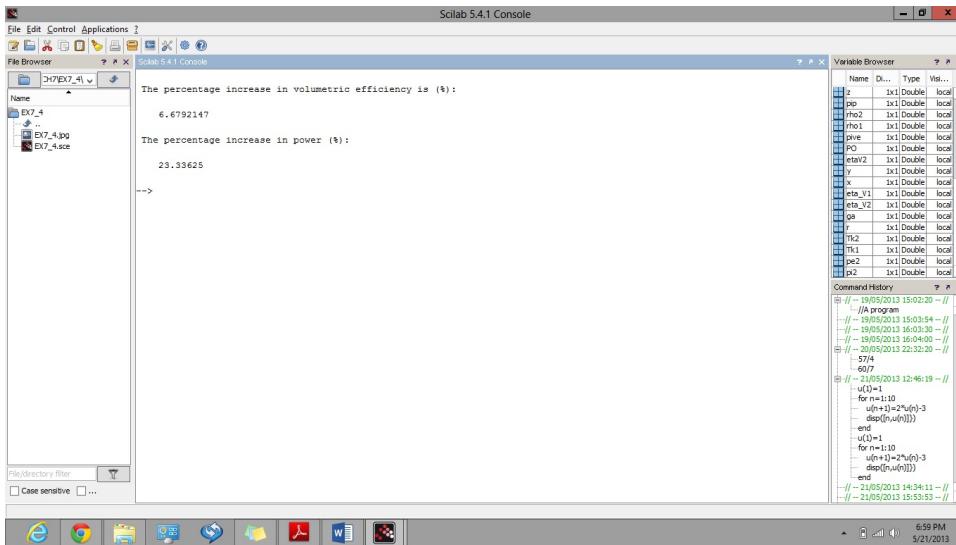


Figure 7.7: Percentage change in output

```

19 //For volumetric efficiency , considering both
   pressure and temperature
20 etaV2 = etaV1*x*y;
21 disp(etaV2*100,"The volumetric efficiency is (%):")
22 P0=((etaV1/Tk1)-(etaV2/Tk2))/(etaV1/Tk1);
23 disp(P0*100,"Percentage Reduction in Output (%):")

```

---

### Scilab code Exa 7.7 Percentage change in output

```

1 clc;funcprot(0)//EXAMPLE 7.7
2
3 // Initializing the variables
4 pi1 = 1.013;.....//Inlet pressure
5 pe1= 1.013;pi2= 1.3;
6 pe2 = 1.013;.....//Exhaust pressure
7 Tk1 = 300;.....//Temperature in Kelvin

```

```

8 Tk2 = 333;.....//Temperature in Kelvin
9 r = 14;.....//compression ratio
10 ga=1.4;.....//degree of freedom for gas
11 R=287;.....//gas constant in J/kg.K
12 //calculations
13 //For pressure change
14 eta_V2 = r - (pe2/pi2)^(1/ga);
15 eta_V1 = r - (pe1/pi1)^(1/ga);
16 x=eta_V2/eta_V1;
17 //For inlet temperature change
18 y = sqrt(Tk2/Tk1);
19 //For volumetric efficiency , considering both
    pressure and temperature
20 pive = ((x*y)-1);.....//percentage increase in
    volumetric efficiency
21 disp(pive*100,"The percentage increase in volumetric
    efficiency is (%):")
22 rho1 = (pi1*10^5)/(R*Tk1);
23 rho2 = (pi2*10^5)/(R*Tk2);
24 z = (rho2/rho1)*x*y;
25 pip = (z-1);
26 disp (pip*100,"The percentage increase in power (%):
    ")

```

---

**Scilab code Exa 7.8** Percentage change in Volumetric efficiency and Brake Power

```

1 clc;funcprot(0)//EXAMPLE 7.8
2
3 // Initializing the variables
4 IP1 = 32;.....//Indicated power output in
    kW
5 etamech=80;.....//Mechanical efficiency at

```

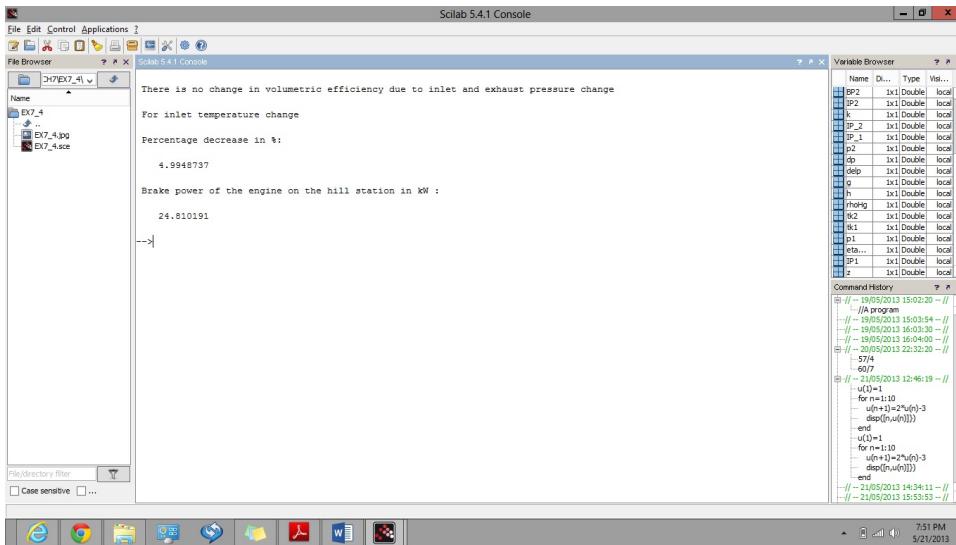


Figure 7.8: Percentage change in Volumetric efficiency and Brake Power

```

sea level
6 p1=1.013;.....//initial pressure at sea
level in bar
7 tk1 = 308;.....//Initial temperature at
sea level in Kelvin
8 tk2 = 278;.....//temperature atop the
hill in Kelvin
9 rhoHg=13600;.....//Density of mercury in kg
/m^3
10 h=2000;.....//Hill altitude
11 g = 9.81;.....//Acceleration due to
gravity
12 delp = 10;.....//drop of mercury in mm Hg
per every 100 m climb
13 //calculations
14
15 disp("There is no change in volumetric efficiency
due to inlet and exhaust pressure change")
16 disp ("For inlet temperature change")
17 x = sqrt (tk2/tk1);.....//for inlet

```

```

        temperature change
18 //x is the ratio of the efficiencies at the
   beginning and on hill top
19 disp ((1-x)*100,"Percentage decrease in %:")
20 dp = rhoHg*g*((delp/1000)*(h/100))*(10^(-5))
   ;.....//Drop in pressure at hill station
21 p2=p1-dp;
22 IP_1 = p1/tk1;
23 IP_2 = (x*p2)/tk2;
24 k = IP_2/IP_1;.....//Ratio of indicative
   power output during initial and final conditions
25 IP2 = (IP1 * k)/(etamech/100);
26 //Since the engine speed is the same at two places ,
   the friction and hence mechanical efficiency
   remains unchanged
27 BP2 = IP2*(etamech/100);
28 disp(BP2,"Brake power of the engine on the hill
   station in kW :")

```

---

### Scilab code Exa 7.9 Volumetric Efficiency and Indicated Power for Supercharged Engine

```

1 clc;funcprot(0)//EXAMPLE 7.9
2
3 // Initializing the variables
4 etaV1 = 0.81;.....//Volumetric efficiency
5 pi1 = 1.01;.....//Inlet pressure before
   supercharger
6 pe1= 1.01;.....//Exhaust pressure before
   supercharger
7 pi2= 1.38;.....//Inlet pressure after
   supercharger
8 pe2 = 1.01;.....//Exhaust pressure in bar after

```

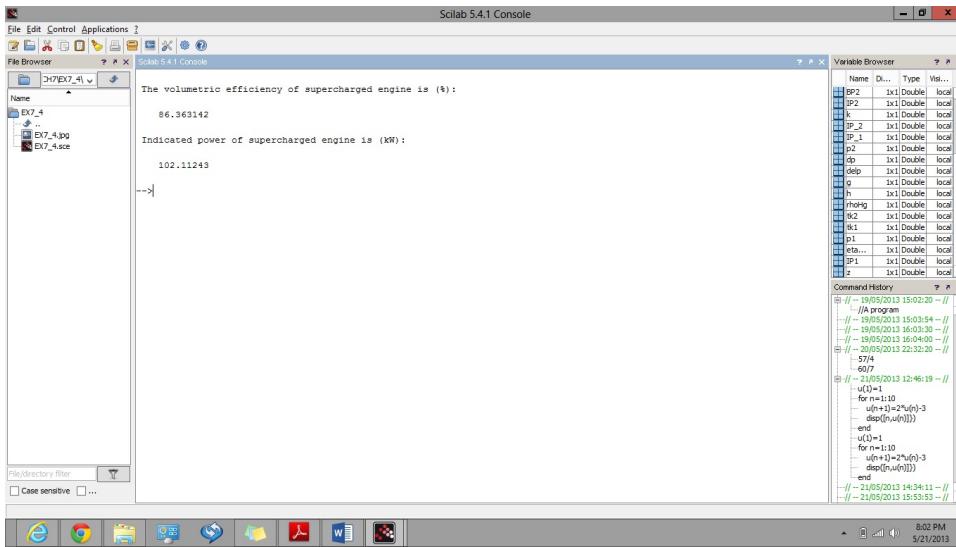


Figure 7.9: Volumetric Efficiency and Indicated Power for Supercharged Engine

```

addition of super charger
9 Tk1 = 300;.....//Temperature in Kelvin
10 Tk2 = 321;.....//Temperature in Kelvin
11 r = 7.5;.....//compression ratio
12 ga=1.4;.....//degree of freedom for gas
13 R=287;.....//Gas constant for air in J/kgK
14 IP1=75;.....//Indicated power output
    before addition of supercharger
15 //calculations
16 //For pressure change
17 eta_V2 = r - (pe2/pi2)^(1/ga);
18 eta_V1 = r - (pe1/pi1)^(1/ga);
19 x=eta_V2/eta_V1;
20 //For inlet temperature change
21 y = sqrt(Tk2/Tk1);
22 //For volumetric efficiency , considering both
    pressure and temperature
23 etaV2 = etaV1*x*y;
24 disp(etaV2*100,"The volumetric efficiency of
```

```

        supercharged engine is (%) :")
25 rho1 = (pi1*10^5)/(R*Tk1);....//density of air
    before addition of supercharger
26 rho2 = (pi2*10^5)/(R*Tk2);..//density of air after
    addition of supercharger
27 IP2 = IP1 * (etaV2*rho2)/(etaV1*rho1);
28 disp(IP2," Indicated power of supercharged engine is
(kW) :")

```

---

### Scilab code Exa 7.10 Volumetric Efficiency and Heating Value

```

1 clc;funcprot(0)//EXAMPLE 7.10
2
3 // Initializing the variables
4 n=1;.....//No of cylinders
5 D=0.32;.....//Bore of the cylinder in m
6 L=0.38;.....//Stroke of the cylinder in m
7 N = 280;.....//Engine rpm
8 CV = 18600;....//calorific value of fues in kJ/m^3
9 Tk1 = 300;....//Initial temperature in Kelvin
10 p1 = 1.013;....//Initial pressure in bar
11 ma = 3.36;.....//mass of air consumed per min
12 tgc = 0.25;....//test gas consumption in m^3/min
13 pw = 120;.....//pressure of water in mm during
    the test gas consumption
14 tgct = 300;.....//Temperature in Kelvin during
    test gas consumption
15 rhow = 1000;....//density of water in kg/m^3
16 R=287;.....//Gas constant in J/kg.K
17 //calculations
18 V= (ma*R*Tk1)/(p1*(10^5));...//Volume of air
    consumed at inlet condition
19
20 gsp = p1 +(pw/rhow)/10.2;.....//Gas
    supply pressure

```

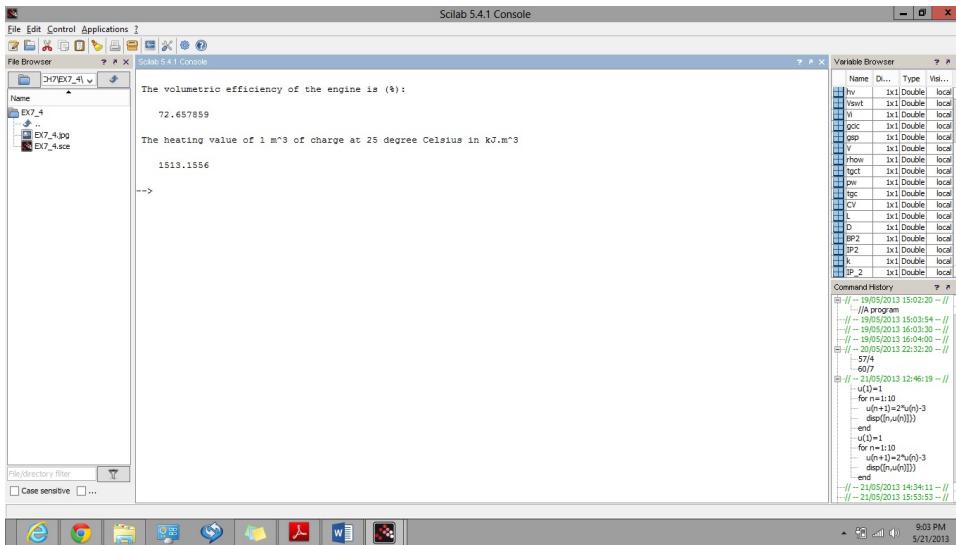


Figure 7.10: Volumetric Efficiency and Heating Value

```

21 //1 bar = 10.2 m
22 gcic = tgc*(gsp/p1);.....//Gas consumption at
   inlet condition
23 Vi = gcic+V;....//Volume of mixture at inlet
   condition
24 Vswt = (%pi/4)*(D^2)*L*(N/2);.....//Swept volume
25 etaV = Vi/Vswt;....//Volumetric efficiency
26 disp(etaV*100,"The volumetric efficiency of the
   engine is (%):")
27 hv = (gcic/Vi)*CV;.....//Heating value
28 disp(hv,"The heating value of 1 m^3 of charge at 25
   degree Celsius in kJ.m^-3")

```

---

The screenshot shows the Scilab 5.4.1 Console window. The code in the console window is as follows:

```

Scilab 5.4.1 Console
File Edit Control Applications ...
File Browser Scilab 5.4.1 Console
Name
EX_12
EX_11
(i)Nominal diameter of the inlet valve is (m):
0.049460
(mm)=
44.946013
(ii)When the engine is modified to develop max indicative power at 2800rpm, nominal diameter of the inlet valve is (m):
0.0485472
(mm)=
48.547242
(iii)The new mach index value is :
0.6416667
Hence the volumetric efficiency drops (There is a steady decrease in volumetric efficiency of an engine if there is an increase in the mach index beyond 0
.55, Refer the FIG 7_12)
(iv)The mach index for the unmodified engine is :
1.1
The volumetric efficiency is approximately 56% (from the FIG 7_12)
-->

```

Figure 7.11: Nominal Diameter of Inlet Valve and Volumetric Efficiency vs Mach Index

**Scilab code Exa 7.12** Nominal Diameter of Inlet Valve and Volumetric Efficiency vs Mach Index

```

1 clc;funcprot(0)//EXAMPLE 7.12
2
3 // Initializing the variables
4 Z=0.55;.....//Mach Index
5 Dcy=0.11;.....//Engine Bore in m
6 L = 0.14;.....//stroke length in m
7 N = 2400;.....//Engine rpm
8 N1 = 2800;.....//Engine rpm after
    modification
9 N2=4800;.....//Max rpm for unmodified engine
10 p = 0.88;.....//pressure at intake valve in bar
11 t=340;.....//temperature at intake valve
    in Kelvin
12 ki = 0.33;.....//Inlet flow co-efficient
13 ga = 1.4;.....//degree of freedom of the
    gas

```

```

14 R = 287;.....//Gas constant for air in J
    /kg.K
15 //calculations
16
17 Us = sqrt(ga*R*t);....//sonic velocity of air-fuel
    mixture at the inlet valve
18 Up = (2*L*N)/60;.....//piston speed
19 Div = sqrt(((Dcy^2)*Up)/(Z*ki*Us));.....//
    Nominal diameter of the inlet valve in m
20 disp(Div,"(i)Nominal diameter of the inlet valve is
    (m):")
21 disp(Div*1000,"(mm)=")
22 Div1 = sqrt(((Dcy^2)*2*L*N1)/(Z*ki*Us*60));....//
    Nominal diameter of inlet valve for the modified
    engine in m
23 disp(Div1,"(ii)When the engine is modified to
    develop max indicative power at 2800rpm, nominal
    diameter of the inlet valve is (m):")
24 disp(Div1*1000,"(mm)=")
25 Up1=(2*L*N1)/60;.....//New piston speed for
    modified engine
26 Z1 = ((Dcy/Div)^2)*(Up1/(ki*Us));
27 disp(Z1,"(iii)The new mach index value is :")
28 disp("Hence the volumetric efficiency drops (There
    is a steady decrease in volumetric efficiency of
    an engine if there is an increase in the mach
    index beyond 0.55, Refer the FIG 7_12)")
29 Up2 = (2*L*N2)/60;.....//Piston speed at
    max rpm for unmodified engine
30 Z2 = ((Dcy/Div)^2)*(Up2/(ki*Us));
31 disp(Z2,"(iv)The mach index for the unmodified
    engine is :")
32 disp("The volumetric efficiency is approximately 56%
    (from the FIG 7_12)")

```

---

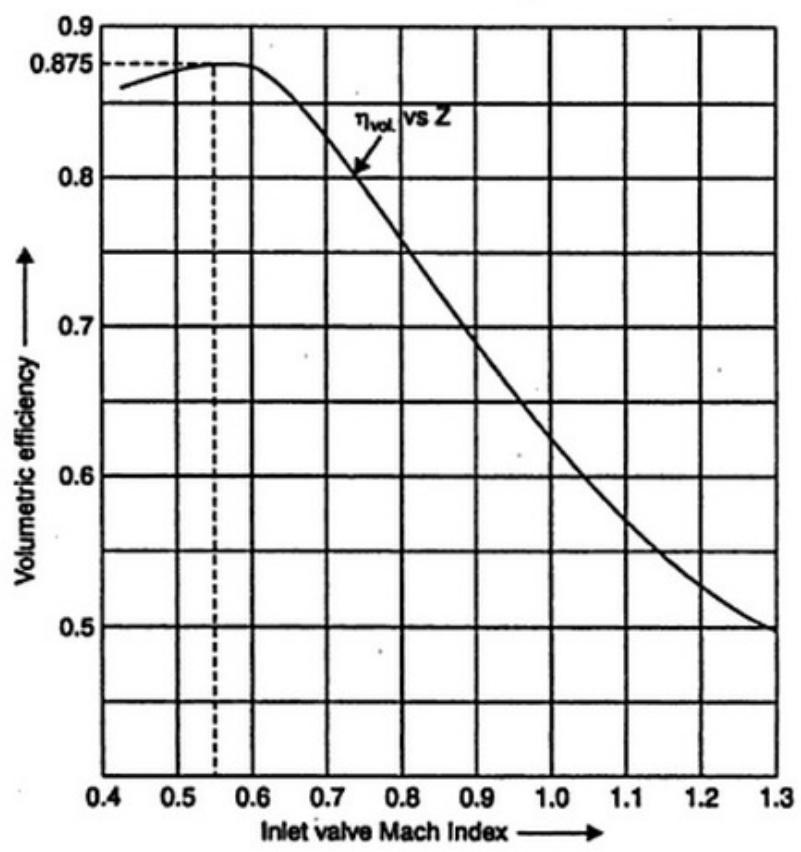


Figure 7.12: Nominal Diameter of Inlet Valve and Volumetric Efficiency vs Mach Index

# Chapter 11

## Carburation and carburettors

Scilab code Exa 11.1 Suction at throat

```
1 clc;funcprot(0); //EXAMPLE 11.1
2 // Initialisation of Variables
3 d=0.1;..... //Cylinder bore in m
4 l=0.12;..... //Cylinder stroke in m
5 N=1800;..... //Engine rpm
6 d2=0.028;..... //Throat diameter in m
7 Cda=0.8;..... //Co efficient of air flow
8 etaV=0.75;..... //Volumetric efficiency
9 rhoa=1.2;..... //Density of air in kg/m^3
10 n=4;..... //No of cylinders
11 //Calculations
12 Vs=(%pi/4)*d*d*l*n;..... //Stroke Volume
   in m^3
13 Va=etaV*Vs;..... //Actual volume
   per stroke in m^3
14 Vas=Va*(N/2)*(1/60);..... //Actual volume
   sucked per second
15 ma=Vas*rhoa;..... //Air consumed
   in kg/sec
```

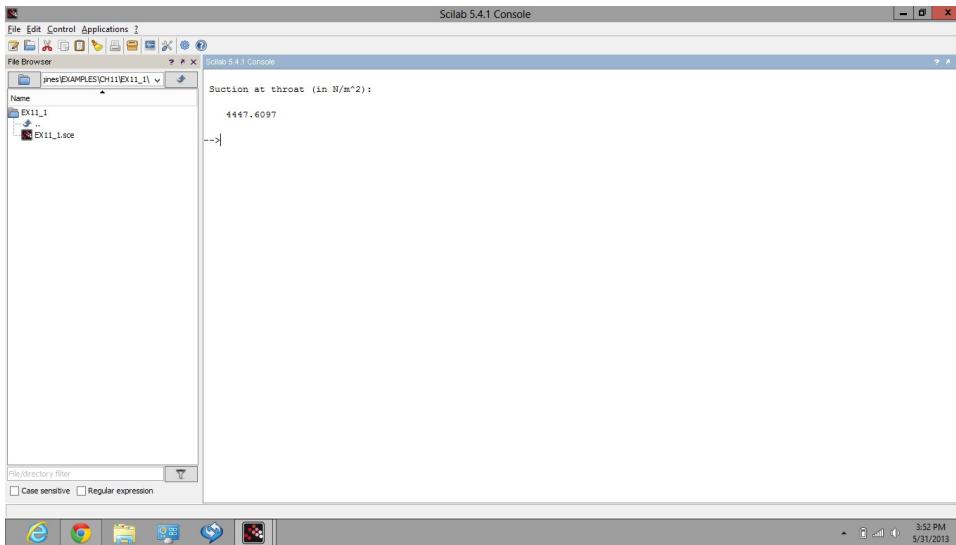


Figure 11.1: Suction at throat

```

16 delp=((ma/(Cda*(%pi/4)*d2*d2))^2)/(2*rhoa)
      ;.....//Suction at throat in N/m^2
17 disp(delp,"Suction at throat (in N/m^2):")

```

---

### Scilab code Exa 11.2 Depression in Venturi throat and throat area

```

1 clc;funcprot(0); //EXAMPLE 11.2
2 // Initialisation of Variables
3 cp=5;.....//Consumption of petrol in kg/
   h
4 afr = 16;.....//Air fuel ratio
5 Af=2*10^(-6);.....//Fuel orifice area in m
   ^2
6 z=0.005;.....//Distance between tip of
   jet and level of petrol in float chamber in m

```

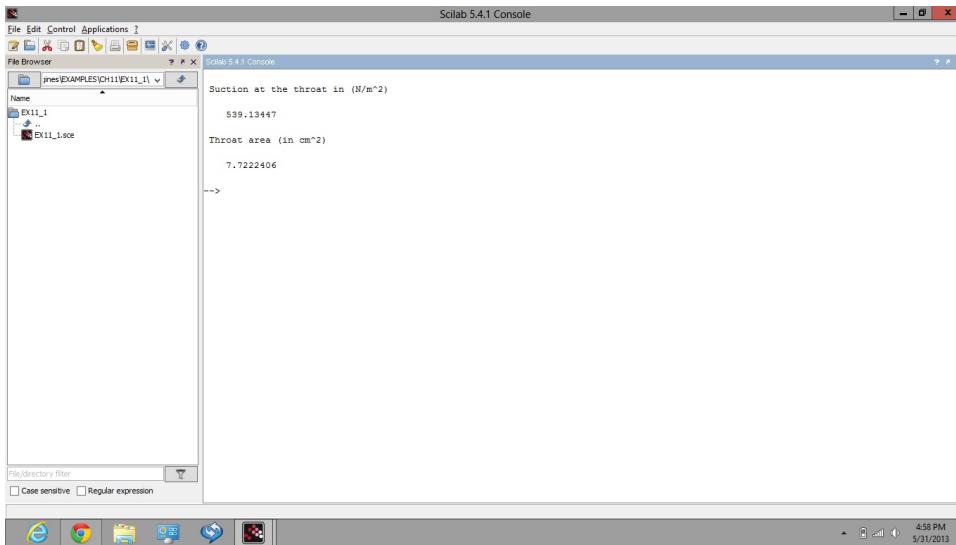


Figure 11.2: Depression in Venturi throat and throat area

```

7 spgrp=0.75;.....// Specific gravity of
petrol
8 rhow=1000;.....// Density of water in kg/
m^3
9 rhoa=1.2;.....// Density of air in kg/
m^3
10 Cda=0.8;.....// Coefficient of discharge
for venturi throat
11 g=9.81;.....// Acceleration due to gravity
in m/sec^2
12 // Calculations
13 mf=cp/3600;.....// Fuel consumed in kg/
sec
14 delp=((mf/(Af*Cda))^2)*(1/(2*spgrp*rhow))+(g*z*
spgrp*rhow);
15 disp(delp,"Suction at the throat in (N/m^2)")
16 ma=mf*afr;.....// Air flow rate
17 Atsqr=((ma/Cda)^2)*(1/(2*rhoa*delp))
;.....// Throat area in m^2
18 disp(sqrt(Atsqr)*10^4,"Throat area (in cm^2)")

```

---

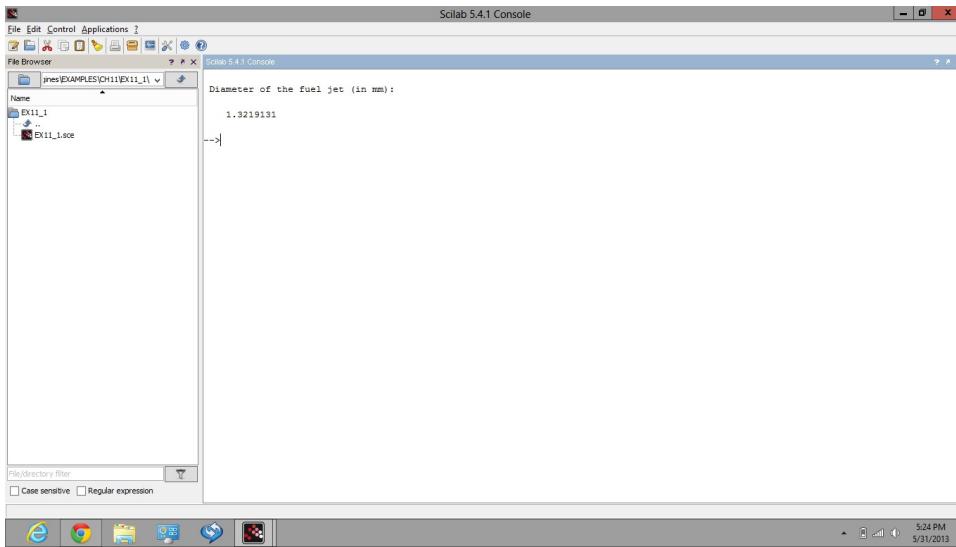


Figure 11.3: Diameter of the fuel jet

### Scilab code Exa 11.3 Diameter of the fuel jet

```
1 clc;funcprot(0); //EXAMPLE 11.3
2 // Initialisation of Variables
3 pc=7.2; ..... //Petrol consumed in kg/h
4 spgrp=0.75; ..... //Specific gravity of
    fuel
5 rhow=1000; ..... //Density of water in kg/
    m^3
6 t1=300; ..... //Temperature of air in
    Kelvin
7 afr=15; ..... //Air fuel ratio
8 d2=0.024; ..... //Diameter of choke
    tube in m
9 z=0.0042; ..... //The height of the jet
```

```

        above petrol level in float chamber in m
10 Cda=0.8;.....//Coefficient of
    discharge for air
11 Cdf=0.7;.....//Coefficient of
    discharge for fuel
12 p1=1.013;.....//Atmospheric pressure
    in bar
13 g=9.81;.....//Acceleration due to
    gravity in m/s^2
14 R=287;.....//Gas constant in J/kg
    .K
15 //calculations
16 mf=pc/3600;.....//Rate of fuel
    consumption in kg/sec
17 rhof=spgrp*rhow;.....//Density of fuel in
    kg/m^3
18 rhoa=(p1*10^5)/(R*t1);.....//Density of air
    in kg/m^3
19 ma=mf*afr;.....//Air flow rate
20 delpa=((ma/(Cda*(%pi/4)*d2^2))^2)*(1/(2*rhoa))
    ;.....//Suction in N/m^2
21 df=sqrt((mf/sqrt(2*rhof*(delpa-(g*z*rhof))))*(1/(Cdf
    *(%pi/4))));.....//Diameter of fuel
    jet in m
22 disp(df*1000,"Diameter of the fuel jet (in mm):")

```

---

**Scilab code Exa 11.4** Venturi depression and diameter and velocity of air across venturi

```

1 clc;funcprot(0); //EXAMPLE 11.4
2 // Initialisation of Variables
3 pc=5.45;.....//Petrol consumption
    in kg/h

```

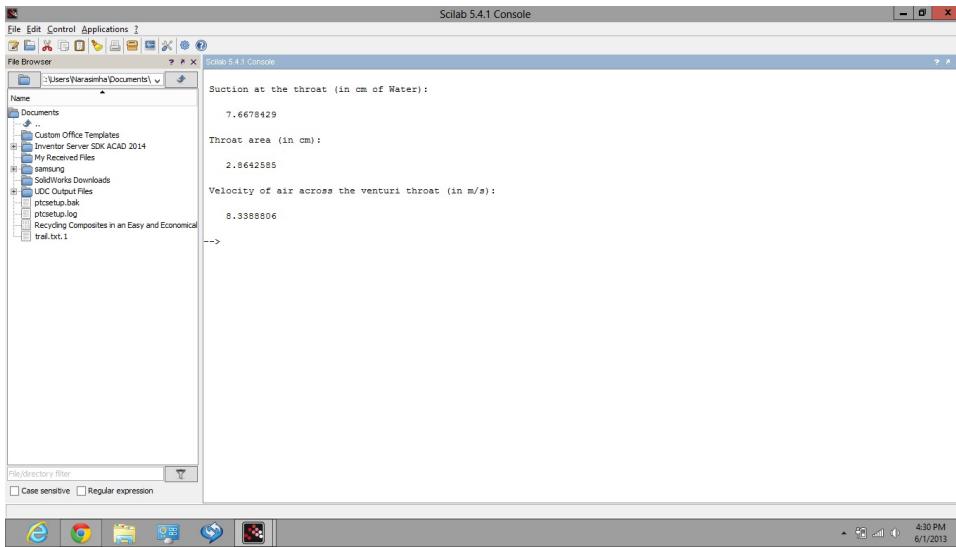


Figure 11.4: Venturi depression and diameter and velocity of air across venturi

```

4 afr=15;.....//Air fuel ratio
5 af=2*10^(-6);.....//Fuel jet orifice area
   in m^2
6 z=0.00635;.....//Distance between tip
   of fuel jet and level of petrol in the float
   chamber in m
7 Cda=0.8;.....//Coefficient of
   discharge of venturi throat
8 rhoa=1.29;.....//Density of air
   in kg/m^3
9 spgrp=0.72;.....//Specific
   gravity of fuel
10 rhow=1000;.....//Density of
   water in kg/m^3
11 g=9.81;.....//Acceleration
   due to gravity in m/s^2
12 Cdf=0.75;.....//Coefficient of
   discharge of the fuel
13 //calculations

```

```

14 mf=pc/3600;.....//Fuel consumed in kg
    /sec
15 rhof=spgrp*rhow;.....//Density of fuel in
    kg/m^3
16 delp=(((mf/(af*Cdf))^2)*(1/(2*rhof)))+(g*z*rhof)
    ;.....//Depression in venturi
    throat in N/m^2
17 h2odep=delp/(g*1000)
    ;.....//Depression in
    venturi throat in cm of Water
18 disp(h2odep*100,"Suction at the throat (in cm of
    Water):")
19 ma=mf*afr;.....//Air flow rate
20 At=sqrt(((ma/Cda)^2)*(1/(2*rhoa*delp)))
    ;.....//Throat area in m^2
21 dt=sqrt(At/(%pi/4))
    ;.....//Throat
    diameter in m
22 disp(dt*100,"Throat area (in cm):")
23 Ct=sqrt((2*g*z*rhof)/rhoa)
    ;.....//Velocity of air
    across the venturi throat in m/sec
24 disp(Ct,"Velocity of air across the venturi throat (
    in m/s):")

```

---

**Scilab code Exa 11.5 Throat pressure with respect to air cleaner**

```

1 clc;funcprot(0); //EXAMPLE 11.5
2 // Initialisation of Variables
3 afr=15;.....//Air fuel ratio
4 p1=1;.....//Atmospheric pressure
    in bar
5 p2=0.8;.....//Pressure at venturi

```

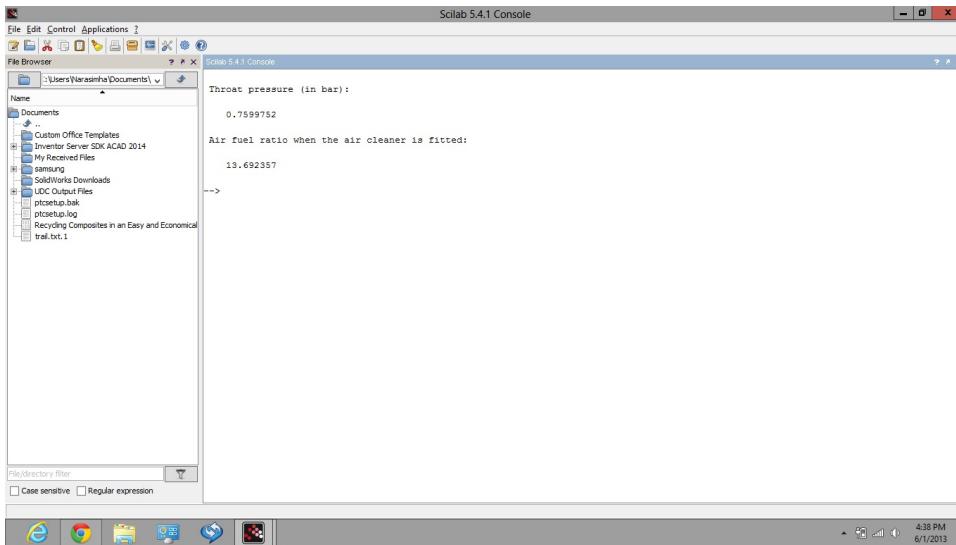


Figure 11.5: Throat pressure with respect to air cleaner

```

throat in bar
6 pd=30;.....//Pressure drop to air
    cleaner in mm of Hg
7 rhohg=13600;.....//Density of Hg in
    kg/m^3
8 af=240;.....//Air flow at sea
    level in kg/h
9 g=9.81;.....//Acceleration due to
    gravity in m/s^2
10 //calculations
11 delpa=p1-p2;.....//When there is
    no air cleaner
12 pt=1-(rhohg*g*(pd/1000)*10^(-5))-delpa
    ;.....//Throat pressure in
    bar
13 disp(pt,"Throat pressure (in bar):")
14 afrn=afr*sqrt(delpa/(p1-pt))
    ;.....//Air fuel ratio
    when the air cleaner is fitted
15 disp(afrn,"Air fuel ratio when the air cleaner is"

```

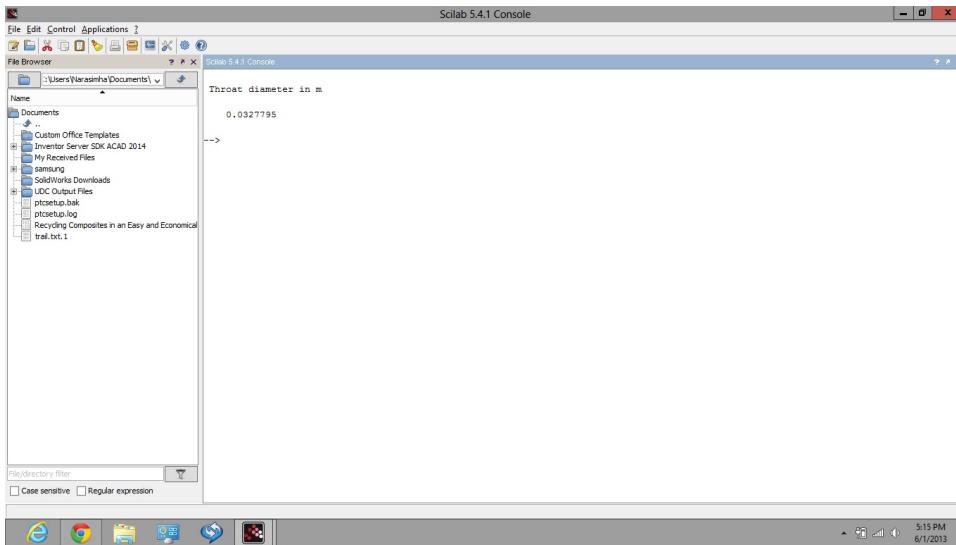


Figure 11.6: Throat diameter

---

fitted :")

### Scilab code Exa 11.6 Throat diameter

```

1 clc;funcprot(0); //EXAMPLE 11.6
2 // Initialisation of Variables
3 as=4.6; ..... // Air supply in kg/
min
4 p1=1.013; ..... // Atmospheric
pressure in bar
5 t1=298; ..... // Atmospheric
temperature in Kelvin
6 C2=80; ..... // Air flow velocity in
m/s
7 Cv=0.8; ..... // Velocity co efficient

```

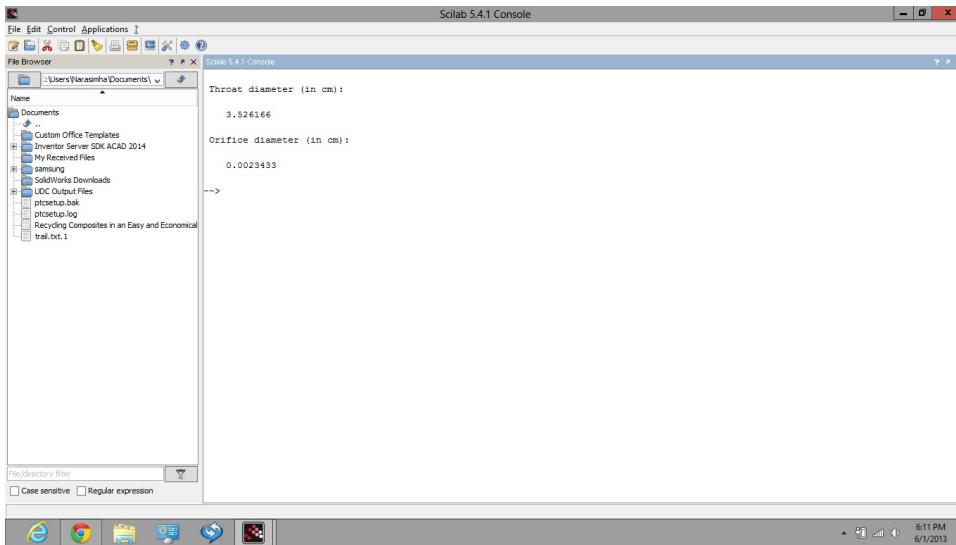


Figure 11.7: Throat diameter and orifice diameter

```

8 ga=1.4; ..... // Degree of freedom
of gas
9 R=0.287; ..... // Gas constant in kJ
/kgK
10 // Calculations
11 cp=R*(ga/(ga-1)); ..... // Specific
heat capacity of air in kJ/kgK
12 p2=((1-(((C2/Cv)^2)*(1/(2*cp*1000*t1))))^(ga/(ga-1))
)*p1; ..... // Throat pressure in bar
13 rho1=(p1*10^5)/(R*1000*t1);
14 rho2=rho1*(p2/p1)^(1/ga);
15 ma=as/60; ..... // Air flow in kg/s
16 A2=ma/(rho2*C2); ..... // Throat area in m
^2
17 d2=sqrt((4*A2)/%pi); ..... // Throat
diameter in m
18 disp(d2,"Throat diameter in m")

```

---

### Scilab code Exa 11.7 Throat diameter and orifice diameter

```
1 clc;funcprot(0); //EXAMPLE 11.7
2 // Initialisation of Variables
3 as=6;..... //Air supply in kg/min
4 fs=0.45;..... //Fuel supply in
    kg/min
5 p1=1.013;..... //Atmospheric
    pressure in bar
6 t1=300;..... //Atmospheric
    temperature in Kelvin
7 rho_f=740;..... //Density of fuel in
    kg/m^3
8 C2=92;..... //Air flow velocity in
    m/s
9 Cda=0.8;..... //Velocity co efficient
10 Cdf=0.6;..... //Coefficient of
    discharge for fuel
11 ga=1.4;..... //Degree of freedom
    of gas
12 r=0.75;..... //ratio of pressure
    drop across venturi and of that of choke
13 R=0.287;..... //Gas constant in kJ
    /kgK
14 // Calculations
15 ma=as/60;..... //Air flow
    in kg/s
16 mf=fs/60;..... //Fuel
    flow in kg/s
17 cp=R*(ga/(ga-1));..... //Specific
    heat capacity of air in kJ/kgK
18 p2=((1-(((C2/Cda)^2)*(1/(2*cp*1000*t1))))^(ga/(ga-1))
    )*p1;..... //Throat pressure in bar
19 v1=(R*t1*1000)/(p1*10^5);
```

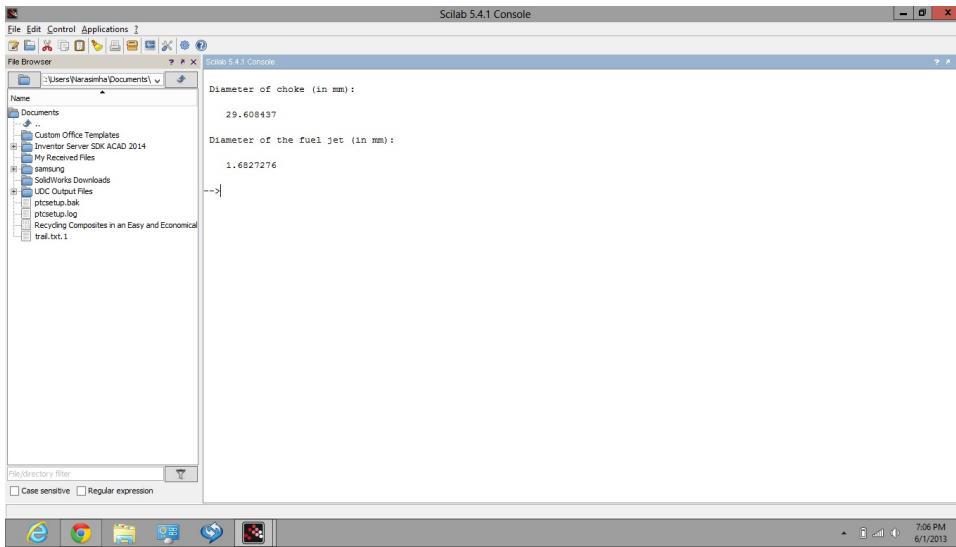


Figure 11.8: Choke diameter and fuel jet diameter

```

20 v2=v1*(p1/p2)^(1/ga);.....// specific
      volume in m^3/kg
21 A2=(ma*v2)/(C2);.....// Throat area in m
      ^2
22 d2=sqrt((4*A2)/%pi);.....// Throat
      diameter in m
23 disp(d2*100,"Throat diameter (in cm):")
24 pdv=p1-p2;.....// Pressure drop at venturi in
      bar
25 pdj=r*pdv;.....// Pressure drop at jet in bar
26 Af=((mf/Cdf)*(1/sqrt(2*rhof*pdj*10^5)))
      ;.....// Area of orifice in m^2
27 df=sqrt((4*Af)/%pi);.....// Orifice
      diameter in m
28 disp(df,"Orifice diameter (in cm):")

```

---

### Scilab code Exa 11.8 Choke diameter and fuel jet diameter

```
1 clc;funcprot(0); //EXAMPLE 11.8
2 // Initialisation of Variables
3 Vs=1489*10^(-6);..... //Capacity of
    engine in m^3
4 N=4200;..... //Engine rpm at which max
    speed is developed
5 etaV=0.75;..... //Volumetric
    efficiency
6 afr=13;..... //air fuel ratio
7 Ct=85;..... //Theoretical air
    speed at peak power in m/s
8 C2=Ct;
9 Cda=0.82;..... //Coefficient of
    discharge for the venturi
10 Cdf=0.65;..... //Coefficient of
    discharge of main petrol jet
11 spgr=0.74;..... //Specific gravity of
    petrol
12 z=0.006;..... //Level of
    petrol surface below choke
13 p1=1.013;..... //Atmospheric
    pressure in bar
14 t1=293;..... //Atmospheric
    temperature in Kelvin
15 r=0.4;..... //Ratio of
    diameter of emulsion tube to choke diameter
16 R=0.287;..... //Gas constant
    in kJ/kgK
17 ga=1.4;..... //Degree of
    freedom for air
18 g=9.81;..... //Acceleration
    due to gravity in m/s^2
19 rhoW=1000;..... //Density of
    water in kg/m^3
20 //calculations
21 rhoF=rhoW*spgr;..... //Density
```

```

        of fuel in kg/m^3
22 Va=(etaV*Vs*N)/(60*2);.....//Volume
        of air induced in m^3/s
23 ma=(p1*10^5*Va)/(R*t1*1000);.....//mass
        flow of air in kg/s
24 cp=R*(ga/(ga-1));.....//Specific
        heat capacity of air in kJ/kgK
25 p2=((1-(((C2)^2)*(1/(2*cp*1000*t1))))^(ga/(ga-1)))*
        p1;.....//Throat pressure in bar
26 pt=p2;
27 vt=Va*(p1/p2)^(1/ga);.....//Volume
        flow of air at choke in m^3/s
28 At=vt/(Ct*Cda);.....//Area of emulsion
        tube in m
29 D=sqrt((4*At*10^6)/(%pi*(1-r^2)))
        ;.....//Diameter of choke in mm
30 disp(D,"Diameter of choke (in mm):")
31 mf=ma/afr;.....//Mass flow of fuel in
        kg/s
32 delpa=(p1-p2)*10^5;
33 df=sqrt((mf/sqrt(2*rhof*(delpa-(g*z*rhof))))*(1/(Cdf
        *(%pi/4))));.....//Diameter of fuel
        jet in m
34 disp(df*1000,"Diameter of the fuel jet (in mm):")

```

---

### Scilab code Exa 11.9 Air fuel ratio with respect to nozzle lip

```

1 clc;funcprot(0); //EXAMPLE 11.9
2 // Initialisation of Variables
3 da=0.018;.....//Throat Diameter
        in m
4 df=0.0012;.....//Diameter of fuel
        orifice in m

```

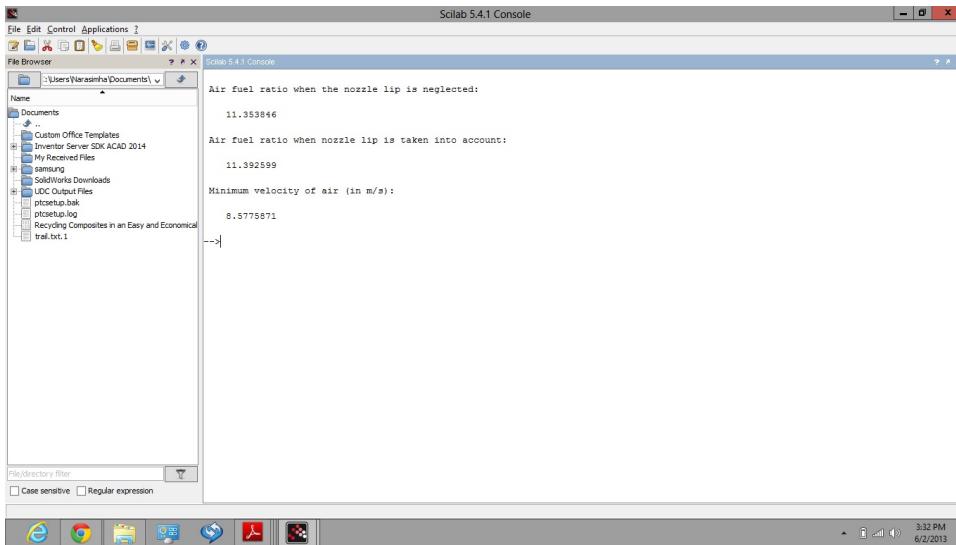


Figure 11.9: Air fuel ratio with respect to nozzle lip

```

5 Cda=0.82; ..... // Coefficient of air flow
6 Cdf=0.65; ..... // Coefficient of fuel
    flow
7 z=0.006; ..... // Level of petrol
    surface below the throat
8 rhoa=1.2; ..... // density of air in
    kg/m^3
9 rhof=750; ..... // density of fuel
    in kg/m^3
10 g=9.81; ..... // Acceleration due to
    gravity in m/s^2
11 delp=0.065*10^5; ..... // Pressure drop
    in N/m^2
12 // Calculations
13 afr1=(Cda/Cdf)*((da/df)^2)*sqrt(rhoa/rhof)
    ; ..... // Air fuel ratio when the
    nozzle lip is neglected
14 disp(afr1,"Air fuel ratio when the nozzle lip is
    neglected:")
15 afr2=afr1*sqrt(delp/(delp-(g*z*rhof)))

```

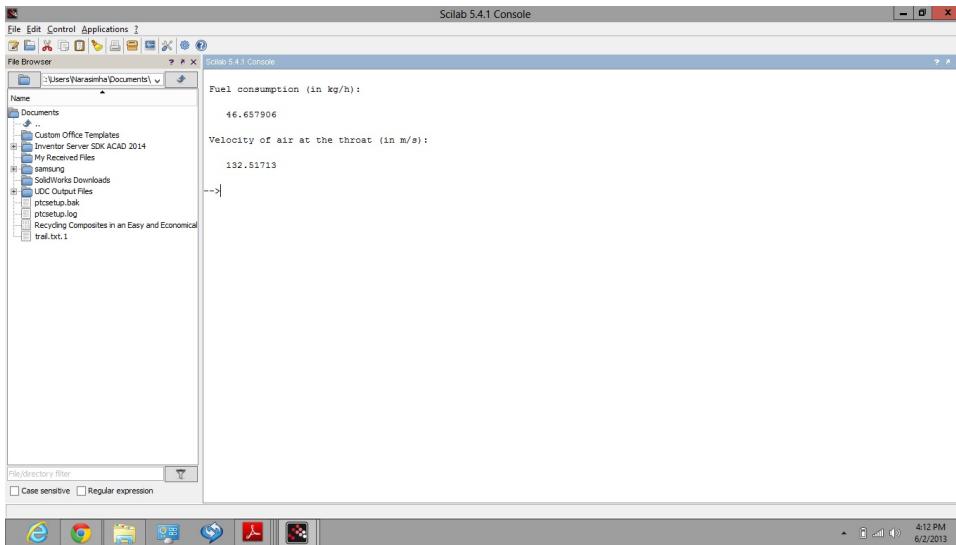


Figure 11.10: Fuel consumption and air velocity through tube

```

; ..... // Air fuel ratio when
nozzle lip is taken into account
16 disp(afr2,"Air fuel ratio when nozzle lip is taken
into account:")
17 C2=sqrt((2*g*z*rhof)/rhoa); ..... //Minimum velocity of air in m/s
18 disp(C2,"Minimum velocity of air (in m/s):")

```

---

### Scilab code Exa 11.10 Fuel consumption and air velocity through tube

```

1 clc;funcprot(0); //EXAMPLE 11.10
2 // Initialisation of Variables
3 d=0.11; ..... // Engine bore in m
4 l=0.11; ..... // Engine length in m
5 da=0.042; ..... // Throat diameter of the
choke tube in m

```

```

6 N=3000;.....//Engine rpm
7 etaV=0.75;.....//Volumetric efficiency
8 Ra=287;.....//Gas constant for air in J
    /kgK
9 Rv=97;.....//Gas constant for fuel
    vapour in J/kgK
10 t=273;.....//Temperature in Kelvin
11 p=1.013;.....//Pressure in bar
12 delpa=0.12;.....//Pressure depression in
    bar
13 t2=273+15;.....//Temperature at throat
14 n=8;.....//No of cylinders
15 m0=32;.....//Mass of Oxygen
    molecule in amu
16 mC=12;.....//Mass of Carbon
    molecule in amu
17 mH=1;.....//Mass of Hydrogen
    molecule in amu
18 cC=84;.....//Composition of carbon
    in %
19 cH2=16;.....//Composition of
    Hydrogen in %
20 //Calculations
21 Vfm=(%pi/4)*d*d*l*n*(N/2)*etaV;.....
    //Volume of fuel mixture supplied in m^3/min
22 afr=((cC*(m0/mC))+(cH2*(m0/(4*mH))))/23;.....
    //Air fuel ratio
23 va=(Ra*t)/(p*10^5);.....//Volume of
    1 kg of air in m^3/kg
24 vf=(Rv*t)/(p*10^5);.....//Volume of
    1 kg of fuel vapour in m^3/kg
25 fc=(Vfm/((afr*va)+vf))*60;.....//Fuel
    consumption in kg/h
26 disp(fc,"Fuel consumption (in kg/h):")
27 rhoa=((p-delpa)*10^5)/(Ra*t2);.....
    //Density of air at the throat in kg/m^3
28 Ca=(afr*(fc/3600))/((%pi/4)*da*da*rhoa);
    .....//Velocity of air at the throat

```

in m/s  
29 **disp**(Ca," Velocity of air at the throat ( in m/s ) :")

---

Scilab code Exa 11.11 Air fuel ratio at a given altitude

```
1 clc;funcprot(0); //EXAMPLE 11.11
2 // Initialisation of Variables
3 a=4500;.....//Altitude
4 afr=14;.....//Air fuel ratio at sea level
5 t1=25;.....//Temperature at sea level in
   Celsius
6 p1=1.013;.....//Pressure at sea level in bar
7 //Calculations
8 t2=t1-(0.0064*a);.....//
   Temperature at the given altitude using the given
   formula in Celsius
9 p2=p1/(10^(a/19300));.....//
   Pressure at the given altitude using the given formula in
   bar
10 afr2=afr*sqrt((p2*(t1+273))/(p1*(t2+273)))
    ;.....//
   Air fuel ratio at the
   altitude
11 disp(afr2,"Air fuel ratio at the altitude:")
```

---

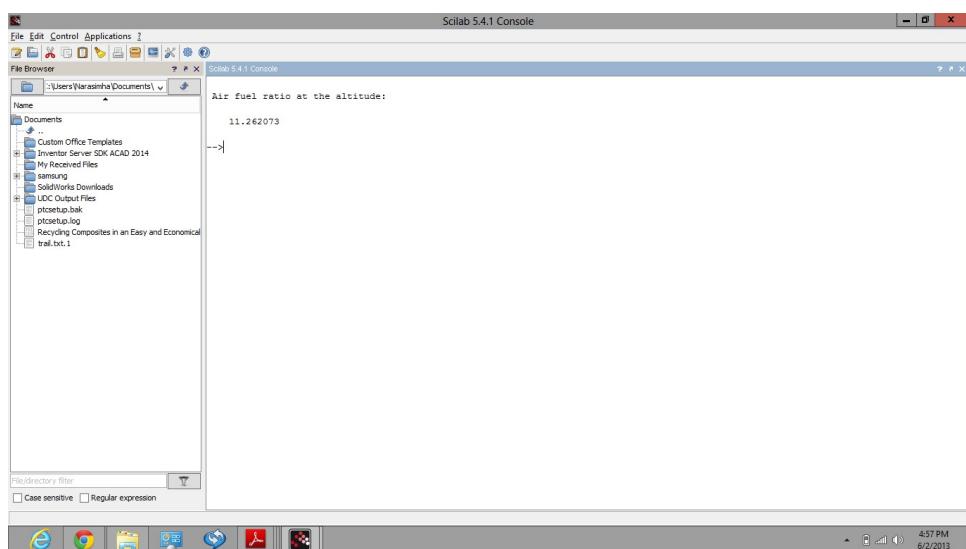


Figure 11.11: Air fuel ratio at a given altitude

# Chapter 12

## Fuel Injection Systems for CI Engines

**Scilab code Exa 12.1** Quantity of fuel injected per cycle

```
1 clc;funcprot(0); //EXAMPLE 12.1
2 // Initialisation of Variables
3
4 n=6; ..... //No of cylinders
5 BP=125; ..... //Brake Power in kW
6 N=3000; ..... //Engine rpm
7 bsfc=200; ..... //Brake Specific Fuel
    Consumption g/kWh
8 spgr=0.85; ..... //Specific Gravity
9
10 // Calculations
11
12 fc=(bsfc/1000)*BP; ..... //Fuel consumption in kg/
    h
13 fcpc=fc/n; ..... //Fuel consumption per
    cylinder
14 FCPC=(fcpc/60)/(N/2); ..... //Fuel
```

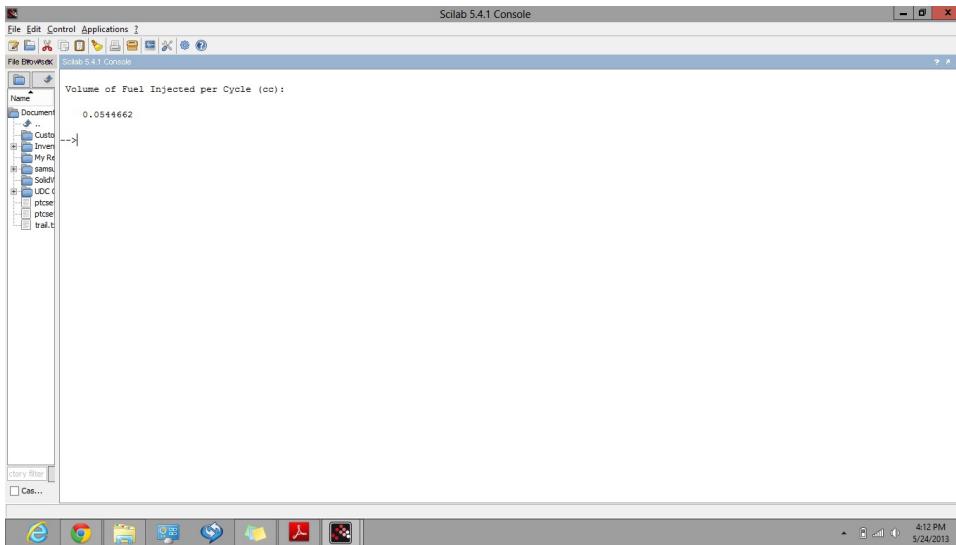


Figure 12.1: Quantity of fuel injected per cycle

Consumption per cycle in kg

```

15 VFIC = (FCPC*1000)/spgr;.....//Volume
      of fuel injected per cycle in cc
16 disp(VFIC,"Volume of Fuel Injected per Cycle (cc):")

```

---

**Scilab code Exa 12.2** Diameter of injector nozzle

```

1 clc;funcprot(0); //EXAMPLE 12.2
2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 N=1500; ..... //Engine rpm
5 BP=220; ..... //Brake Power in kW
6 bsfc=0.273; ..... //Brake Specific Fuel
      Consumption in kg/kWh
7 theta=30; ..... //The Period of Injection in
      degrees of crank angle

```

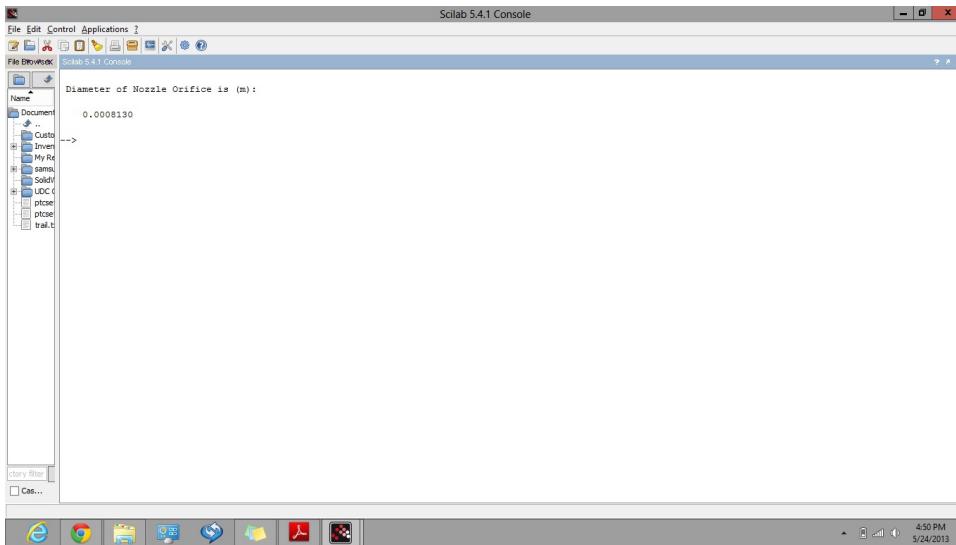


Figure 12.2: Diameter of injector nozzle

```

8 spgr=0.85;.....// Specific Gravity of fuel
9 Cf=0.9;.....//Orifice discharge co-
    efficient
10 ip=160;.....//Injection pressure in bar
11 cp=40;.....//Pressure in combustion
    chamber in bar
12 rho_w=1000;.....//Density of water in kg/m
    ^3
13 // Calculations
14 vf = Cf*sqrt((2*(ip-cp)*10^5)/(spgr*rho_w))
    ;.....//Actual fuel velocity of injection
    in m/sec
15 qf=(bsfc*BP)/(spgr*rho_w*3600);.....// 
    Volume of fuel injected per sec in m^3
16 d=sqrt (qf/((pi/4)*n*vf*(theta/360)*(60/N)*(N/120)))
    ;.....//Diameter of nozzle orifice
17 disp(d,"Diameter of Nozzle Orifice is (m):")
```

---

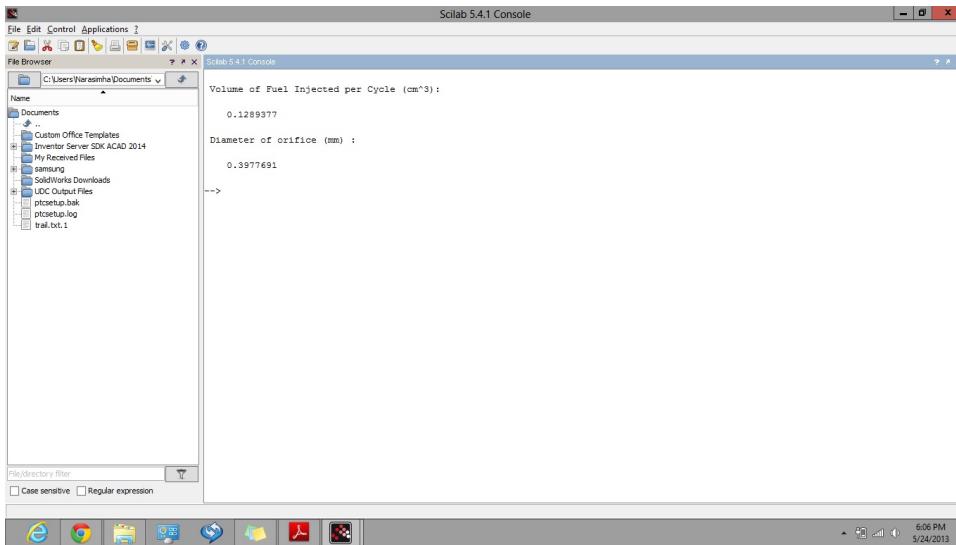


Figure 12.3: Volume of fuel injected and diameter of Injector

### Scilab code Exa 12.3 Volume of fuel injected and diameter of Injector

```

1 clc;funcprot(0); //EXAMPLE 12.3
2 // Initialisation of Variables
3 n=1;.....//No of cylinders
4 N=650;.....//Engine rpm
5 theta=28;.....//Crank Travel in degree
6 fc=2.2;.....//Fuel consumption in kg/h
7 spgr=0.875;.....//Specific Gravity
8 ip=150;.....//Injection Pressure in bar
9 cp=32;.....//Combustion chamber Pressure
   in bar
10 Cd=0.88;.....//co-efficient of discharge
    of orifice
11 rhow=1000;.....//Density of water in kg/m^3
12 //Calculation
13 fcp = fc/60;.....//Fuel consumption per

```

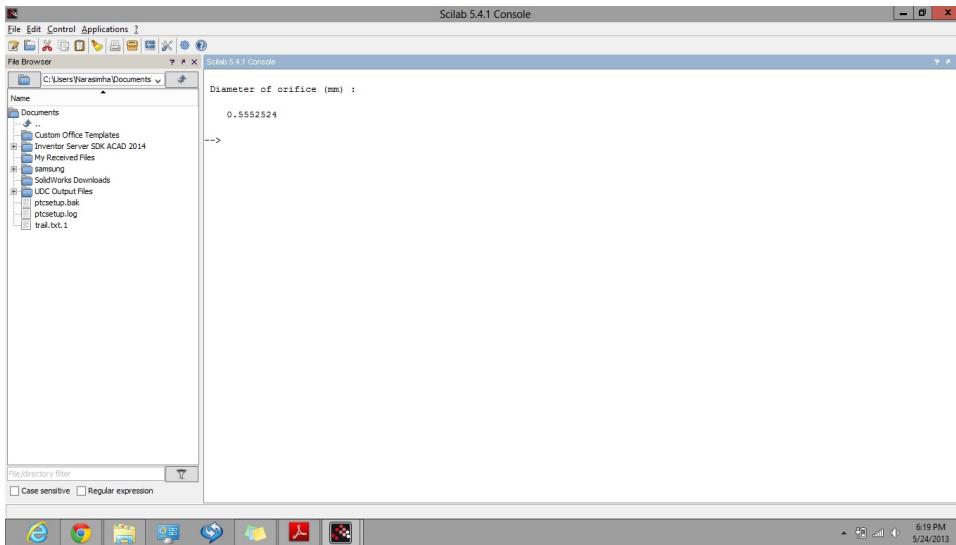


Figure 12.4: Diameter of injector nozzle

```

cylinder
14 fipc = fcpc/(N/2);.....//Fuel Injected per cycle
      in kg
15 vfpc = fipc/(spgr*rhow);....//volume of fuel
      injected per cycle
16 disp(vfpc*10^6,"Volume of Fuel Injected per Cycle (
      cm^3):")
17 tfic=(theta/360)*(60/N);....//Time for Fuel
      Injection per Cycle in sec
18 mf = fipc/tfic;.....//Mass of fuel
      injected per cycle in kg/s
19 vf = Cd*sqrt((2*(ip-cp)*10^5)/(spgr*rhow))
      ;.....//Actual fuel velocity of injection
      in m/sec
20 d=sqrt((mf*4)/(%pi*vf*spgr*rhow))
21 disp(d*1000,"Diameter of orifice (mm) :")

```

---

### Scilab code Exa 12.4 Diameter of injector nozzle

```
1 clc;funcprot(0); //EXAMPLE 12.4
2 // Initialisation of Variables
3 N=2000;.....//Engine rpm
4 theta=30;.....//Crank Travel in degree
5 sfc=0.272;.....//Fuel consumption in kg/kWh
6 ip=120;.....//Injection Pressure in bar
7 cp=30;.....//Combustion chamber Pressure
    in bar
8 Cd=0.9;.....//co-efficient of discharge of
    orifice
9 rhow=1000;.....//Density of water in kg/m^3
10 api = 32;.....//API in degree
11 pw=15;.....//Power Output in kW
12 //Calculation
13 spgr= 141.5/(131.5+api);.....// Specific
    Gravity
14 fcpc = (sfc*pw)/((N/2)*60);.....//Fuel
    consumption per cycle in kg
15 tfic=(theta/360)*(60/N);....//Time for Fuel
    Injection per Cycle in sec
16 mf = fcpc/tfic;.....//Mass of fuel
    injected per cycle in kg/s
17 vf = Cd*sqrt((2*(ip-cp)*10^5)/(spgr*rhow))
    ;.....//Actual fuel velocity of injection
    in m/sec
18 d=sqrt((mf*4)/(%pi*vf*spgr*rhow))
19 disp(d*1000,"Diameter of orifice (mm) :")
```

---

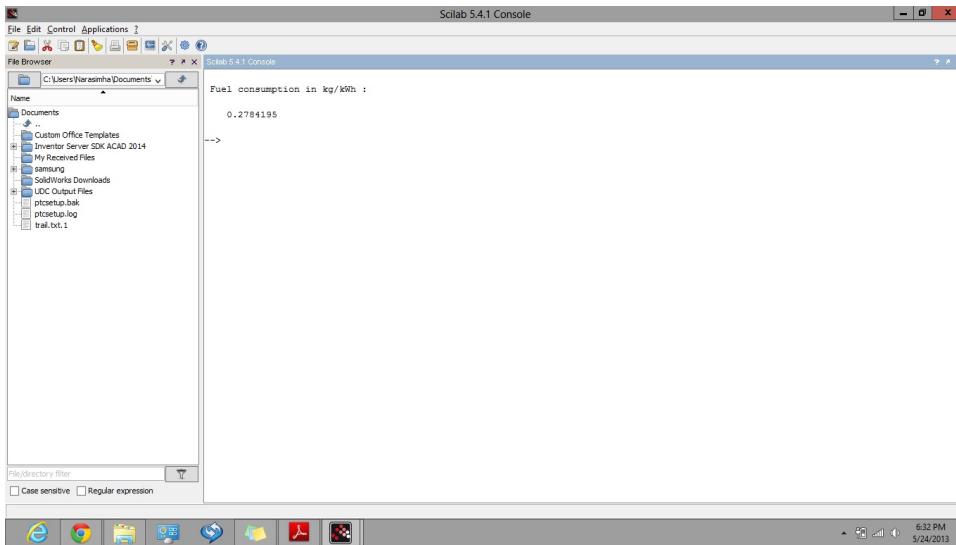


Figure 12.5: Fuel consumption

### Scilab code Exa 12.5 Fuel consumption

```

1 clc;funcprot(0); //EXAMPLE 12.5
2 // Initialisation of Variables
3 N=1800;.....//Engine rpm
4 theta=32;.....//Crank Travel in degree
5 ip=118.2;.....//Injection Pressure in bar
6 cp=31.38;.....//Combustion chamber
    Pressure in bar
7 Cd=0.9;.....//co-efficient of discharge of
    orifice
8 rhow=1000;.....//Density of water in kg/m^3
9 api = 32;.....//API in degree
10 pw=11;.....//Power Output in kW
11 d=0.47;.....//Fuel Injection orifice
    diameter in mm
12 //Calculation
13 spgr= 141.5/(131.5+api);.....//Specific
    Gravity
14 tfic=(theta/360)*(60/N);....//Time for Fuel

```

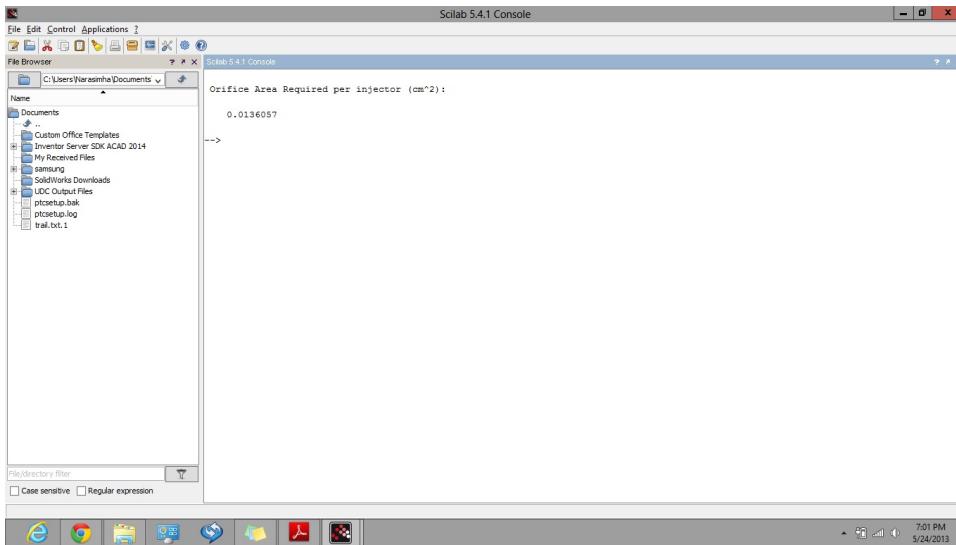


Figure 12.6: Injector orifice area

```

Injection per Cycle in sec
15 vf = Cd*sqrt((2*(ip-cp)*10^5)/(spgr*rhow))
;.....//Actual fuel velocity of injection
      in m/sec
16 mf=vf*spgr*rhow*(%pi/4)*(d/1000)^2;
17 tnccp=(N/2)*60;.....//Total no of cycles
      per hour
18 FIPC=mf*tfic;.....//Mass of fuel
      injected per cycle in kg/cycle
19 fc=FIPC*tnccp*(1/pw);.....//Fuel
      consumption in kg/kWh
20 disp(fc,"Fuel consumption in kg/kWh :")

```

---

### Scilab code Exa 12.6 Injector orifice area

```
1 clc;funcprot(0); //EXAMPLE 12.6
```

```

2 // Initialisation of Variables
3 n=8;.....//No of cylinders
4 pw=386.4;.....//Power output in kW
5 N=800;.....//Engine rpm
6 fc=0.25;.....//Fuel Consumption in kg/kWh
7 theta=12;.....//Crank Travel in degree (for
    injection)
8 spgr=0.85;.....//Specific Gravity
9 patm=1.013;.....//Atmospheric pressure
10 cf=0.6;.....//Co-efficient of discharge
    for injector
11 pcb=32;.....//Pressure in cylinder in
    beginning in bar
12 piB=207;.....//Pressure in injector in
    beginning in bar
13 pcE=55;.....//Pressure in cylinder at the
    end in bar
14 piE=595;.....//Pressure in injector at
    the end in bar
15 rhow=1000;.....//density of water in kg/m^3
16 //calculations
17 pwpc = pw/n;.....//Output per
    cylinder
18 fcpc = (pwpc*fc)/60;.....//Fuel consumption
    per cylinder in kg/min
19 fipc = fcpc/(N/2);.....//Fuel injected
    per cycle in kg
20 tfic = (theta*60)/(360*N);.....//Time for fuel
    Injection per cycle
21 mf = fipc/tfic;.....//Mass of fuel
    injected per second
22 pdb = piB-pcb;.....//Pressure
    difference at beginning
23 pde = piE-pcE;.....//Pressure
    difference at end
24 apd = (pdb+pde)/2;
25 Ao=mf/(cf*sqrt(2*apd*10^5*spgr*rhow));
26 disp(Ao*10000," Orifice Area Required per injector (

```

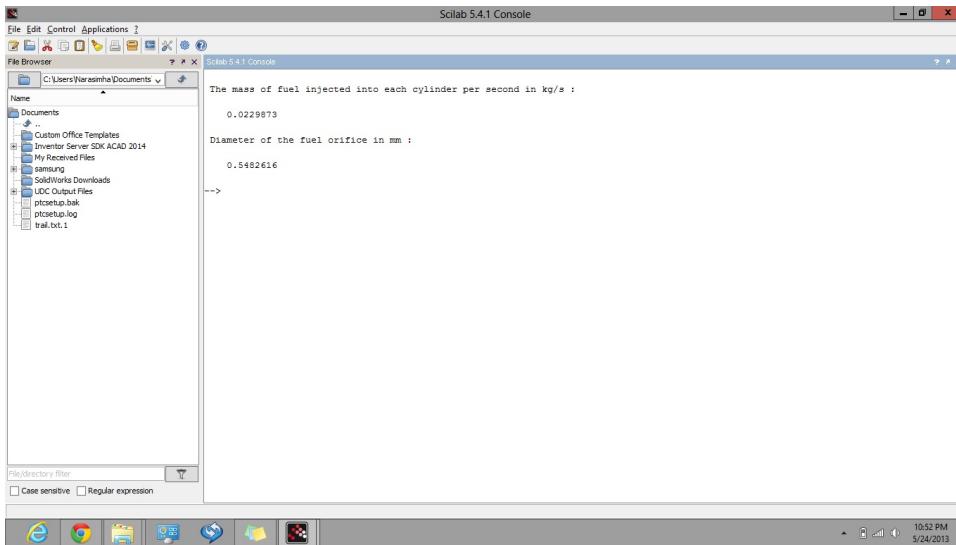


Figure 12.7: Amount of fuel injected and injector diameter

$\text{cm}^2)$  : ” )

---

### Scilab code Exa 12.7 Amount of fuel injected and injector diameter

```

1 clc;funcprot(0); //EXAMPLE 12.7
2 // Initialisation of Variables
3 n=6;.....//No of cylinders
4 afr=20;.....//Air fuel ratio
5 d = 0.1;.....//cylinder bore in mm
6 l=0.14;.....//Cylinder length in mm
7 etav=0.8;.....//Volumetric Efficiency
8 pa=1;.....//Pressure at the beginning of
    the compression in bar
9 ta = 300;.....//Temperature at the beginning
    of the compression in Kelvin

```

```

10 theta = 20;.....//Crank travel in degree
   for injection
11 N = 1500;.....//engine rpm
12 rhof=960;.....//Fuel density in kg/m^3
13 cf=0.67;.....//Co efficient of discharge
   for injector
14 pi=150;.....//injection pressure in
   bar
15 pc=40;.....//combustion pressure in
   bar
16 R=287;.....//gas constant for air
   in kJ/kg.K
17 //calculations
18 V=(%pi/4)*d^2*l*etav;.....//Volume
   of air supplied per cylinder per cycle in m^3
19 ma=(pa*10^5*V)/(R*ta);.....//Mass of
   this air at suction conditions in kg/cycle
20 mf=ma/afr;.....//Mass of fuel
   in kg/cycle
21 fipc = (theta*60)/(360*N);.....//Time taken
   for fuel injection per cycle in seconds
22 MF = mf/fipc;.....//Mass of fuel
   injected into each cylinder per second
23 disp(MF,"The mass of fuel injected into each
   cylinder per second in kg/s :")
24 vf=cf*sqrt((2*(pi-pc)*10^5)/rhof);.....// 
   fuel velocity injection in m/s
25 d0=sqrt((MF*4)/(%pi*vf*rhof));.....// 
   diameter of fuel orifice in m
26 disp(d0*1000,"Diameter of the fuel orifice in mm :")

```

---

**Scilab code Exa 12.8** Plunger displacement and effective stroke

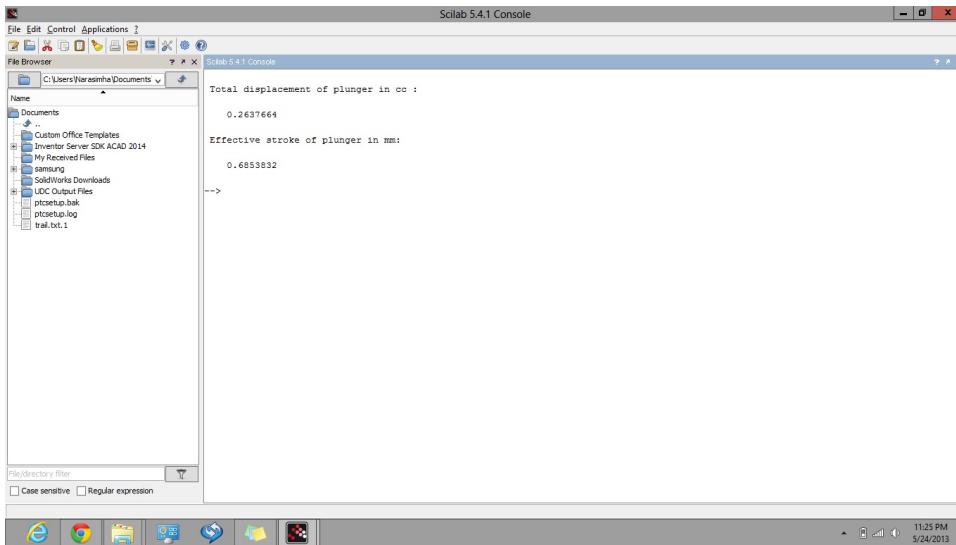


Figure 12.8: Plunger displacement and effective stroke

```

1 clc;funcprot(0); //EXAMPLE 12.8
2 // Initialisation of Variables
3 Vpbes=7;.....//Volume of fuel in the
   pump barrel before commencement of effective
   stroke in cc
4 df=3;.....//Diameter of fuel line from
   pump to injector in mm
5 lf=700;.....//Length of fuel line from
   pump to injector in mm
6 Vfiv=2;.....//Volume of fuel in the
   injection valve in cc
7 Vfd=0.1;.....//Volume of fuel to be
   delivered in cc
8 p1=150;.....//Pressure at which fuel is
   delivered in bar
9 p2=1;.....//atmospheric pressure in bar
10 cc=78.8*10^(-6);.....//Co - efficient of
    compressibility per bar
11 dp=7;.....//Diameter of plunger in mm
12 //calculations

```

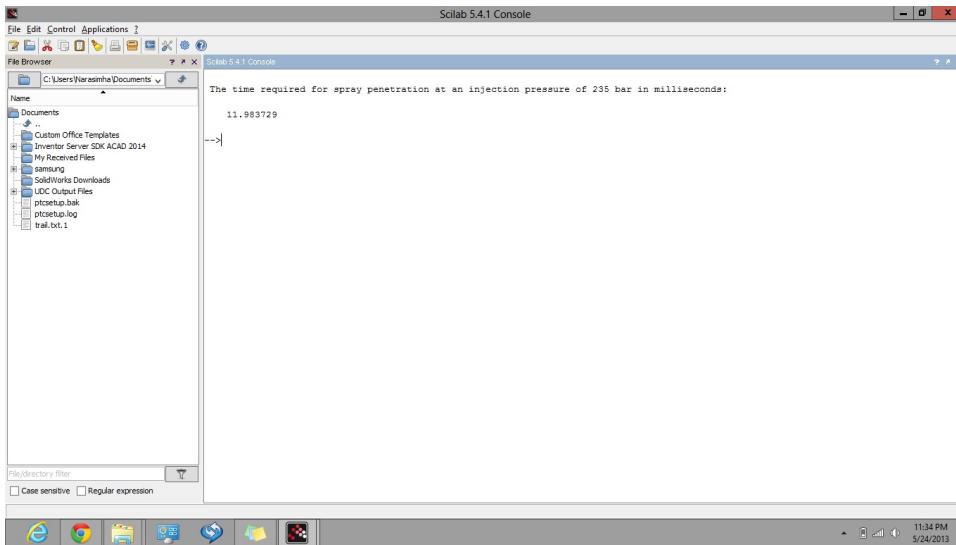


Figure 12.9: Calculation of fuel spray time

```

13 V1=Vpb*π/4*((df/10)^2)*(lf/10)+Vfiv
      ;.....//Total initial fuel volume
14 delV=cc*(p1-p2)*V1;.....//Change in
      volume due to compression
15 displu=delV+Vfd;.....//Total
      displacement of plunger
16 disp(displu,"Total displacement of plunger in cc :")
17 lp=(displu*4)/(π*(dp/10)^2);.....// 
      Effective stroke of plunger
18 disp(lp,"Effective stroke of plunger in mm:")
```

---

### Scilab code Exa 12.9 Calculation of fuel spray time

```

1 clc;funcprot(0); //EXAMPLE 12.9
2 // Initialisation of Variables
3 p1=145; .....//injection pressure in bar
```

```

4 p2=235;.....// Injection pressure in bar (2nd
   case)
5 t1=16;.....//spray penetration time in
   milliseconds
6 s1=22;.....// spray penetration length in
   cm
7 s2=22;.....// spray penetration length in
   cm (2nd case)
8 pc=30;.....//combustion chamber pressure
   in bar
9 //calculations
10 delp1=p1-pc;
11 delp2=p2-pc;
12 t2=(s2/s1)*t1*sqrt(delp1/delp2);.....//Spray
   time in seconds for 2nd case
13 //Given that s=t*sqrt(delp)
14 disp(t2,"The time required for spray penetration at
   an injection pressure of 235 bar in milliseconds:
   ")

```

---

# Chapter 15

## Engine Cooling

**Scilab code Exa 15.1** Coolant required for petrol and diesel engine

```
1 clc;funcprot(0); //EXAMPLE 15.1
2 // Initialisation of Variables
3 BP=90;..... //Brake Power in kW
4 deltw=27;..... //Raise in temperature of
water
5 etaP=0.25;..... //Efficiency of petrol
engine
6 etaD=0.3;..... //Efficiency od diesel
engine
7 Pec=32;..... //Percentage of energy
going to coolant in petrol engine
8 Dec=28;..... //Percentage of energy
going to coolant in diesel engine
9 cp=4.187;..... //specific heat of water at
constant pressure
10 //Calculations
11 hsP = BP/etaP;..... //Heat supplied in kW or
kJ/s
12 ecP=hsP*(Pec/100);..... //Energy going to
```

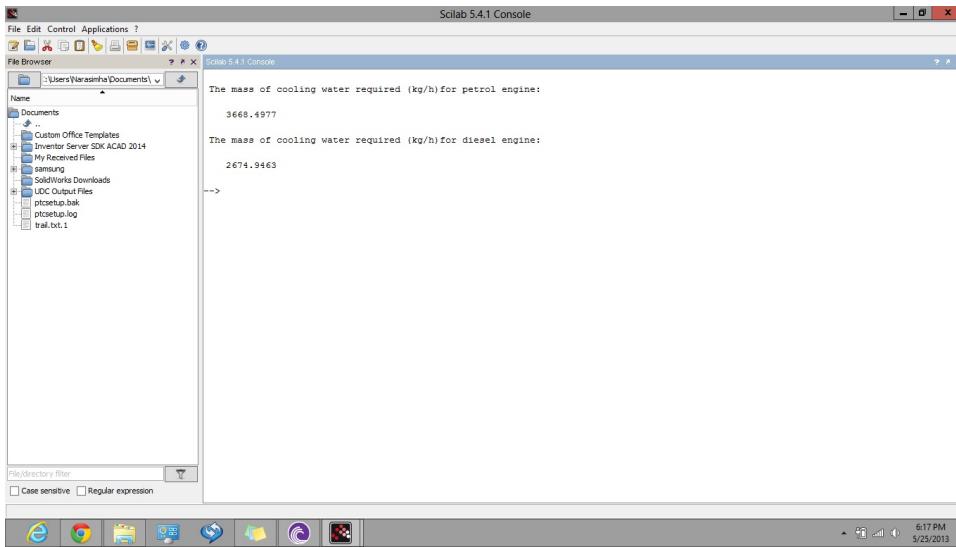


Figure 15.1: Coolant required for petrol and diesel engine

```

cooling water in kg/s
13 mwP=ecP/(cp*deltw);.....//Mass of cooling
    water required
14 hsD = BP/etaD;.....//Heat supplied in kW or
    kJ/s
15 ecD=hsD*(Dec/100);.....//Energy going to
    cooling water in kg/s
16 mwD=ecD/(cp*deltw);.....//Mass of cooling
    water required
17 disp(mwP*3600,"The mass of cooling water required (
    kg/h) for petrol engine:")
18 disp(mwD*3600,"The mass of cooling water required (
    kg/h) for diesel engine:")

```

---

**Scilab code Exa 17.28** Indicated mean effective pressure and brake mean effective pressure

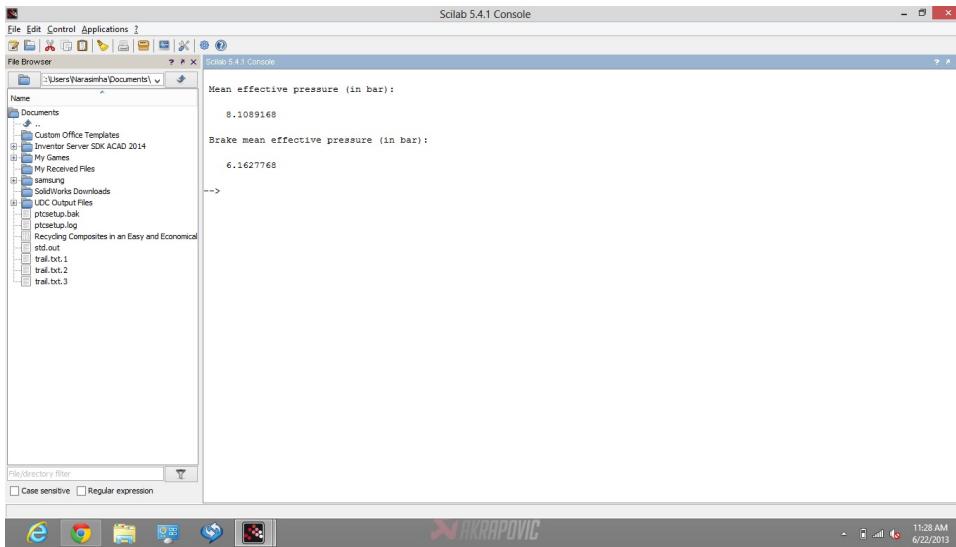


Figure 15.2: Indicated mean effective pressure and brake mean effective pressure

```

1 clc;funcprot(0); //EXAMPLE 17.28
2 // Initialisation of Variables
3 D=0.2;.....//Engine bore in m
4 L=0.25;.....//Engine stroke in m
5 n=2;.....//No of cylinders
6 r=13;.....//Compression ratio
7 fc=14;.....//Fuel consumption in kg/h
8 N=300;.....//Engine rpm
9 etarel=0.65;.....//Relative efficiency
10 etamech=0.76;.....//Mechanical efficiency
11 co=0.05;.....//Cut off of the stroke
12 C=41800;.....//Calorific value of
    fuel in kJ/kg
13 k=1;.....//Two stroke engine
14 ga=1.4;.....//Degree of freedom
15 //calculations
16 rho=1+(co*(r-1));
17 etast=1-((1/(r^(ga-1)))*(1/ga)*((rho^ga)-1)*(1/(rho
    -1)));.....//Air standard efficiency

```

```
18 etath=etarel*etast;.....//Thermal  
efficiency  
19 IP=etath*(fc/3600)*C;.....//  
Indicated power in kW  
20 BP=etamech*IP;.....//  
Brake power in kW  
21 pmi=(6*IP)/(n*N*L*(%pi/4)*D*D*k*10);.....//  
mean effective pressure in bar  
22 disp(pmi,"Mean effective pressure (in bar):")  
23 pmb=pmi*etamech;.....//Brake  
mean effective pressure in bar  
24 disp(pmb,"Brake mean effective pressure (in bar):")
```

---

# Chapter 16

## Supercharging of IC Engines

**Scilab code Exa 16.1** Power supplied to supercharger

```
1 clc;funcprot(0); //EXAMPLE 16.1
2 // Initialisation of Variables
3 pwu=735;.....//Power developed by naturally
               aspirated engine in kW
4 afra=12.8;.....//Air fuel ratio for
               naturally aspirated engine
5 bsfc=0.350;.....//Brake specific fuel consumption
               in kg/kWh
6 metau=0.86;.....//Mechanical efficiency of
               naturally aspirated engine
7 pi=730;.....//Inlet pressure in mm of Hg
               absolute
8 tm=325;.....//Mixture temperature in Kelvin
9 pr=1.6;.....//Pressure ratio of supercharged
               engine
10 etaa=0.7;.....//Adiabatic efficiency of
               supercharged engine
11 metas=0.9;.....//Mechanical efficiency of
               supercharged engine
```

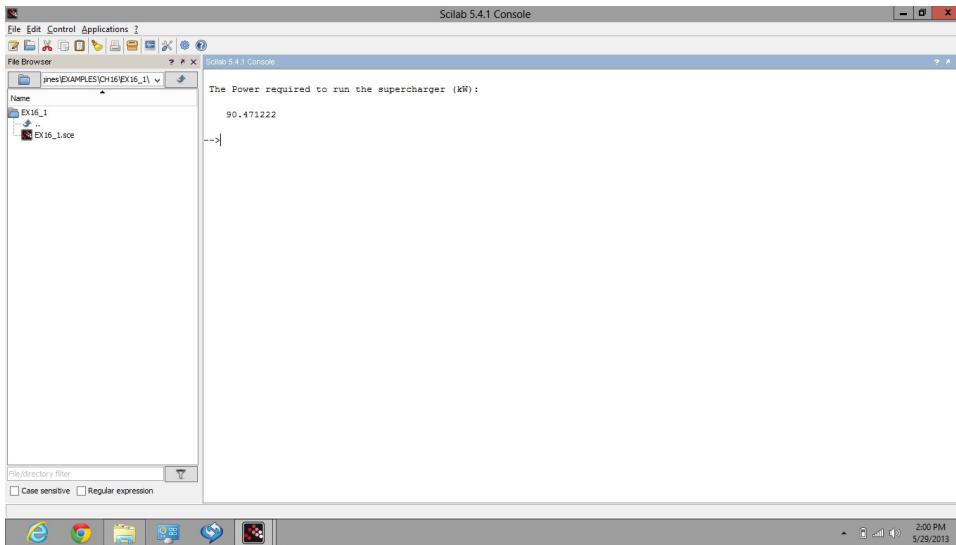


Figure 16.1: Power supplied to supercharger

```

12 afrrs=12.8;.....//Air fuel ratio for
    supercharged engine
13 rhohg=13600;.....//Density of mercury in kg/
    m^3
14 R=0.287;.....//Gas constant in kJ/kgK
15 ga=1.4;.....//Degree of freedom for gas
16 cp=1.005;.....//Specific heat of the
    fuel
17 g=9.81;.....//Acceleration due to gravity
    in m/s^2
18 //calculations
19 t2=tm*(pr)^((ga-1)/ga);.....//Ideal
    temperature for the supercharged engine
20 t2a=tm+(t2-tm)/etaa;.....//Actual
    temperature for the supercharged engine
21 wa=cp*(t2a-tm);.....//Work of the
    supercharger
22 wsup=cp*(t2a-tm)/metas;.....//Work required
    to drive the supercharger in kJ/kg of air
23 //When unsupercharged

```

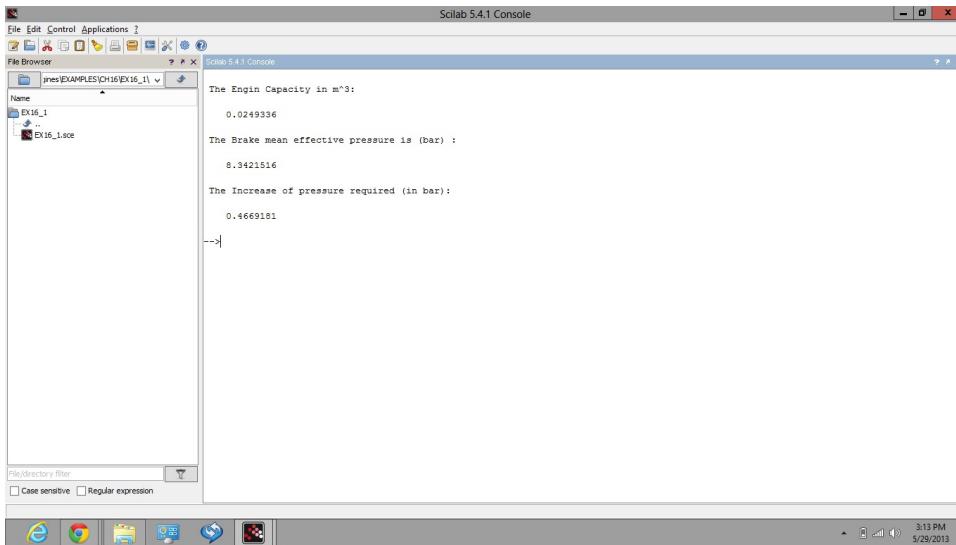


Figure 16.2: Engine Capacity and Brake Mean effective Pressure

```

24 p1=(pi/1000)*((g*rhohg)/1000);..... // Inlet
      pressure in kN/m^2
25 rhounsup=p1/(R*tm);
26 maunsup=(bsfc*pwu*afrs)/3600;..... // Air consumption in kg/s for unsupercharged engine
27 //When supercharged
28 rhosup=(pr*p1)/(R*t2a);
29 masup=maunsup*(rhosup/rhounsup);..... // Air consumption in kg/s
30 Psup=masup*wsup;..... //Power required to
      run the supercharger in kW
31 disp(Psup,"The Power required to run the
      supercharger (kW):")

```

---

**Scilab code Exa 16.2** Engine Capacity and Brake Mean effective Pressure

```

1 clc;funcprot(0); //EXAMPLE 16.2
2 // Initialisation of Variables
3 p1=1.0132;.....//Mean pressure at sea level
   in bar
4 t1=283;.....//Mean temperature at sea
   level in Kelvin
5 BP=260;.....//Brake Power output in
   kW
6 etaV=0.78;.....//Volumetric efficiency
   at sea level free air condition
7 sfc=0.247;.....//Specific Fuel consumption in
   kg/kW.h
8 afr=17;.....//Air fuel ratio
9 N=1500;.....//Engine rpm
10 at=2700;.....//Altitude in mts
11 p2=0.72;.....//Pressure in bar at the
   given altitude
12 Psup=0.08;.....//8% power of engine is
   taken by the supercharger
13 R=287;.....//Gas constant in J/kgK
14 t2=32+273;.....//Temperature in Kelvin at
   the given altitude
15 //calculations
16 mf=(sfc*BP)/60;.....//Fuel consumption in kg
   /min
17 ma = mf*afr;.....//Air consumption in
   ig/min
18 acps = ma/(N/2);.....//Air consumption per
   stroke in kg
19 Vs=(acps*R*t1)/(etaV*p1*10^5);.....//
   Engine capacity in m^3
20 disp(Vs,"The Engin Capacity in m^3:")
21 pmb=(BP*6)/(Vs*10*(N/2));.....//Brake Mean
   Effective Pressure in bar
22 disp(pmb,"The Brake mean effective pressure is (bar)
   :")
23 gp=BP/(1-Psup);.....//Gross power
   produced by supercharged engine in kW

```

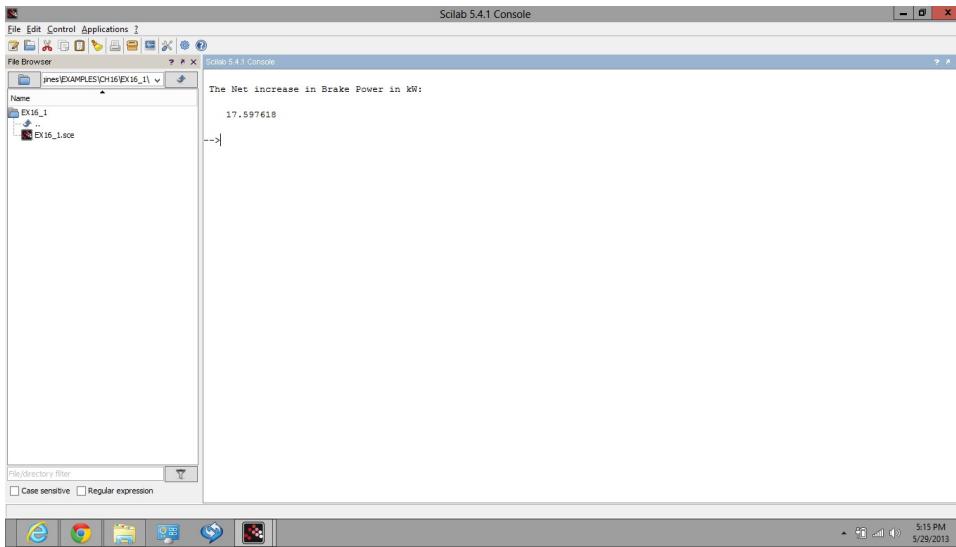


Figure 16.3: Increase in Brake Power due to supercharger

```

24 masup=ma*gp/BP;.....//Mass of air
    required for supercharged engine in kg
25 matc=masup/(N/2);.....//Mass of air taken
    per cycle
26 pressure=(matc*R*t2)/(etaV*10^5*Vs);
27 disp(pressure-p2,"The Increase of pressure required
    (in bar):")

```

---

### Scilab code Exa 16.3 Increase in Brake Power due to supercharger

```

1 clc;funcprot(0); //EXAMPLE 16.3
2 // Initialisation of Variables
3 ec=3600*10^(-6);.....//Engine capacity in m
    ^3
4 pw=13;.....//Power developed in kW per m^3
    of free air induced per minute

```

```

5 etaV=0.82;.....//Volumetric Efficiency
6 N=3000;.....//Engine rpm
7 p1=1.0132;.....//Initial Air
   pressure in bar
8 t1=298;.....//Initial Temperature
   in Kelvin
9 pr=1.8;.....//Pressure ratio in
   rotary compressor
10 etaC=0.75;.....//Isentropic efficiency
   of compressor
11 etaM=0.8;.....//Mechanical efficiency
12 ga=1.4;.....//Degree of freedom for
   the gas
13 td=4;.....//The amount by which
   the temperature is less than delivery temperature
   from compressor
14 R=287;.....//Gas constant in J/kg.K
15 cp=1.005;.....//Specific heat
   capacity
16 // Calculations
17 Vs=(ec*N)/2;.....//Swept volume in m
   ^3/min
18 Vu=Vs*etaV;.....//Unsupercharged
   volume induced per min
19 rcdp=pr*p1;.....//Rotary compressor delivery
   pressure
20 t2=t1*(pr)^((ga-1)/ga);.....//Ideal
   temperature for the supercharged engine
21 t2a=t1+(t2-t1)/etaC;.....//Actual
   temperature for the supercharged engine
22 ta=t2a-td;.....//Temperature
   of air at intake to the engine cylinder
23 V1=(rcdp*Vs*t1)/(p1*ta);.....//
   Equivalent volume at 1.0132 bar and 298 K
24 Vinc=V1-Vs;.....//Increase in
   induced Volume of air in m^3/min
25 ipincai=pw*Vinc;.....//Increase in
   IP from air induced in kW

```

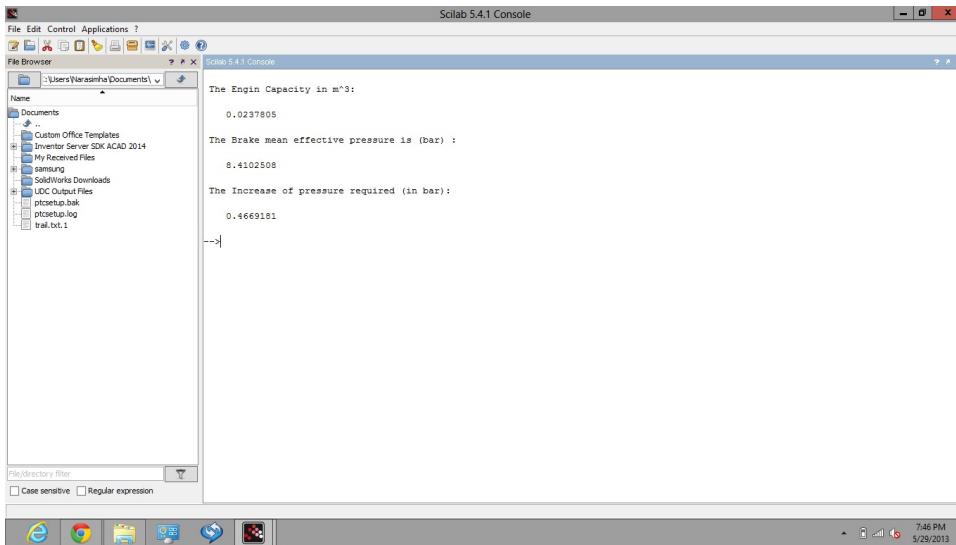


Figure 16.4: Engine Capacity and Brake Mean effective Pressure

```

26 ipinciip=((rcdp-p1)*10^5*Vs)/(60*1000);.....//  

     Increase in IP due to increased induction  

     pressure kW  

27 ipinctot=ipincai+ipinciip;.....//Total  

     increase in Input Power in kW  

28 bpinc=ipinctot*etaM;.....//Increase  

     in Brake Power of the engine in kW  

29 ma=(rcdp*10^5*Vs)/(60*R*ta);.....//  

     Mass of air delivered by the compressor kg/s  

30 pc=(ma*cp*(t2a-t1))/etaM;.....//Power  

     required by the compressor  

31 bpincnet=bpinc-pc;.....//Net  

     Increase in BP  

32 disp(bpincnet,"The Net increase in Brake Power in kW  

   :" )

```

---

### Scilab code Exa 16.4 Engine Capacity and Brake Mean effective Pressure

```
1 clc;funcprot(0); //EXAMPLE 16.4
2 // Initialisation of Variables
3 p1=1.0132;.....//Mean pressure at sea level
    in bar
4 t1=283;.....//Mean temperature at sea
    level in Kelvin
5 BP=250;.....//Brake Power output in
    kW
6 etaV=0.78;.....//Volumetric efficiency
    at sea level free air condition
7 sfc=0.245;.....// Specific Fuel consumption in
    kg/kW.h
8 afr=17;.....//Air fuel ratio
9 N=1500;.....//Engine rpm
10 at=2700;.....//Altitude in mts
11 p2=0.72;.....//Pressure in bar at the
    given altitude
12 Psup=0.08;.....//8% power of engine is
    taken by the supercharger
13 R=287;.....//Gas constant in J/kgK
14 t2=32+273;.....//Temperature in Kelvin at
    the given altitude
15 //calculations
16 mf=(sfc*BP)/60;.....//Fuel consumption in kg
    /min
17 ma = mf*afr;.....//Air consumption in
    ig/min
18 acps = ma/(N/2);.....//Air consumption per
    stroke in kg
19 Vs=(acps*R*t1)/(etaV*p1*10^5);.....//
    Engine capacity in m^3
20 disp(Vs,"The Engin Capacity in m^3:")
21 pmb=(BP*6)/(Vs*10*(N/2));.....//Brake Mean
    Effective Pressure in bar
22 disp(pmb,"The Brake mean effective pressure is (bar)
    :")
```

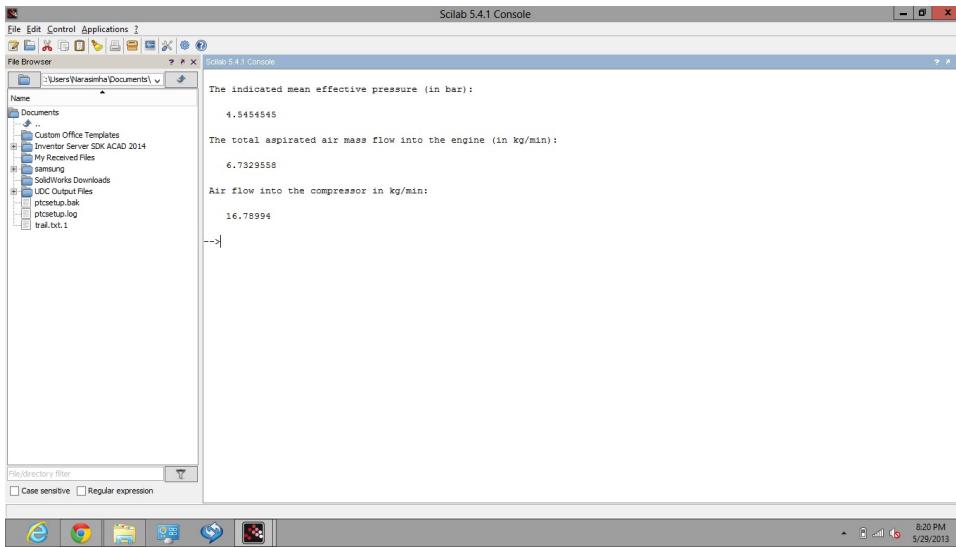


Figure 16.5: Compressor run by supercharged Engine

```

23 gp=BP/(1-Psup);.....//Gross power
    produced by supercharged engine in kW
24 masup=ma*gp/BP;.....//Mass of air
    required for supercharged engine in kg
25 matc=masup/(N/2);.....//Mass of air taken
    per cycle
26 pressure=(matc*R*t2)/(etaV*10^5*Vs);
27 disp(pressure-p2,"The Increase of pressure required
    (in bar):")

```

---

### Scilab code Exa 16.5 Compressor run by supercharged Engine

```

1 clc;funcprot(0); //EXAMPLE 16.5
2 // Initialisation of Variables
3 t1=298;.....//Temperature of the air
    while entering the compressor in Kelvin

```

```

4 qrej=1210;.....//Amount of heat rejected in
   cooler in kJ/min
5 t2=273+65;.....//Temperature of the air
   leaving the cooler in Kelvin
6 p2=1.75;.....//Pressure of the air
   leaving the cooler in bar
7 n=6;.....//No of cylinders
8 d=0.1;.....//Bore of the cylinder in m
9 l=0.11;.....//Stroke of the cylinder
   in m
10 etaV=0.72;.....//volumetric efficiency
11 N=2000;.....//Engine rpm
12 Tout=150;.....//Torque Output in Nm
13 etaM=0.8;.....//Mechanical efficiency
14 R=287;.....//Gas constant for air
   in J/kgK
15 cp=1.005;.....// Specific capacity of
   air
16 //calculations
17 BP=(2*%pi*N*Tout)/(60*1000);.....//Brake power
   in kW
18 IP=BP/etaM;.....//Input Power in kW
19 Vc=(%pi/4)*d*d*l;.....//Cylinder
   Volume in m^3
20 pmi=(6*IP)/(n*Vc*(N/2)*10);.....//
   Indicated mean effective pressure
21 disp(pmi,"The indicated mean effective pressure (in
   bar):")
22 Vs=Vc*6*(N/2);.....//Engine
   Swept Volume in m^3/min
23 Vaa=Vs*etaV;.....//Aspirated
   volume of air into engine in m^3/min
24 maa=(p2*10^5*Vaa)/(R*t2);.....//Aspirated
   air mass flow into the engine in kg/min
25 disp(maa,"The total aspirated air mass flow into the
   engine (in kg/min):")
26 t2a=((((BP/cp)/(qrej/(60*cp)))*t2)-t1)/(((BP/cp)/(
   qrej/(60*cp)))-1);

```

```
27 mc=((BP/cp)/(t2a-t1))*60;.....//  
      Air flow into the compressor in kg/min  
28 disp(mc,"Air flow into the compressor in kg/min:")
```

---

# Chapter 17

## Testing and Performance of IC Engines

**Scilab code Exa 17.1** Indicated power

```
1 clc;funcprot(0); //EXAMPLE 17.1
2 // Initialisation of Variables
3 Pmi=6;.....//Mean effective pressure
    in bar
4 N=1000;.....//Engine rpm
5 d=0.11;.....//Diameter of piston in
    m
6 l=0.14;.....//Stroke length in m
7 n=1;.....//No of cylinders
8 k=1;.....//k=1 for two stroke
    engine
9 //Calculations
10 V=l*(%pi/4)*d*d;.....//Volume of the
    cylinder in m^3
11 IP=(n*Pmi*V*k*10*N)/6;.....//Indicated Power
    developed in kW
12 disp(IP," Indicated power developed (in kW) :")
```

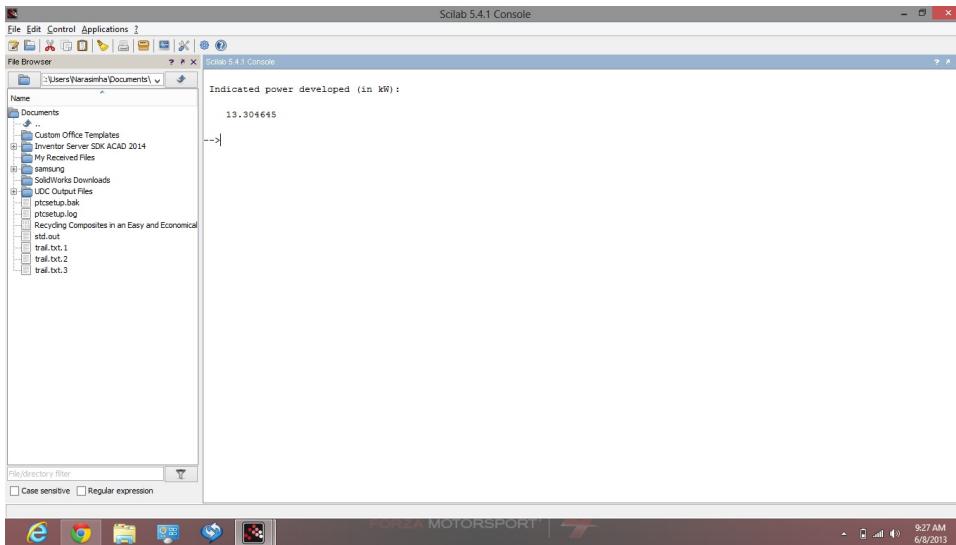


Figure 17.1: Indicated power

---

### Scilab code Exa 17.2 Bore and Stroke of engine

```
1 clc;funcprot(0); //EXAMPLE 17.2
2 // Initialisation of Variables
3 n=4; ..... //No of cylinders
4 P=14.7; ..... //Power developed in kW
5 N=1000; ..... //Engine speed in rpm
6 Pmi=5.5; ..... //Mean effective
    pressure in bar
7 lbyd=1.5; ..... //Ratio of stroke to
    bore
8 k=0.5; ..... //For four stroke
    engine
9 // Calculations
```

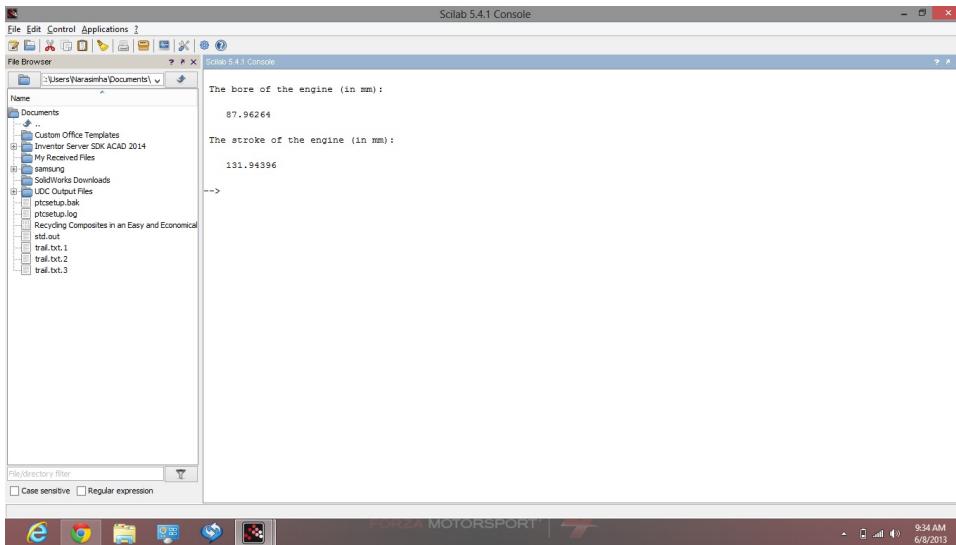


Figure 17.2: Bore and Stroke of engine

```

10 d=((P*6)/(n*Pmi*N*k*10*(%pi/4)*lbyd))^(1/3)
    ;.....// Calculation of bore in m
11 l=lbyd*d;.....// Calculation of stroke in m
12 disp(d*1000,"The bore of the engine (in mm):")
13 disp(l*1000,"The stroke of the engine (in mm):")

```

---

### Scilab code Exa 17.3 Brake power

```

1 clc;funcprot(0); //EXAMPLE 17.3
2 // Initialisation of Variables
3 Db=0.6;.....//Diameter of the brake
    wheel in m
4 d=0.026;.....//Diameter of the rope
    in m

```

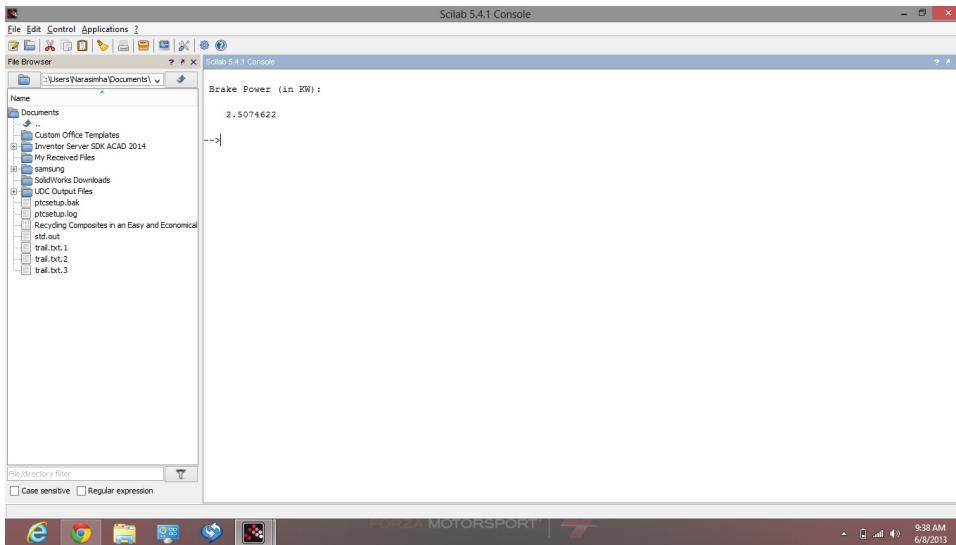


Figure 17.3: Brake power

```

5 W=200;..... //Dead load on the
               brake in N
6 S=30;..... //Spring balance reading
               in N
7 N=450;..... //Engine speed in rpm
8 //Calculations
9 BP=((W-S)*%pi*(Db+d)*N)/(60*1000);..... // 
               Brake Power in KW
10 disp(BP,"Brake Power (in KW):")

```

---

#### Scilab code Exa 17.4 Engine displacement

```

1 clc;funcprot(0); //EXAMPLE 17.4
2 // Initialisation of Variables
3 n=4;..... //No of cylinders
4 k=0.5;..... //For four stroke engine

```

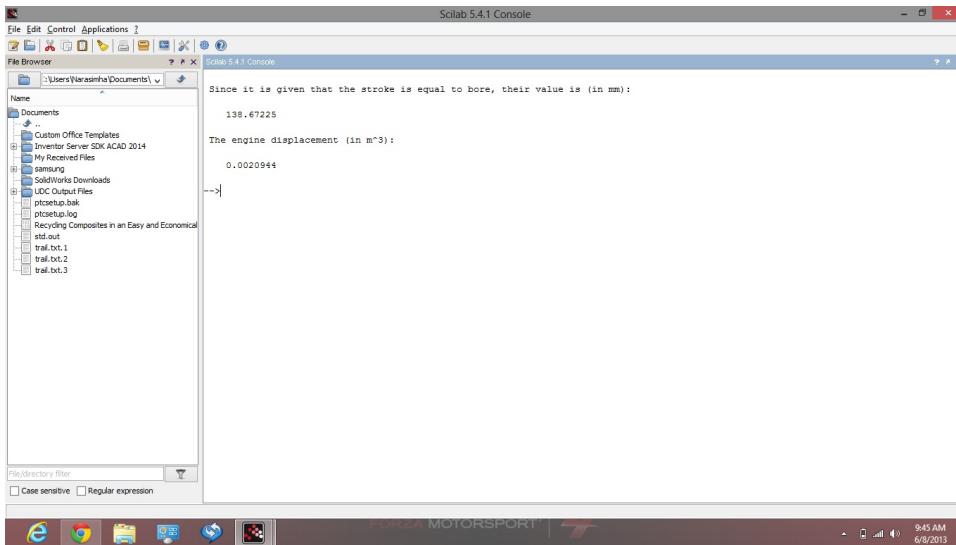


Figure 17.4: Engine displacement

```

5 Tb=160; ..... //Max brake torque in Nm
6 N=3000; ..... //Engine rpm
7 Pm=9.6; ..... //Brake mean effective
                  pressure in bar
8 // Calculations
9 D=((2*%pi*N*Tb*6)/(60*1000*Pm*(%pi/4)*N*k*10))^(1/3)
      ..... //Bore of engine in m
10 L=D; ..... //Given that the stroke is
                  equal to bore
11 Disp=(%pi/4)*D*D*L
      ..... //Displacement in m^3
12 disp(D*1000,"Since it is given that the stroke is
                  equal to bore, their value is (in mm): ")
13 disp(Disp,"The engine displacement (in m^3): ")

```

---

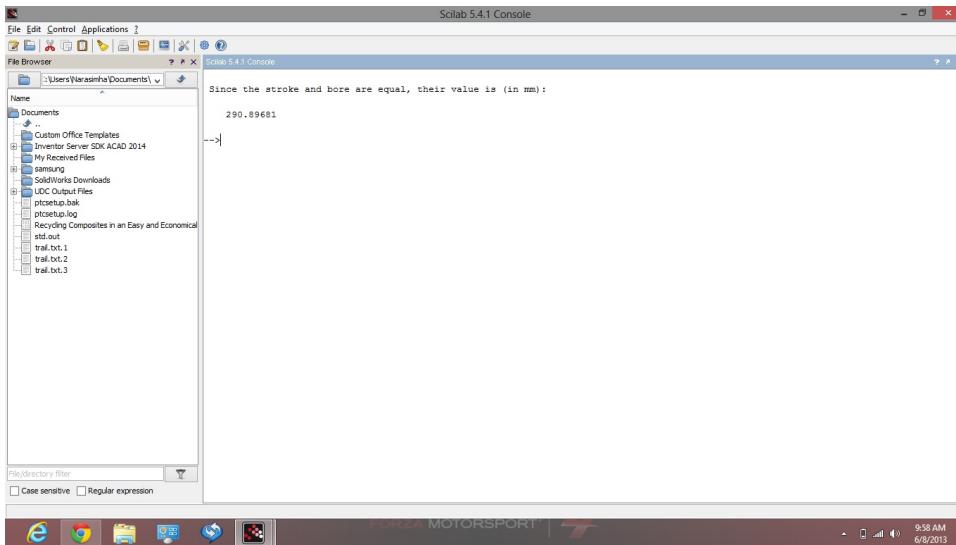


Figure 17.5: Bore and stroke

### Scilab code Exa 17.5 Bore and stroke

```

1 clc;funcprot(0); //EXAMPLE 17.5
2 // Initialisation of Variables
3 n=6;.....//No of cylinders
4 Pmb=6;.....//Brake mean effective
   pressure in bar
5 N=1000;.....//Engine rpm
6 k=0.5;.....//For four stroke
   engine
7 Wce=820;.....//Work during compression
   and expansion in kW
8 Wie=50;.....//Work during intake and
   exhaust in kW
9 f=150;.....//Rubbing friction in
   engiine in kW
10 WnetT=40;.....//Net work done by
    turbine in kW
11 //Calculations
12 BP=Wce-(Wie+f+WnetT);.....//Net work

```

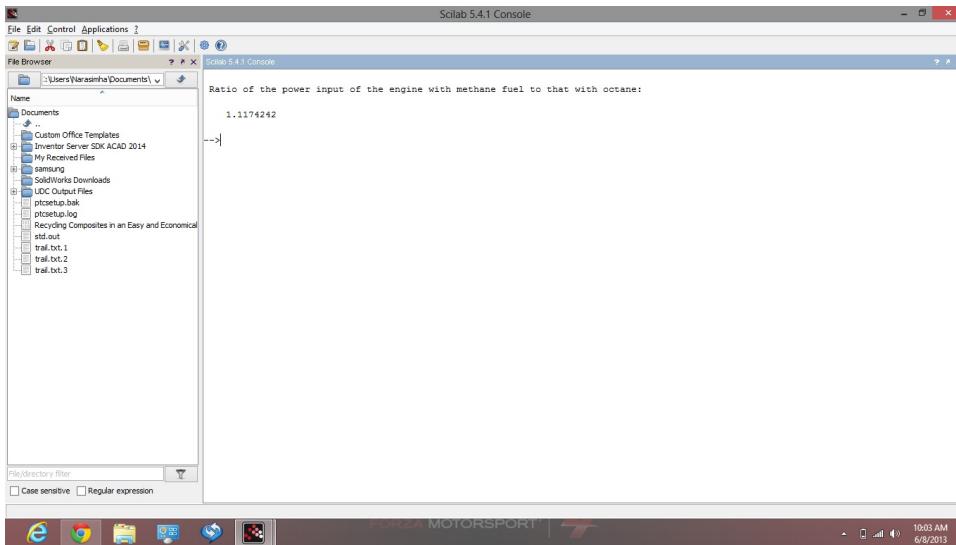


Figure 17.6: Ratio of power output when using different fuels

```

available or brake power in kW
13 D=((BP*6)/(n*Pmb*(%pi/4)*N*k*10))^(1/3)
; ..... //Bore of engine in m
14 L=D; ..... // Given
      that bore is equal to stroke
15 disp(D*1000,"Since the stroke and bore are equal,
      their value is (in mm):")

```

---

### Scilab code Exa 17.6 Ratio of power output when using different fuels

```

1 clc;funcprot(0); //EXAMPLE 17.6
2 // Initialisation of Variables
3 Cm=50150; ..... // Heating value
      of methane in kJ/kg
4 Co=44880; ..... // Heating value
      of octane in kJ/kg

```

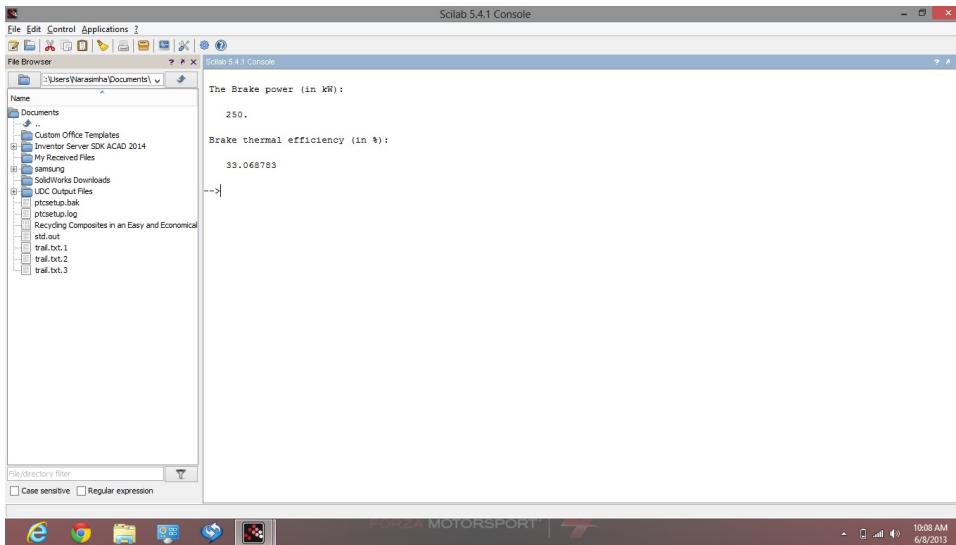


Figure 17.7: Brake power and brake thermal efficiency

---

```

5 // Calculations
6 // Since Energy supplied is proportional to mass of
   fuel supplied time calorific value of the fuel
   supplied
7 ratioP=Cm/Co;.....//Ratio of the
   power input of the engine with methane fuel to
   that with octane
8 disp(ratioP,"Ratio of the power input of the engine
   with methane fuel to that with octane:")

```

---

### Scilab code Exa 17.7 Brake power and brake thermal efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.7
2 // Initialisation of Variables
3 N=2000;..... // Engine rpm

```

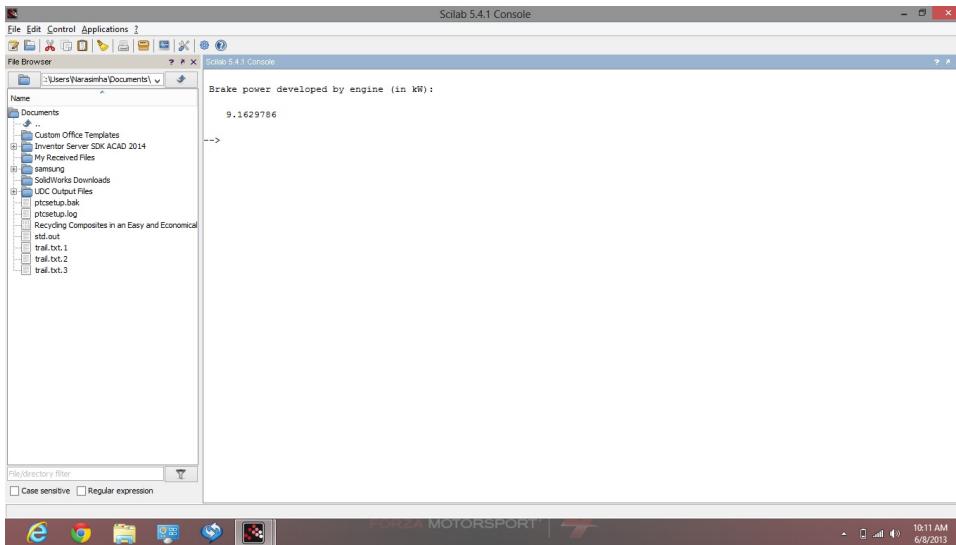


Figure 17.8: Brake power

```

4 k=0.5;..... //Four stroke
               engine
5 Disp=0.025;..... //Engine
                  displacement in m^3
6 Pmb=6;..... //Brake mean
               effective pressure in bar
7 mf=0.018;..... //Fuel
               consumption in kg/s
8 Cf=42000;..... //Calorific
               value of fuel in kJ/kg
9 //Calcuations
10 BP=(Pmb*Disp*N*k*10)/(6);..... //Brake
               power in kW
11 etaBT=BP/(mf*Cf);..... //Brake thermal
               efficiency
12 disp(BP,"The Brake power (in kW):")
13 disp(etaBT*100,"Brake thermal efficiency (in %):")

```

---

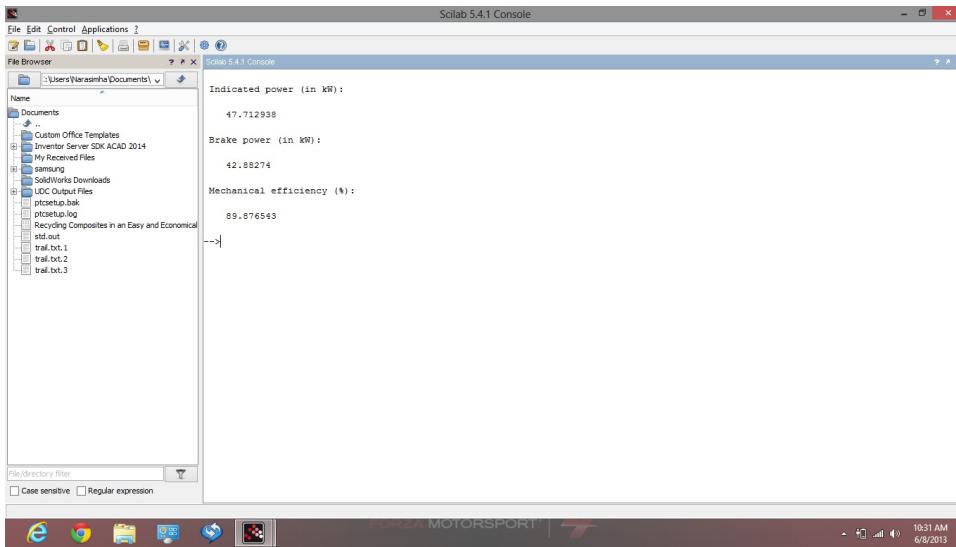


Figure 17.9: Indicated power and brake power and mechanical efficiency

### Scilab code Exa 17.8 Brake power

```

1 clc;funcprot(0); //EXAMPLE 17.8
2 // Initialisation of Variables
3 T=175;..... //Torque due to brake
   load in Nm
4 N=500;..... //Engine speed in rpm
5 //calcuations
6 BP=(2*pi*N*T)/(60*1000);..... // 
   Brake power developed by engine in kW
7 disp(BP,"Brake power developed by engine (in kW):")

```

---

**Scilab code Exa 17.9** Indicated power and brake power and mechanical efficiency

```
1 clc;funcprot(0); //EXAMPLE 17.9
2 // Initialisation of Variables
3 D=0.3;..... //Bore of engine
   cylinder in m
4 L=0.45;..... //Stroke of
   engine cylinder in m
5 N=300;..... //Engine rpm
6 Pmi=6;..... //Indicated mean
   effective pressure in bar
7 Nbl=1.5;..... //Net brake load
   in kN
8 Db=1.8;..... //Diameter of
   brake drum in m
9 d=0.02;..... //Brake rope
   diameter
10 k=0.5;..... //Four stroke
   engine
11 n=1;..... //No of cylinders
12 //Calculations
13 IP=(n*Pmi*L*(%pi/4)*D*D*N*k*10)
      /6;..... //Indicated power in kW
14 BP=(Nbl*%pi*(Db+d)*N)
      /60;..... //Brake power
      in kW
15 etam=BP/IP
      ;..... //Mechanical efficiency
16 disp(IP," Indicated power ( in kW ) :")
17 disp(BP," Brake power ( in kW ) :")
18 disp(etam*100," Mechanical efficiency ( % ) :")
```

---

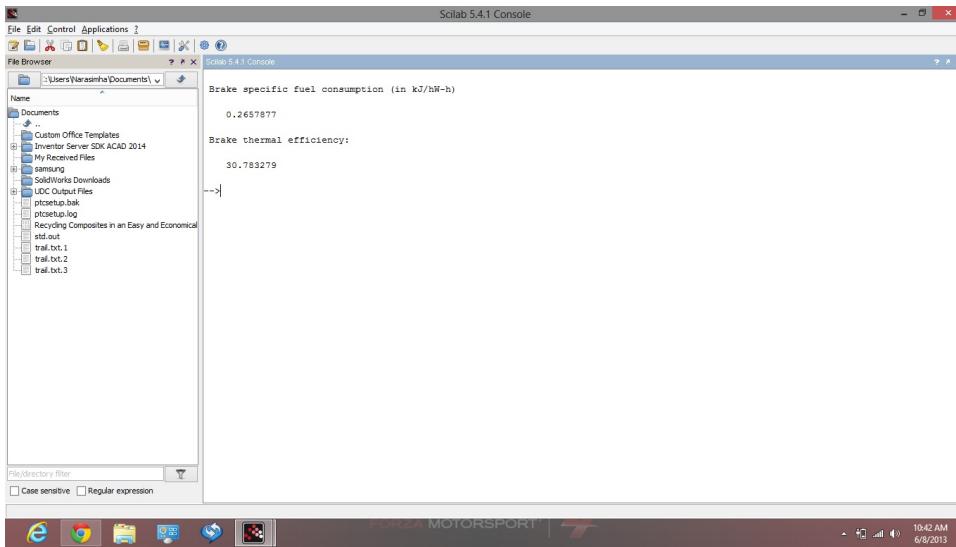


Figure 17.10: BSFC and brake thermal efficiency

### Scilab code Exa 17.10 BSFC and brake thermal efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.10
2 // Initialisation of Variables
3 Db=0.7; ..... //Diameter of
   brake pulley in m
4 d=0.025; ..... //Diameter of
   the rope in m
5 W=50; ..... //Load on the
   tight side of the rope in kg
6 S=50; ..... //Spring balance
   reading in N
7 N=900; ..... //Engine rpm
8 mf=4; ..... //Rate of fuel
   consumption in kg/h
9 C=44000; ..... //Calorific
   value of fuel in kJ/kg
10 g=9.81; ..... // Acceleration
   due to gravity in m/s^2
11 // Calculations

```

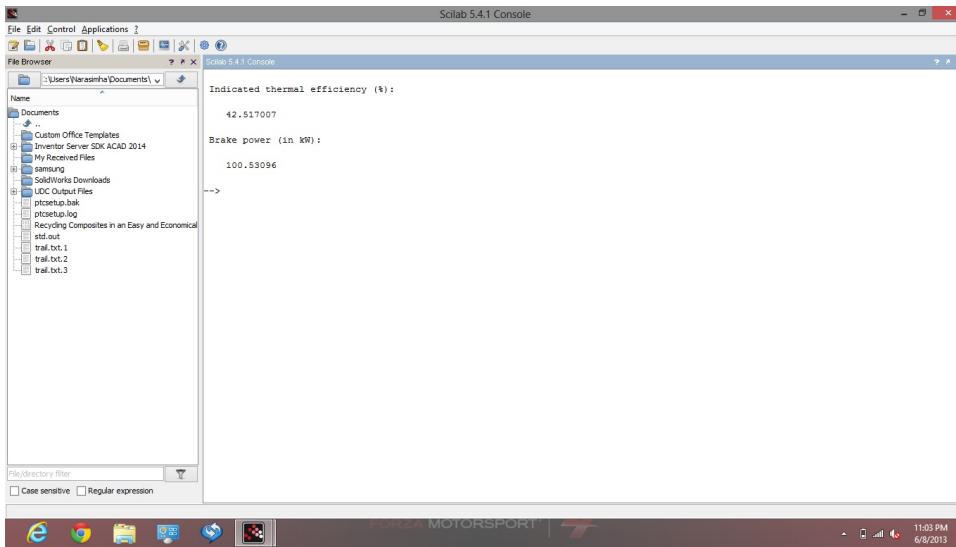


Figure 17.11: Indicated thermal efficiency and brake power

```

12 BP=(((W*g)-S)*%pi*(Db+d)*N)/(60*1000)
      ; ..... // Brake power in kW
13 bsfc=mf/BP
      ; ..... // Brake specific fuel consumption in kJ/hW-h
14 disp(bsfc," Brake specific fuel consumption (in kJ/hW-
      -h)")
15 etathB=(BP*3600)/(mf*C)
      ; ..... // Brake thermal efficiency
16 disp(etathB*100," Brake thermal efficiency :")

```

---

### Scilab code Exa 17.11 Indicated thermal efficiency and brake power

```

1 clc;funcprot(0); //EXAMPLE 17.11
2 // Initialisation of Variables

```

```

3 n=4; ..... //No of cylinders
4 k=0.5; ..... //Four stroke engine
5 r=8; ..... //Compression ratio
6 d=0.1; ..... //Engine bore in m
7 l=0.1; ..... //Engine stroke in m
8 etaV=0.75; ..... //Volumetric efficiency
9 N=4800; ..... //Engine rpm
10 afr=15; ..... //Air fuel ratio
11 C=42000000; ..... //Calorific value of fuel
12 rhoa=1.12; ..... //Atmospheric density in
    kg/m^3
13 Pmi=10; ..... //Mean effective pressure
    in bar
14 etamech=0.8; ..... //Mechanical efficiency
15 //Calculations
16 IP=(n*Pmi*l*(%pi/4)*d*d*N*k*10)/6; .....
    // Indicated power in kW
17 Ac=n*(%pi/4)*d*d*l*(N/2)*(etaV/60)
    ; ..... // Air consumption in m^3/s
18 ma=Ac*rhoa; .....
    // Mass flow of air in kg/s
19 mf=ma/afr; .....
    // Mass flow of fuel in kg/s
20 etath=(IP*1000)/(mf*C)
    ; ..... // Indicated
    thermal efficiency
21 disp(etath*100," Indicated thermal efficiency (%) : ")
22 BP=IP*etamech; .....
    // Brake Power in kW
23 disp(BP," Brake power ( in kW) : ")

```

---

**Scilab code Exa 17.12 Volumetric efficiency and BSFC**

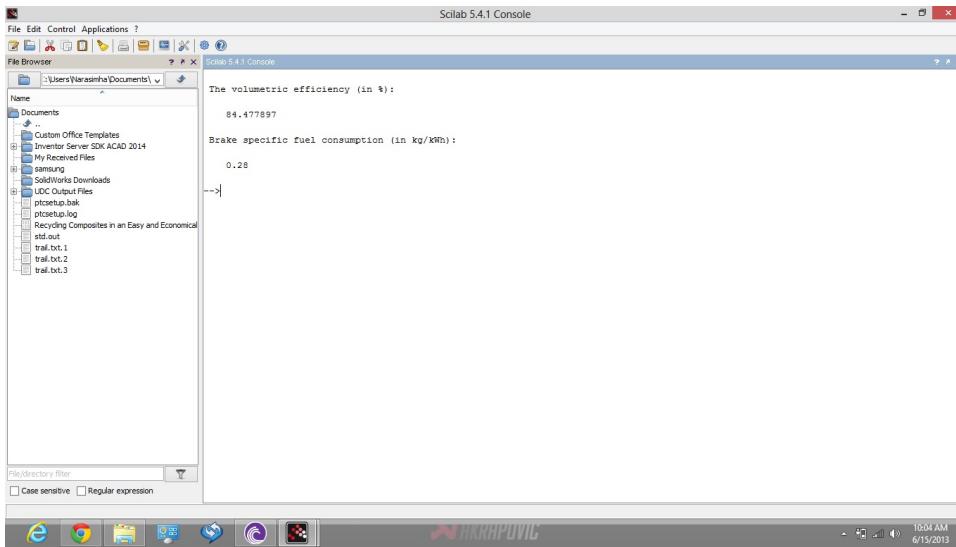


Figure 17.12: Volumetric efficiency and BSFC

```

1 clc;funcprot(0); //EXAMPLE 7.12
2 // Initialisation of Variables
3 N=1800; ..... //Engine rpm
4 l=0.11; ..... //Engine stroke in m
5 d=0.085; ..... //Engine bore in m
6 ma=0.56; ..... //Air flow rate in kg/min
7 BP=6; ..... //Brake power developed in
    kW
8 afr=20; ..... //Air fuel ratio
9 C=42550; ..... //Calorific value of fuel
    in kJ/kg
10 rhof=1.18; ..... //Density of fuel in kg/m
    ^3
11 //calculations
12 V=(%pi/4)*d*d*l*(N/2); ..... //Volume
    displacemt in m^3/min
13 Ma=V*rhof; ..... //Mass of
    air in kg/min
14 etaV=ma/Ma; ..... ////
    Volumetric efficiency

```

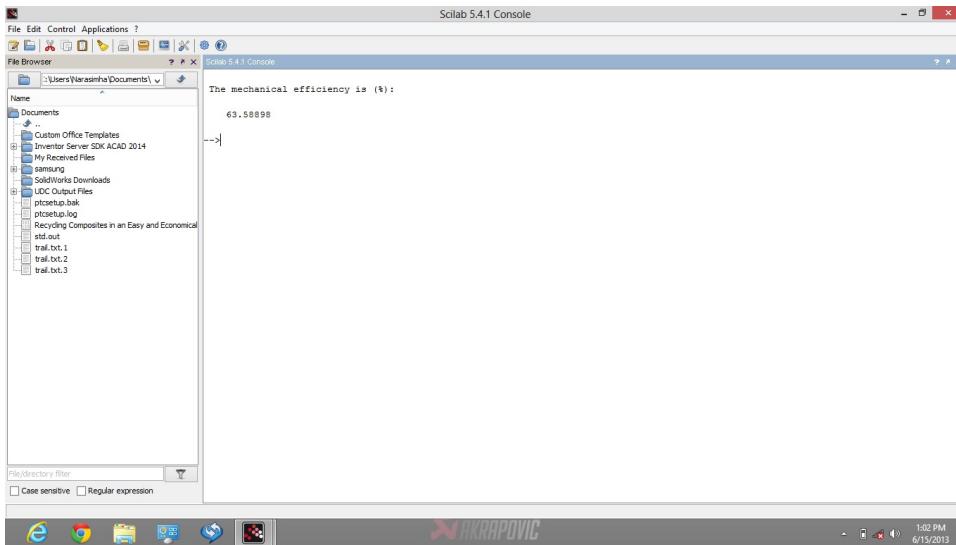


Figure 17.13: Mechanical efficiency

---

```

15 fc=ma/afr; ..... // Fuel
    concumption
16 bsfc=(fc*60)/BP; ..... // Brake
    specific fuel consumption in kg/kWh
17 disp(etaV*100,"The volumetric efficiency (in %):")
18 disp(bsfc,"Brake specific fuel consumption (in kg/
    kWh) :")
```

---

### Scilab code Exa 17.13 Mechanical efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.13
2 // Initialisation of Variables
3 pmicover=6.5; ..... //Mean effective
    pressure on cover side in bar
4 pmicrank=7; ..... //Mean effective
    pressure on crank side in bar
```

```

5 D=0.2;.....//Engine bore in m
6 l=0.35;.....//Engine stroke in
   m
7 drod=0.02;.....//Diameter of
   piston rod in m
8 W=1370;.....//Dead load on
   the brake in N
9 S=145;.....//Spring balance
   reading in N
10 Db=1.2;.....//Brake wheel
    diameter in m
11 d=0.02;.....//Brake rope
    diameter in m
12 k=0.5;.....//Four stroke
   engine
13 N=420;.....//Engine rpm
14 //calculations
15 Acover=(%pi/4)*D*D;.....//Area of
   cylinder on the cover side in m^2
16 Acrank=(%pi/4)*((D^2)-(drod^2));.....//
   Effective area of cylinder on the crank end side
   in m^2
17 IPcover=(pmicover*l*Acover*N*k*10)
   /6;.....//Indicated power on the cover
   end side in kW
18 IPcrank=(pmicrank*l*Acrank*N*k*10)
   /6;.....//Indicated power on the crank
   end side in kW
19 IPTotal=IPcover+IPcrank;.....//Total
20 BP=((W-S)*%pi*(Db+d)*N)/(60*1000)
   ;.....//Brake power in kW
21 etamech=BP/IPTotal
   ;.....//Mechanical
   efficiency
22 disp(etamech*100,"The mechanical efficiency is (%):"
   )

```

---

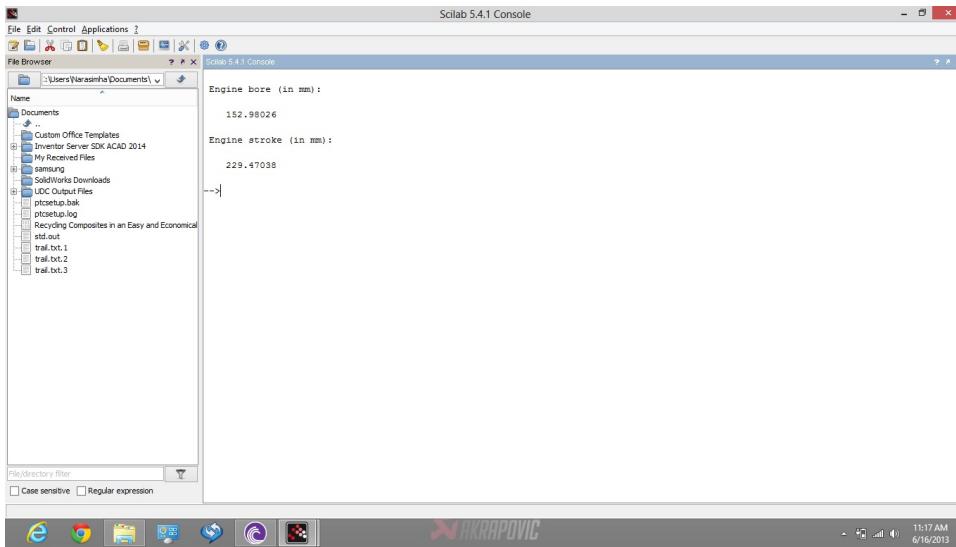


Figure 17.14: Engine bore and stroke

### Scilab code Exa 17.14 Engine bore and stroke

```

1 clc;funcprot(0); //EXAMPLE 17.14
2 // Initialisation of Variables
3 BP=14.7;.....//Brake power in kW
4 p1=0.9;.....//Suction pressure
   in bar
5 etamech=0.8;.....//Mechanical
   efficiency
6 r=5;.....//Compression ratio
7 p3=24;.....//maximum explosion
   pressure in bar
8 N=1000;.....//Engine rpm
9 rld=1.5;.....//Ratio of length
   and stroke

```

```

10 ic=1.35;.....//Index of
    compression curve
11 ie=1.3;.....//Index of expansion
    curve
12 k=0.5;.....//Four stroke engine
13 //calculations
14 p2=(r^ic)*p1;.....//intermediate
    pressure (in bar) during compression
15 p4=p3/(r^ie);.....//Intermediate
    pressure (in bar) during expansion
16 pm=((((p3-r*p4)/(ie-1))-((p2-p1*r)/(ic-1)))*(10^5))
    /(r-1);.....//Mean effective pressure in N/
    m^2
17 pmb=pm
    /100000;.....//Mean effective pressure in bar
18 IP=BP/etamech
    ;.....//Indicated power in kW
19 D=((IP*6*4)/(pmb*rld*(%pi)*N*k*10))^(1/3)
    ;.....//Engine bore in m
20 L=rld*D
    ;.....//Engine stroke in m
21 disp(D*1000,"Engine bore (in mm):")
22 disp(L*1000,"Engine stroke (in mm):")

```

---

**Scilab code Exa 17.15** Indicated thermal efficiency and brake thermal efficiency and mechanical efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.15
2 //Initialisation of Variables
3 IP=30;.....//Indicated power in

```

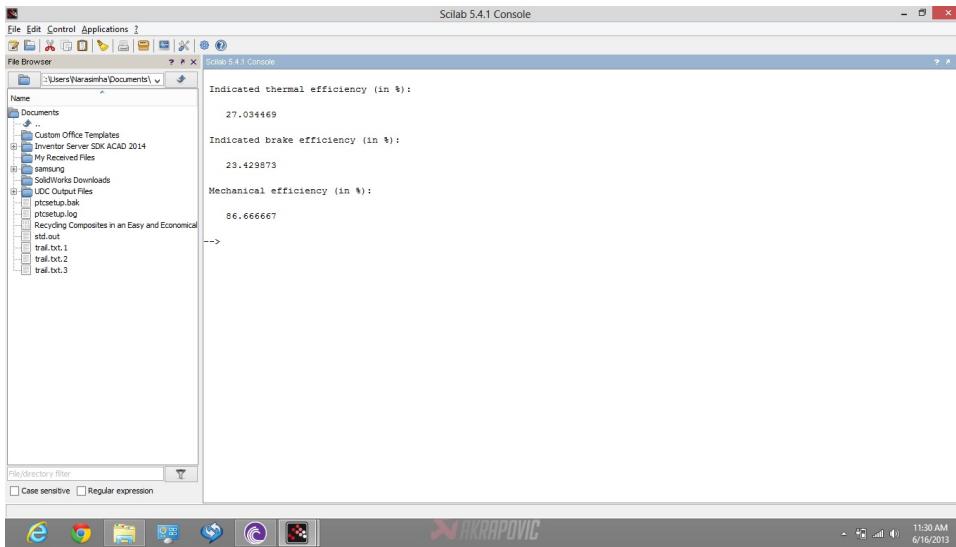


Figure 17.15: Indicated thermal efficiency and brake thermal efficiency and mechanical efficiency

```

kW
4 BP=26; ..... // Brake power in kW
5 N=1000; ..... // Engine rpm
6 fpbph=0.35; ..... // Fuel per brake power
hour in kg/B.P.h
7 C=43900; ..... // Calorific value of
fuel used in kJ/kg
8 // Calculations
9 mf=BP*fpbph; ..... // Fuel consumption per hour
in kg/h
10 etaIth=IP/((mf/3600)*C); ..... // Indicated
thermal efficiency
11 etaBth=BP/((mf/3600)*C); ..... // Indicated
brake efficiency
12 etamech=BP/IP; ..... // 
Mechanical efficiency
13 disp(etaIth*100," Indicated thermal efficiency (in %)
:")
14 disp(etaBth*100," Indicated brake efficiency (in %):"

```

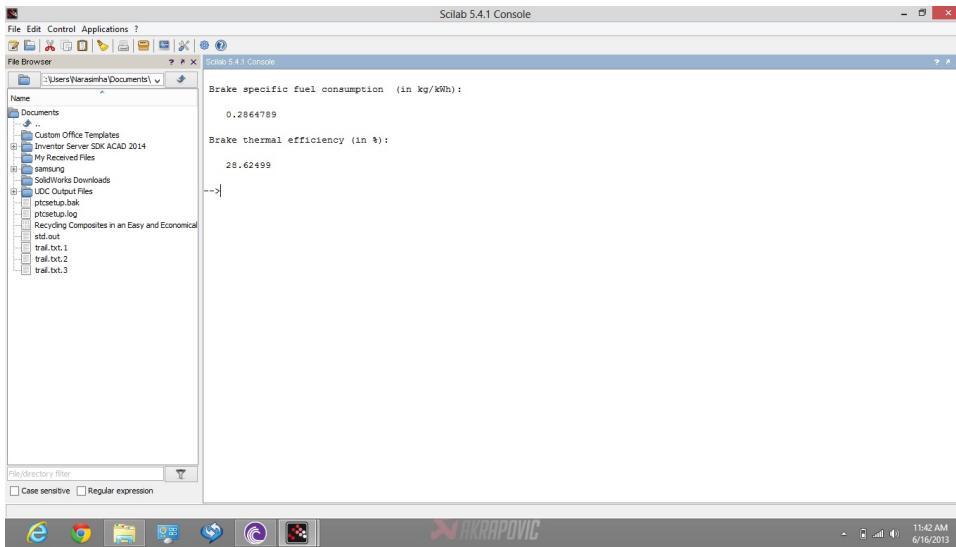


Figure 17.16: BSFC and brake thermal efficiency

---

```

)
15 disp(etamech*100,"Mechanical efficiency (in %):")

```

---

### Scilab code Exa 17.16 BSFC and brake thermal efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.16
2 //Initialisation of Variables
3 Db=0.75;.....//Diameter of brake
    pulley in m
4 d=0.05;.....//Rope diameter in m
5 W=400;.....//Dead load in N
6 S=50;.....//Spring balance
    reading in N
7 cf=4.2;.....//Consumption of fuel
    in kg/h
8 N=1000;.....//Engine rpm

```

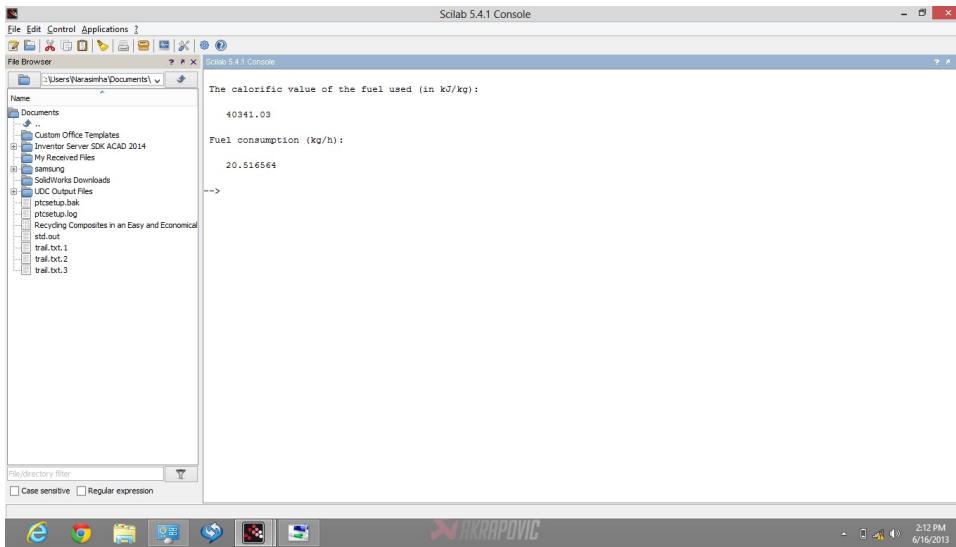


Figure 17.17: Fuel consumption and calorific value of fuel

```

9 C=43900;..... // Calorific value of
    fuel in kJ/kg
10 // Calculations
11 BP=((W-S)*%pi*(Db+d)*N)/(60*1000);..... // 
    Brake power in kW
12 bsfc=cf/BP;..... // 
    Brake specific fuel consumption in kg/kWh
13 etabth=BP/((cf/3600)*C);..... //
    Brake thermal efficiency
14 disp(bsfc,"Brake specific fuel consumption (in kg/
    kWh):")
15 disp(etabth*100,"Brake thermal efficiency (in %):")

```

---

### Scilab code Exa 17.17 Fuel consumption and calorific value of fuel

```
1 clc;funcprot(0); //EXAMPLE 17.17
```

```

2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 D=0.09; ..... //Bore of cylinder
   in m
5 L=0.1; ..... // Stroke length in
   m
6 r=7; ..... // Compression ratio
7 etarel=0.55; ..... // Relative
   efficiency
8 isfc=0.3; ..... // Indicated
   specific fuel consumption in kg/kWh
9 imep=8.6; ..... // Indicated mean
   effective pressure in bar
10 N=2500; ..... // Engine speed
11 ga=1.4; ..... // Degree of freedom
   for air
12 k=0.5; ..... //Four stroke
   engine
13 //calculations
14 etastan=1-1/(r^(ga-1)); ..... // Air
   standard efficiency
15 etath=etarel*etastan; ..... //
   Indicated thermal efficiency
16 C=3600/(etath*isfc); ..... //
   Calorific value of fuel in kJ/kg
17 IP=(n*imep*L*D*(pi/4)*N*k*10)/6; .....
   //Indicated power in kW
18 fc=IP*isfc; ..... //Fuel
   consumption in kg/h
19 disp (C,"The calorific value of the fuel used (in kJ
   /kg):")
20 disp(fc,"Fuel consumption (kg/h):")

```

---

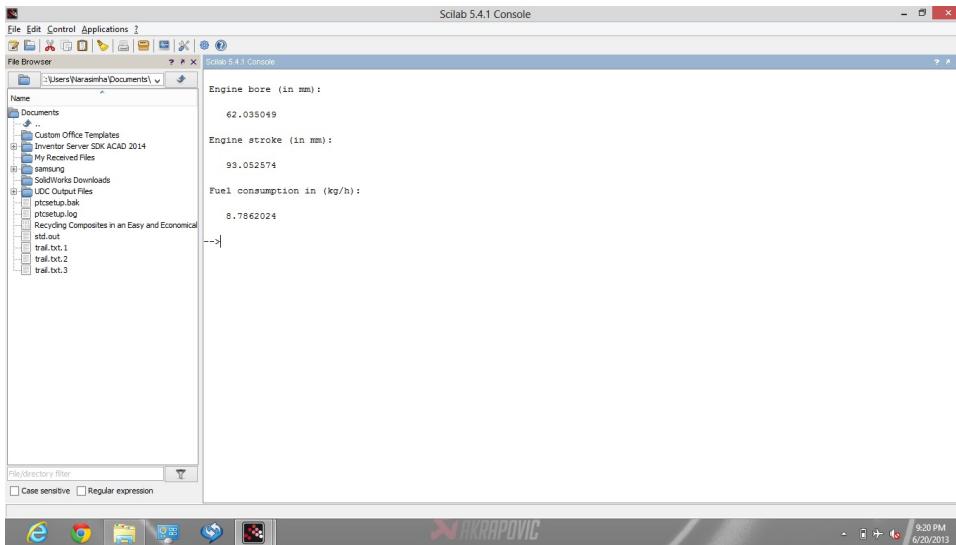


Figure 17.18: Engine bore and stroke and Fuel consumption

### Scilab code Exa 17.18 Engine bore and stroke and Fuel consumption

```

1 clc;funcprot(0); //EXAMPLE 17.18
2 // Initialisation of Variables
3 BP=30;..... //Brake power in kW
4 pmi=8;..... //Mean effective
   pressure in bar
5 etamech=0.8;..... //Mechanical
   efficiency
6 n=4;..... //No of cylinders
7 N=2500;..... //Engine rpm
8 rld=1.5;..... //Ratio of length
   and stroke
9 etabth=0.28;..... //Brake thermal
   efficiency
10 k=1;..... //Two stroke engine
11 C=43900;..... //Calorific value
   of fuel in kJ/kg
12 //calculations
13 IP=BP/etamech

```

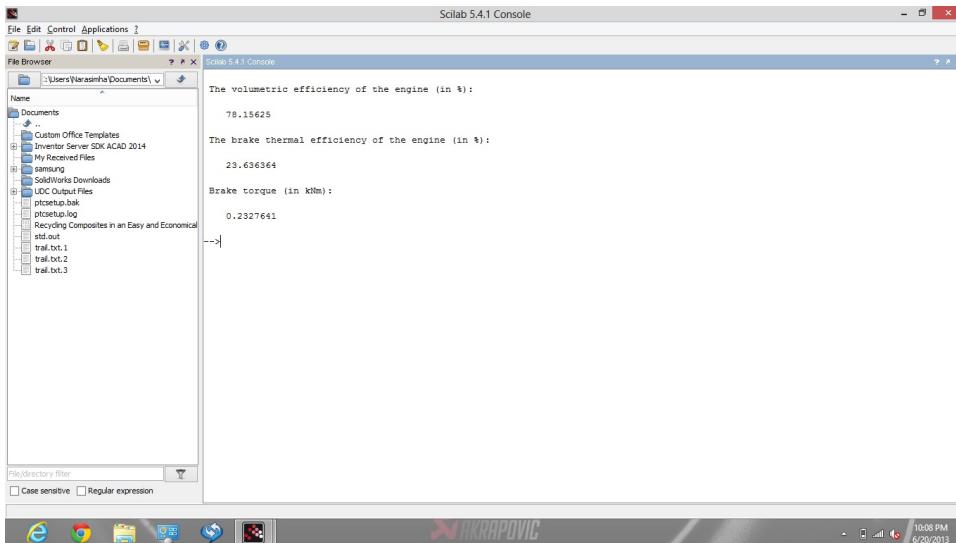


Figure 17.19: Volumetric efficiency and brake thermal efficiency and brake torque

## Scilab code Exa 17.19 Volumetric efficiency and brake thermal efficiency and brake torque

```

1 clc;funcprot(0); //EXAMPLE 17.19
2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 pdpc=700*10^(-6); ..... //Piston
   displacement per cylinder in m^3
5 P=78; ..... //Power developed
   in kW
6 N=3200; ..... //Engine rpm
7 mf=27; ..... //Fuel
   consumption in kg/h
8 C=44000; ..... //Calorific value
   of fuel in kJ/kg
9 afr=12; ..... //Air fuel
   ratio
10 p1=0.9; ..... //Intake air
   pressure
11 pa=p1;
12 t1=305; ..... //Intake air
   temperature
13 ta=t1;
14 R=0.287; ..... //Gas constant in kJ/
   kgK
15 // Calculations
16 ma=afr*mf; ..... //mass of air
   in kg/h
17 Va=(ma*R*t1)/(p1*100); ..... //Volume of air
   intake in m^3/h
18 Vs=pdpc*n*(N/2)*60; ..... //Swept
   volume in m^3/h
19 etaV=Va/Vs; ..... //Volumetric
   efficiency
20 disp(etaV*100,"The volumetric efficiency of the
   engine (in %):")
21 etabt=P/(mf*(C/3600)); ..... //Brake
   thermal efficiency
22 disp(etabt*100,"The brake thermal efficiency of the
   engine (in %):")
23 Tb=(P*60)/(2*pi*N); ..... //

```

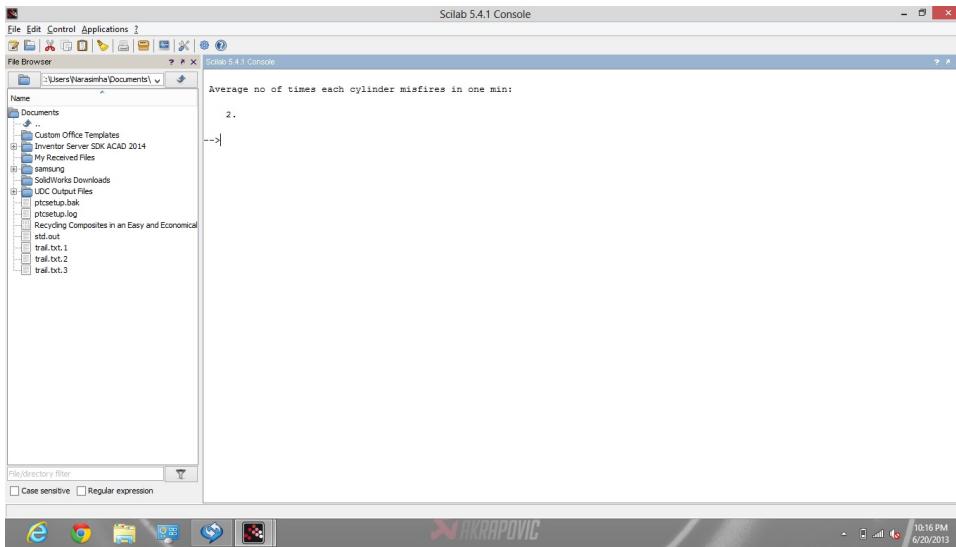


Figure 17.20: Average no of misfires per min

Brake torque in kNm

24 `disp(Tb," Brake torque ( in kNm ) :")`

---

### Scilab code Exa 17.20 Average no of misfires per min

```

1 clc;funcprot(0); //EXAMPLE 17.20
2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 Vs=1.75*10^(-3); ..... //Stroke volume in m^3
5 IP=26.3; ..... //Indicated power in kW
6 Ne=504; ..... //Expected Engine rpm
7 Pmi=6; ..... //Mean effective
     pressure in bar
8 k=0.5; ..... //Four stroke engine
9 // Calculations

```

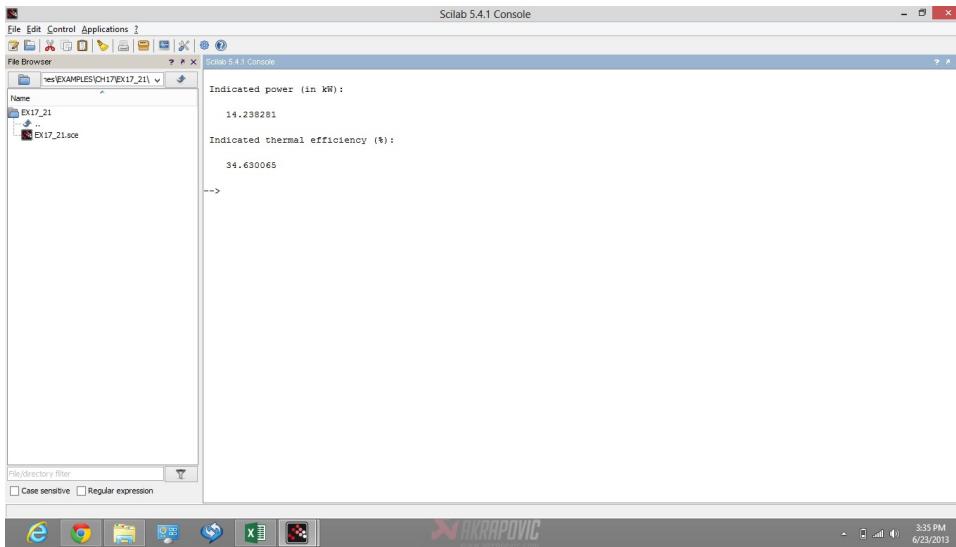


Figure 17.21: Indicated power and indicated thermal efficiency

```

10 Na=floor((IP*6)/(n*Pmi*Vs*k*10))
    ;..... //Actual Engine rpm
11 af=(Na*n)/2;..... //Actual no of
    fires in min
12 ef=(Ne*n)/2;..... //Expected no of
    fires in min
13 Nm=ef-af;..... //No of misfires/
    min
14 nm=Nm/n;..... //Average no of times
    each cylinder misfires in one min
15 disp(nm," Average no of times each cylinder misfires
    in one min:")

```

---

**Scilab code Exa 17.21** Indicated power and indicated thermal efficiency

```
1 clc;funcprot(0); //EXAMPLE 17.21
```

```

2 // Initialisation of Variables
3 n=4; ..... //No of cylinders
4 D=0.075; ..... //Engine bore in m
5 L=0.09; ..... //Engine length in m
6 err=39/8; ..... //Engine to rear
    axle ratio
7 Dw=0.65; ..... //Wheel diameter in
    m
8 pc=0.227; ..... // Petrol consumption
    in kg
9 pmi=5.625; ..... //Mean effective
    pressure in bar
10 C=43470; ..... // Calorific
    value of petrol in kJ/kg
11 k=0.5; ..... //Four stroke
    engine
12 sc=48; ..... //Speed of the car
    in km/h
13 d=3.2; ..... //Distance
    covered by car in km
14 //Calculations
15 sc1=sc*(1000/60); ..... //Speed of the
    car in m/min
16 Nt=sc1/(%pi*Dw); ..... // Revolutions
    made by tire per min
17 Ne=Nt*err; ..... //Speed of
    engine shaft
18 IP=(n*pmi*L*(%pi/4)*D*D*Ne*k*10)/6; ..... //
    Indicated power in kW
19 disp(IP," Indicated power (in kW) :")
20 sc2=sc/60; ..... //Speed of the car
    in km/min
21 t=d/sc2; ..... //Time for
    covering 3.2 km in min
22 fc=pc/(t*60); ..... //Fuel consumed
    per second in kg
23 etaIt=IP/(fc*C); ..... //Indicated thermal
    efficiency

```

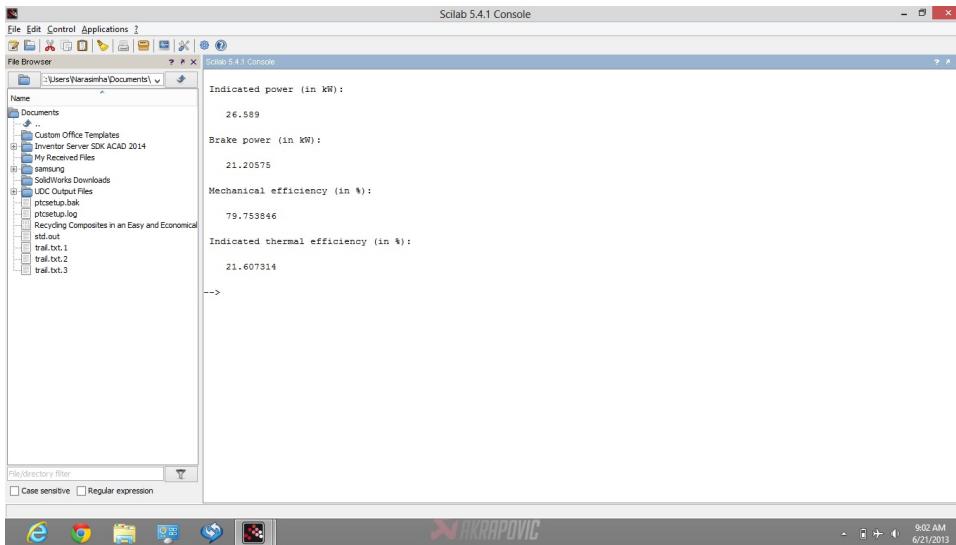


Figure 17.22: Finding all engine parameters

---

24 **disp(etait\*100," Indicated thermal efficiency (%) :")**

---

### Scilab code Exa 17.22 Finding all engine parameters

```

1 clc;funcprot(0); //EXAMPLE 17.22
2 // Initialisation of Variables
3 n=1;.....//No of cylinders
4 D=0.25;.....//Engine bore in m
5 L=0.4;.....//Engine stroke in m
6 pmg=7;.....//Gross mean effective
    pressure in bar
7 pmp=0.5;.....//Pumping mean effective
    pressure in bar
8 N=250;.....//Engine rpm
9 Db=1.5;.....//Effective diameter of the
    brake in m

```

```

10 N1=1080;.....//Net load on the brake in N
11 fh=10;.....//Fuel used per hour in kg
12 C=44300;.....//Calorific value of fuel in
    kJ/kg
13 k=0.5;.....//Four stroke engine
14 // Calculations
15 mf=fh/3600;.....//Fuel used per
    second in kg
16 pm=pmg-pmp;.....//Net pressure
17 IP=(n*pm*L*(%pi/4)*D*D*N*k*10)/6;.....///
    Indicated power in kW
18 disp(IP," Indicated power (in kW):")
19 BP=((N1)*%pi*Db*N)/(60*1000);.....//Brake
    power in kW
20 disp(BP," Brake power (in kW):")
21 etamech=BP/IP;.....///
    Mechanical efficiency
22 disp(etamech*100," Mechanical efficiency (in %):")
23 etath=IP/(mf*C);.....//Indicated
    thermal efficiency
24 disp(etath*100," Indicated thermal efficiency (in %):"
    )

```

---

### Scilab code Exa 17.23 Brake mean effective pressure

```

1 clc;funcprot(0); //EXAMPLE 17.23
2 // Initialisation of Variables
3 etabth=0.3;.....//Brake thermal
    efficiency
4 afrw=20;.....//Air fuel ratio by
    weight
5 C=41800;.....//Calorific value
    of fuel used in kJ/kg

```

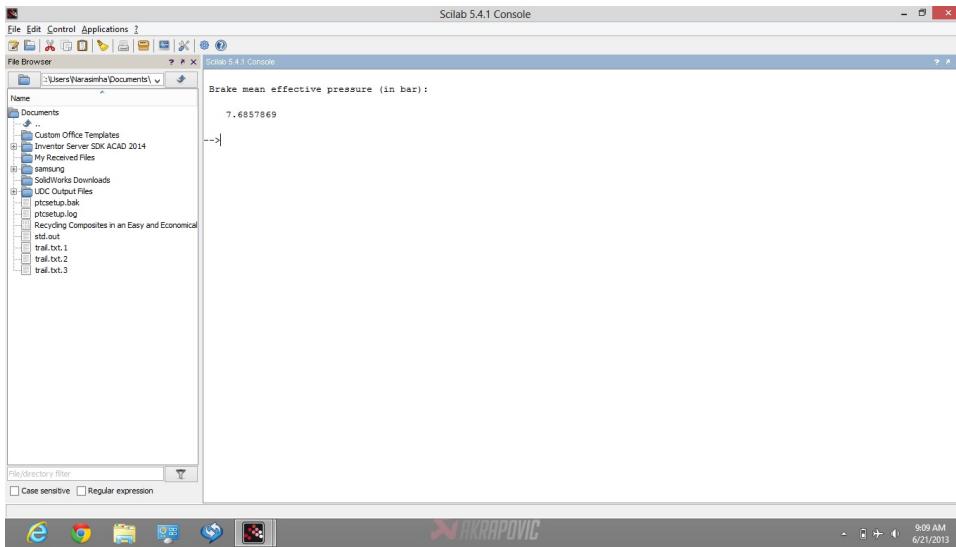


Figure 17.23: Brake mean effective pressure

```

6 R=287;.....//Gas constant in J/kg
7 // Calculations
8 Wp=etabth*C;.....//Work produced per
   kg of fuel in kJ
9 p1=1.0132;t=273+15;.....//STP conditions in
   bar and Kelvin
10 V=(afrw*t*R)/(p1*10^5);.....//Volume of air used
    in m^3
11 pmb=(Wp*1000)/(V*10^5);.....//Brake mean
    effective pressure in bar
12 disp(pmb,"Brake mean effective pressure (in bar):")

```

---

#### Scilab code Exa 17.24 Volumetric efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.24
2 // Initialisation of Variables

```

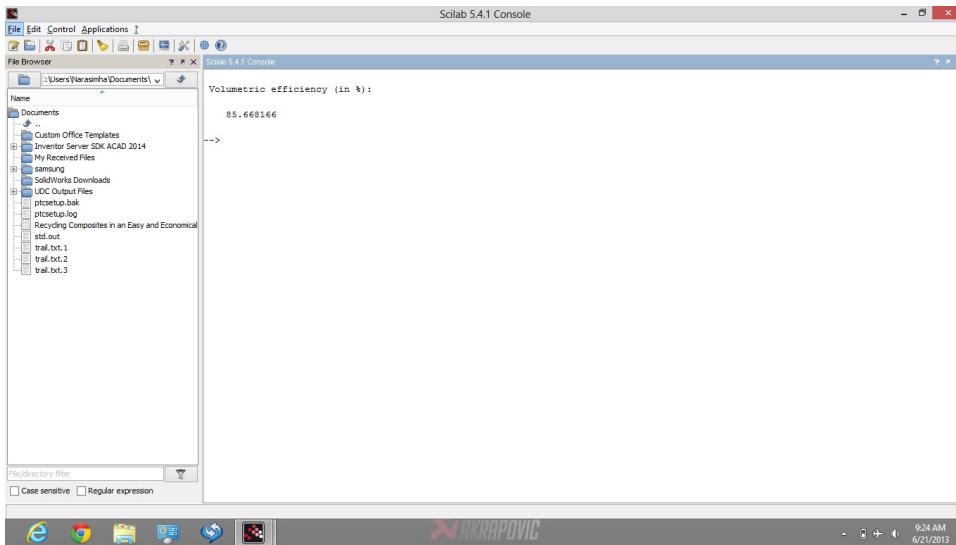


Figure 17.24: Volumetric efficiency

```

3 v1=0.216; ..... //Gas consumption in m3/min
4 pw=75; ..... // Pressure of gas in mm of water
5 t1=290; ..... //Temperature of gas in K
6 ac=2.84; ..... //Air consumption in kg/min
7 br=745; ..... //Barometer reading in mm of Hg
8 D=0.25; ..... //Engine bore in m
9 L=0.475; ..... //Engine stroke in m
10 N=240; ..... //Engine rpm
11 R=287; ..... //Gas constant for air in J/kgK
12 //Calculations
13 p1=br+(pw/13.6); ..... //Pressure of gas in mm of mercury
14 p2=760; t2=273; ..... //NTP conditions in mm of Hg and Kelvin

```

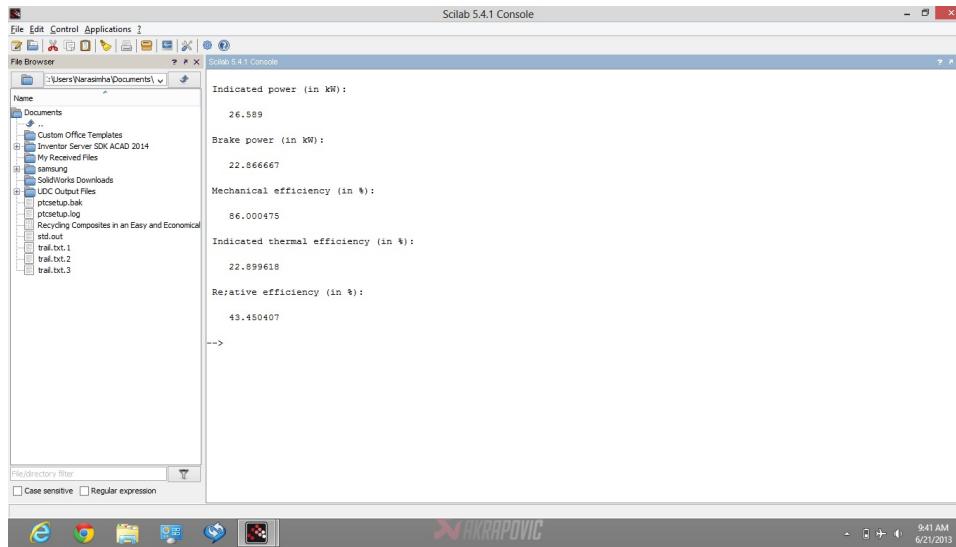


Figure 17.25: finding all parameters of engine

```

15 v2=(p1*v1*t2)/(t1*p2);.....//Volume of gas
     used at NTP in m^3
16 gs=v2/(N/2);.....//Gas used per
     stroke in m^3
17 v=(ac*R*t2)/(1.0132*10^5);.....//Volume
     occupied by air at NTP in m^3/min
18 aps=v/(N/2);.....//Air used
     per stroke
19 Va=gs+aps;.....//Actual volume of
     mixture in m^3 drawn per stroke at NTP
20 Vs=(%pi/4)*D*D*L;.....//Swept volume in mm
     ^3
21 etaV=(Va/Vs);.....//Volumetric
     efficiency
22 disp(etaV*100," Volumetric efficiency (in %):")

```

---

### Scilab code Exa 17.25 finding all parameters of engine

```
1 clc;funcprot(0); //EXAMPLE 17.25
2 // Initialisation of Variables
3 t=1;..... //Duration of trial in hrs
4 Rev=14000;..... //Revolutions
5 nmc=500;..... //Number of missed cycles
6 bl=1470;..... //Net Brake load in N
7 mep=7.5;..... //Mean effective pressure in
bar
8 gc=20000;..... //Gas consumption in litres
9 lcv=21;..... //LCV of gas at supply
condition in kJ/litre
10 D=0.25;..... //Engine bore in m
11 L=0.4;..... //Engine stroke in m
12 r=6.5;..... //Compression ratio
13 n=1;..... //No of cylinders
14 Cb=4;..... //Effective brake
Circumference
15 k=0.5;..... //Four stroke engine
16 ga=1.4;..... //Degree of freedom
17 //Calculations
18 N=Rev/60;..... //Engine rpm
19 Vg=gc/3600;..... //Fuel consumption in litres
/s
20 Na=((Rev/2)-nmc)/60;..... //Working cycles
per min
21 IP=(n*mep*L*(%pi/4)*D*D*Na*10)/6;..... //
indicated power in kW
22 disp(IP," Indicated power (in kW) :")
23 BP=((bl)*Cb*N)/(60*1000);..... //Brake
power in kW
24 disp(BP," Brake power (in kW) :")
25 etamech=BP/IP;..... //
Mechanical efficiency
26 disp(etamech*100," Mechanical efficiency (in %) :")
27 etath=IP/(Vg*lcv);..... //
Indicated thermal efficiency
```

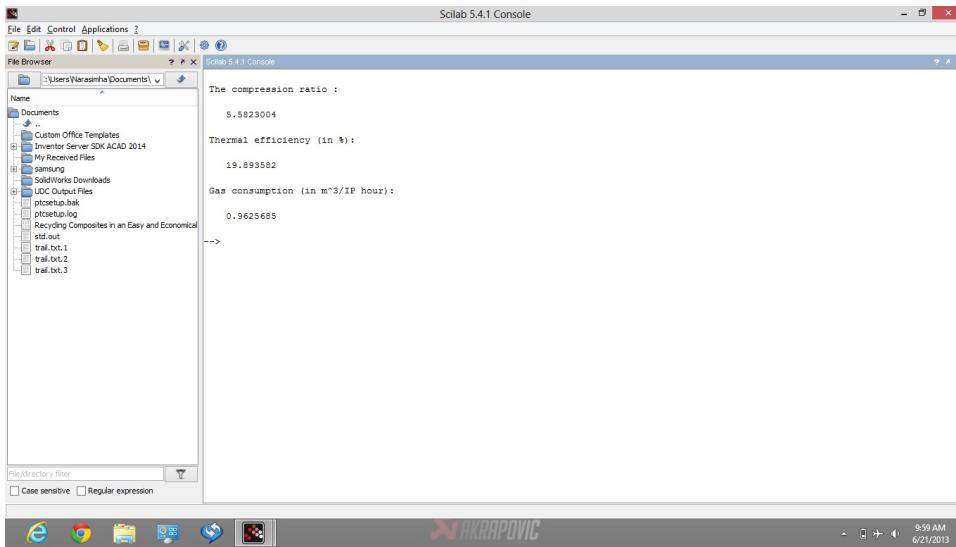


Figure 17.26: Compression ratio and thermal efficiency and gas consumption

---

```

28 disp(etath*100," Indicated thermal efficiency (in %):"
      ")
29 etast=1-(1/r^(ga-1));.....//Air standard
    efficiency
30 etarel=etath/etast;.....//Relative efficiency
31 disp(etarel*100," Relative efficiency (in %):")

```

---

**Scilab code Exa 17.26** Compression ratio and thermal efficiency and gas consumption

```

1 clc;funcprot(0); //EXAMPLE 17.26
2 // Initialisation of Variables
3 n=1.3;.....//Index of compression
4 pa=1.4;pb=3.6;posa=(1/4);.....//Point a - the
    position 1/4 of the stroke

```

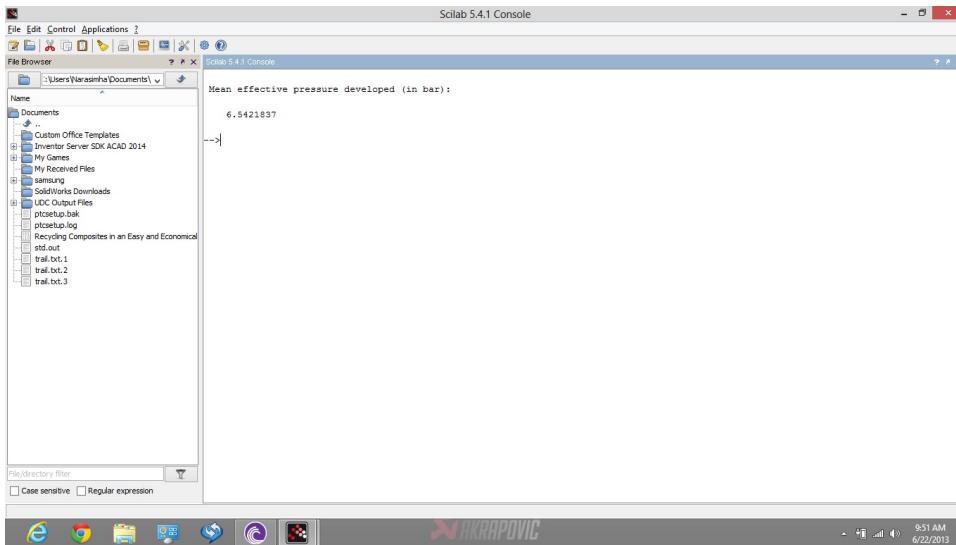


Figure 17.27: Mean effective pressure developed

```

5 posb=(3/4);.....//Point b - the position 3/4 of
   the stroke
6 ga=1.4;.....//Degree of freedom for gas
7 etarel=0.4;.....//Relative efficiency
8 C=18800;.....//Calorific value of
   fuel in kJ/m^3
9 //Calculations
10 r=1+(((pb/pa)^(1/n))-1)/(posb-((pb/pa)^(1/n))*( 
    posa)));.....//Compression ratio
11 disp(r,"The compression ratio :")
12 etast=1-(1/r^(ga-1));.....//Air standard
   efficiency
13 etath=etarel*etast;.....//Thermal efficiency
14 disp(etath*100,"Thermal efficiency (in %):")
15 v=1/(etath*C);.....//Gas consumption per
   IP sec
16 disp(v*3600,"Gas consumption (in m^3/IP hour):")

```

---

**Scilab code Exa 17.27** Mean effective pressure developed

```
1 clc;funcprot(0); //EXAMPLE 17.27
2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 r=5; ..... //Compression ratio
5 Vc=0.000115; ..... //Clearance volume of
    each cylinder in m^3
6 fc=10.5; ..... //Fuel consumed in kg/h
7 C=41800; ..... //Calorific value of
    fuel in kJ/kg
8 N=2500; ..... //Engine speed in rpm
9 er=0.65; ..... //Efficiency ratio
10 ga=1.4; ..... //Degree of freedom
11 //calculations
12 etast=1-(1/r^(ga-1)); .....
    //Air standard efficiency
13 etath=etast*er; .....
    // Thermal efficiency
14 IP=etath*(fc/3600)*C; .....
    // Indicated power in kW
15 Wnet=(IP*(10^3)*60)/(n*(N/2)); .....
    //Net work from one cycle per cylinder in N-m
16 Vs=(r-1)*Vc; .....
    //Swept volume in m^3
17 pm=Wnet/(Vs*10^5); .....
    //Mean effective pressure developed
18 disp(pm,"Mean effective pressure developed (in bar):"
")
```

---

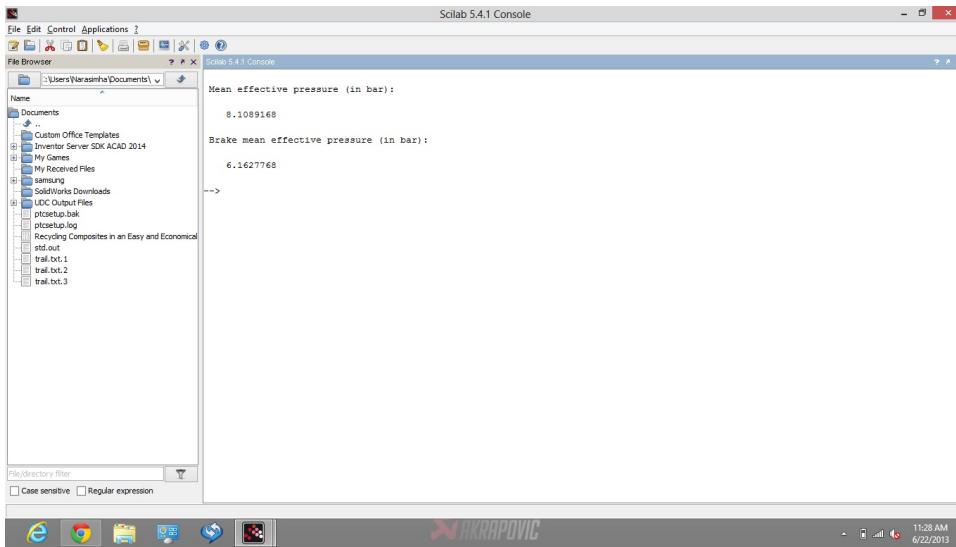


Figure 17.28: Indicated mean effective pressure and brake mean effective pressure

**Scilab code Exa 17.28** Indicated mean effective pressure and brake mean effective pressure

```

1 clc;funcprot(0); //EXAMPLE 17.28
2 // Initialisation of Variables
3 D=0.2;.....//Engine bore in m
4 L=0.25;.....//Engine stroke in m
5 n=2;.....//No of cylinders
6 r=13;.....//Compression ratio
7 fc=14;.....//Fuel consumption in kg/h
8 N=300;.....//Engine rpm
9 etarel=0.65;.....//Relative efficiency
10 etamech=0.76;.....//Mechanical efficiency
11 co=0.05;.....//Cut off of the stroke
12 C=41800;.....//Calorific value of
    fuel in kJ/kg
13 k=1;.....//Two stroke engine
14 ga=1.4;.....//Degree of freedom
15 //calculations

```

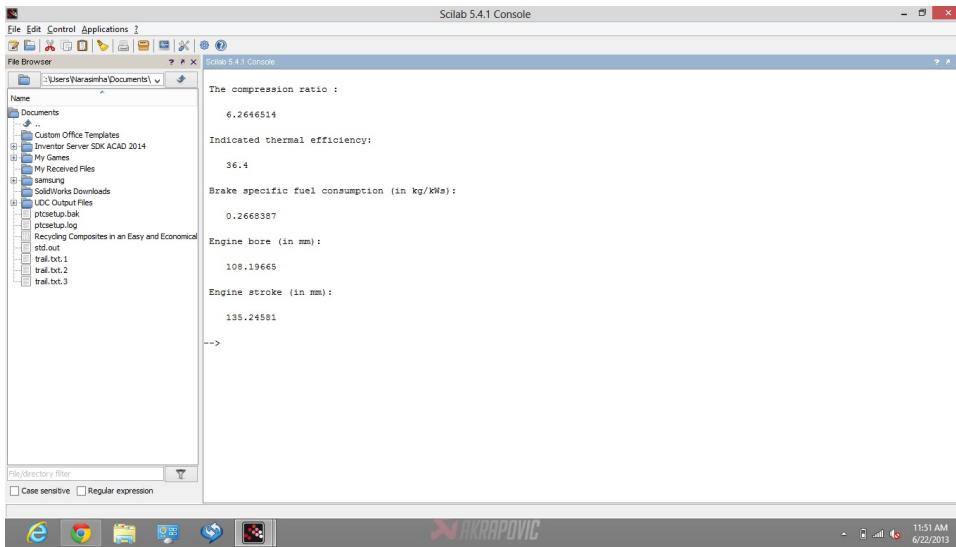


Figure 17.29: Finding all parameters of engine

```

16 rho=1+(co*(r-1));
17 etast=1-((1/(r^(ga-1)))*(1/ga)*((rho^ga)-1)*(1/(rho
-1)));.....//Air standard efficiency
18 etath=etarel*etast;.....//Thermal
    efficiency
19 IP=etath*(fc/3600)*C;.....// 
    Indicated power in kW
20 BP=etamech*IP;.....// 
    Brake power in kW
21 pmi=(6*IP)/(n*N*L*(%pi/4)*D*D*k*10);.....//
    mean effective pressure in bar
22 disp(pmi,"Mean effective pressure (in bar):")
23 pmb=pmi*etamech;.....//Brake
    mean effective pressure in bar
24 disp(pmb,"Brake mean effective pressure (in bar):")

```

---

### Scilab code Exa 17.29 Finding all parameters of engine

```
1 clc;funcprot(0); //EXAMPLE 17.29
2 // Initialisation of Variables
3 n=4;..... //No of cylinders
4 C=45200;..... // calorific value of fuel
    in kJ/kg
5 etamech=0.82;..... // Mechanical efficiency
6 etarel=0.7;..... // Relative efficiency
7 etast=0.52;..... // Air standard efficiency
8 etav=0.78;..... // Volumetric efficiency
9 sbr=1.25;..... // Stroke bore ratio
10 N=2400;..... // Engine rpm
11 p=1;..... // Suction pressure in bar
12 t=298;..... // Suction temperature in
    bar
13 BP=72;..... // Brake power in kW
14 ga=1.4;..... //Degree of freedom
15 afr=16;..... //Air fuel ratio
16 R=287;..... //Gas constant in J/kg
17 //calculations
18 r=(1/(1-etast))^(1/(ga-1));..... //Compression
    ratio
19 disp(r,"The compression ratio :")
20 etath=etast*etarel;..... // Indicated
    thermal efficiency
21 disp(etath*100," Indicated thermal efficiency:")
22 IP=BP/etamech;..... // Indicated power
    in kW
23 mf=IP/(etath*C);..... // Fuel
    consumption in kg/s
24 bsfc=mf/BP;..... // Brake specific
    fuel consumption in kg/kWs
25 disp(bsfc*3600,"Brake specific fuel consumption (in
    kg/kWs):")
26 mafm=afr+1;..... //Mass of air fuel
    mixture in kg/kg of fuel
27 mafm1=mafmaf ;..... //Mass of air fuel
```

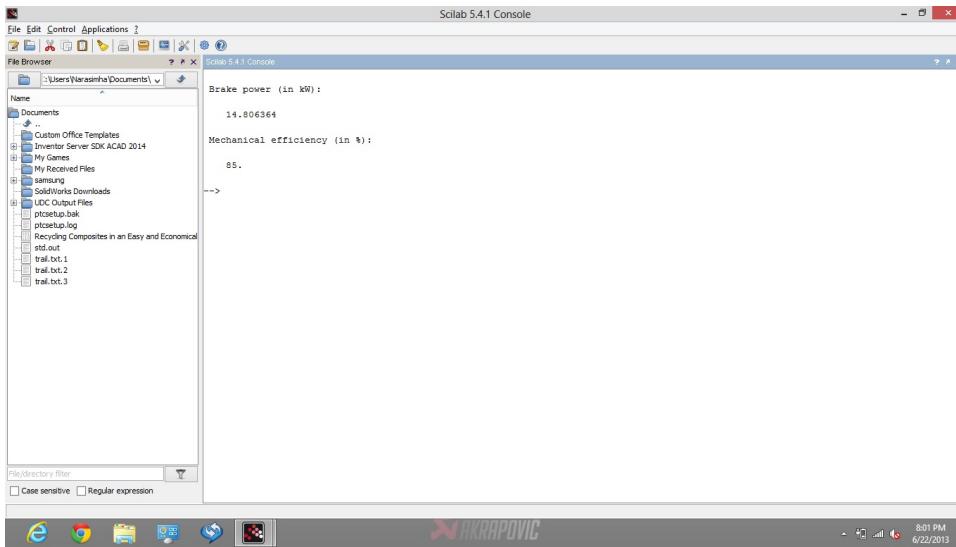


Figure 17.30: Full load brake power and mechanical efficiency

```

mixture when mf amount of fuel is supplied to
engine per second
28 v=(maf m1*R*t)/(p*10^5);.....///
Volume of air fuel mixture supplied to the engine
in m^3
29 Vs=v/etav;.....//Swept
volume in m^3
30 D=((Vs)/((pi/4)*sbr*n*(N/(2*60))))^(1/3)
;.....//Engine bore in m
31 disp(D*1000,"Engine bore (in mm):")
32 disp(D*1000*sbr,"Engine stroke (in mm):")

```

---

### Scilab code Exa 17.30 Full load brake power and mechanical efficiency

```

1 clc;funcprot(0); //EXAMPLE 17.30
2 // Initialisation of Variables

```

```

3 n=1;.....//No of cylinders
4 D=0.18;.....//Engine bore in m
5 L=0.34;.....//Engine stroke in m
6 N=400;.....//Engine rpm
7 mepw=6.4;.....//Mean effective pressure
    of working loop in bar
8 mepp=0.36;.....//Mean effective
    pressure of pumping loop in bar
9 mepd=0.64;.....//Mean effective pressure
    (dead cycle) iin bar
10 fs=46;.....//Firing strokes per min
11 //calculations
12 pminet=mepw-mepp;.....//Net indicated mean
    effective pressure in bar
13 dc=(N/2)-fs;.....//Dead cycles per min
14 IPnet=(n*pminet*(%pi/4)*L*D*D*fs*4*10)
    /6;.....//Net indicated power output in
    kW
15 ppdc=(n*pminet*L*(%pi/4)*D*D*10*dc)/6;.....
    //Pumping power of dead cycles in kW
16 FP=IPnet-ppdc;.....///
    Frictional power in kW
17 IP=(n*pminet*L*(%pi/4)*D*D*(N/2)*10)
    /6;.....//Indicated power in kW
18 BP=IP-FP;.....//Brake power in kW
19 disp(BP," Brake power (in kW):")
20 etamech=BP/IP;.....// Mechanical
    efficiency
21 disp(etamech*100," Mechanical efficiency (in %):")

```

---

**Scilab code Exa 17.31** Mechanical efficiency and brake thermal efficiency

```
1 clc;funcprot(0); //EXAMPLE 17.31
```

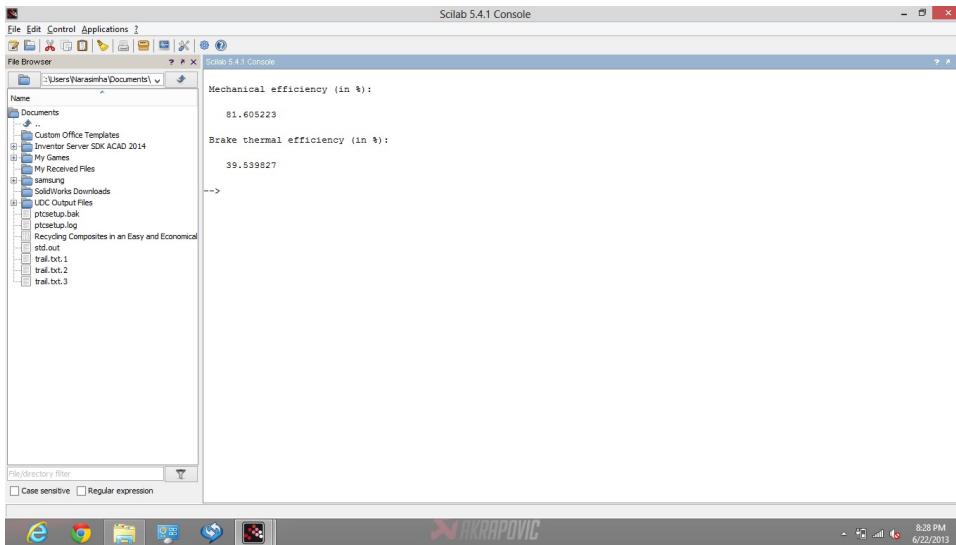


Figure 17.31: Mechanical efficiency and brake thermal efficiency

```

2 // Initialisation of Variables
3 n=1; ..... //No of cylinders
4 B=0.32; ..... //Engine bore in m
5 L=0.42; ..... //Engine stroke in m
6 N=200; ..... //Engine rpm
7 Nk=90; ..... //No of explosions per min
8 v1=11.68; ..... //Gas used in m^3/h
9 pg=170; ..... //Pressure of gas in mm of
    water
10 br=755; ..... //Barometer reading in mm of
    Hg
11 pmi=6.2; ..... //Mean effective pressure
    in bar
12 C=21600; ..... //Calorific value of
    gas in kJ/kg
13 bl=2040; ..... //Net load on brake in
    N
14 Db=1.2; ..... //Brake drum diameter
    in m
15 t1=298; ..... //Ambient temperature in
```

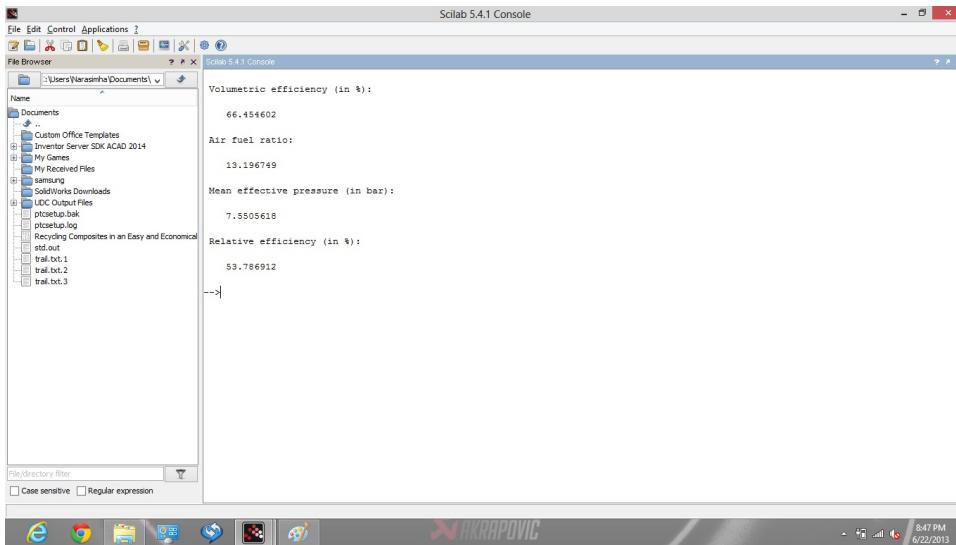


Figure 17.32: Finding all parameters of the engine

```

    Kelvin
16 // Calculations
17 IP=(n*pmb*L*(%pi/4)*B*B*Nk*10)
      /6; ..... // Indicated power in
      kW
18 BP=(bl*%pi*Db*N)/(60*1000); .....
      // Brake power in kW
19 etamech=(BP/IP); ..... // Mechanical
      efficiency
20 disp(etamech*100," Mechanical efficiency (in %):")
21 p1=br+(pg/13.6); ..... // In mm of Hg
22 p2=760; t2=273; ..... // NTP conditions in
      mm of Hg and Kelvin
23 v2=(p1*v1*t2)/(p2*t1);
24 etabth=BP/((v2/3600)*C); ..... // Brake
      thermal efficiency
25 disp(etabth*100," Brake thermal efficiency (in %):")

```

---

**Scilab code Exa 17.32** Finding all parameters of the engine

```
1 clc;funcprot(0); //EXAMPLE 17.32
2 // Initialisation of Variables
3 n=1;.....//No of cylinders
4 d=0.032;.....//Diameter of circular
   orifice in m
5 Cd=0.62;.....//Co efficient of discharge
6 hw=150;.....//Pressure across orifice in
   mm of water
7 t=20+273;.....//Temperature of air in the
   room in Kelvin
8 p=1.0132;.....//Ambient pressure in bar
9 pd=0.00178;.....//Piston displacement in m^3
10 R=287;.....//Gas constant in J/kg
11 r=6.5;.....//Compression ratio
12 fc=0.135;.....//Fuel consumption in kg/
   min
13 C=43900;.....//Calorific value of fuel
   in kJ/kg
14 BP=28;.....//Brake power in kW
15 N=2500;.....//Engine rpm
16 k=0.5;.....//Four stroke engine
17 g=9.81;.....//Acceleration due to
   gravity in m/s^2
18 rho_w=1000;.....//Density of water in
   kg/m^3
19 ga=1.4;.....//Degree of freedom
20 //calculations
21 mbyv=(p*10^5)/(R*t);
22 pw=(hw/rho_w)*rho_w;.....//Pressure
   across orifice in kg/m^2
23 H=pw/mbyv;.....//Head of air
   column causing the flow in m
```

```

24 ma=Cd*(%pi/4)*d*d*sqrt(2*g*H);.....//Air
    flow through orifice in m^3/s
25 maps=(ma*60)/(N/2);.....//Air
    consumption per stroke
26 etav=maps/pd;.....//Volumetric
    efficiency
27 disp(etav*100,"Volumetric efficiency (in %):")
28 ac=ma*60*mbyv;.....//Mass of air drawn
    into cylinder per min in kg
29 afr=ac/fc;.....//Air fuel ratio
30 disp(afr,"Air fuel ratio:")
31 pmb=(6*BP)/(n*pd*N*k*10);.....//Mean
    effective pressure in bar
32 disp(pmb,"Mean effective pressure (in bar):")
33 etast=1-(1/(r^(ga-1)));.....//Air standard
    efficiency
34 etabth=BP/((fc/60)*C);.....//Brake thermal
    efficiency
35 etarel=etabth/etast;.....//Relative
    efficiency
36 disp(etarel*100,"Relative efficiency (in %):")

```

---

**Scilab code Exa 17.33** Finding all parameters of the engine

```

1 clc;funcprot(0); //EXAMPLE 17.33
2 // Initialisation of Variables
3 N=400;.....//Engine rpm
4 n=1;.....//no of cylinders
5 W=370;.....//Load on the brake in N
6 S=50;.....//Spring balance readin in N
7 Db=1.2;.....//Diameter of the brake drum
8 mf=2.8;.....//Fuel consumption in kg/h
9 C=41800;.....//Calorific value of fuel

```

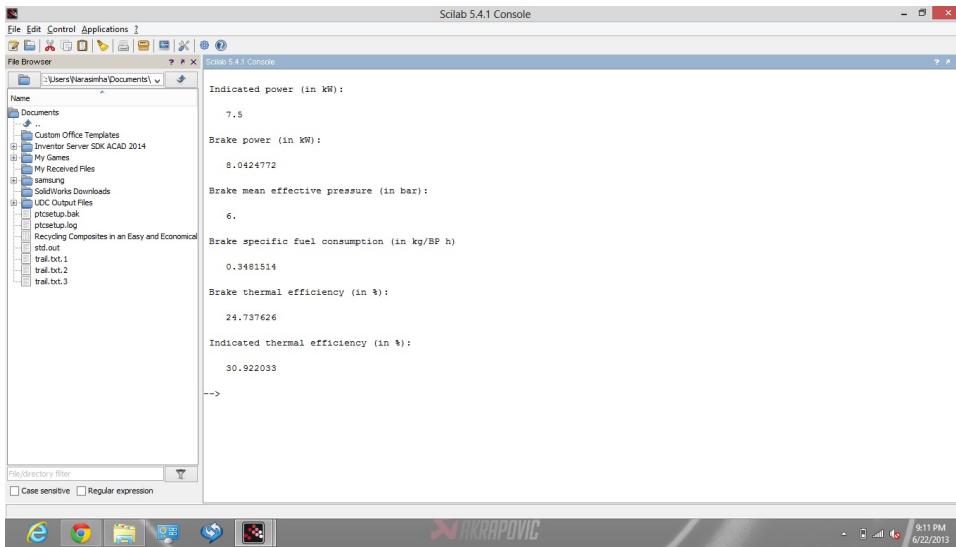


Figure 17.33: Finding all parameters of the engine

```

in kJ/kg
10 D=0.16;.....//Engine bore in m
11 L=0.2;.....//Engine stroke in m
12 k=0.5;.....//Four stroke engine
13 Sc=1;.....//Spring constant in bar/mm
14 l=40;.....//Length of diagram in mm
15 aic=300;.....//Area of indicator card in
                 mm^2
16 //Calculations
17 pmi=aic*(Sc/l);.....//Mean effective
                         pressure in bar
18 IP=(n*pmi*L*(%pi/4)*D*D*k*N*10)/6;.....// 
             Indicated power in kW
19 disp(pmi," Indicated power ( in kW) : ")
20 BP=((W-S)*%pi*Db*N)/(60*1000);.....// Brake
               power in kW
21 disp(BP," Brake power ( in kW) : ")
22 pmb=(BP*6)/(n*L*D*D*(%pi/4)*k*N*10);.....//
               Brake mean effective pressure in bar
23 disp(pmb," Brake mean effective pressure ( in bar) : ")

```



Figure 17.34: Indicated thermal efficiency and brake mean effective pressure

```

24 bsfc=mf/BP;.....//Brake specific fuel
    consumption in kg/BP h
25 disp(bsfc,"Brake specific fuel consumption (in kg/BP
    h)")
26 etabth=BP/((mf/3600)*C);.....//Brake
    thermal efficiency
27 disp(etabth*100,"Brake thermal efficiency (in %):")
28 etaith=IP/((mf/3600)*C);.....//  

    Indicated thermal efficiency
29 disp(etaith*100,"Indicated thermal efficiency (in %)
    :")

```

---

**Scilab code Exa 17.34** Indicated thermal efficiency and brake mean effective pressure

```
1 clc;funcprot(0); //EXAMPLE 17.34
```

```

2 // Initialisation of Variables
3 R=287;.....//Gas constant in J/kg K
4 n=4;.....//No of cylinders
5 D=0.0825;.....//Engine bore in m
6 L=0.13;.....//Engine stroke in m
7 BP=28;.....//Brake power in kW
8 N=1500;.....//Engine rpm
9 afrth=14.8;.....//theoretical air fuel
    ratio
10 C=45980;.....//Calorific value of fuel
    in kJ/kg
11 etamech=0.9;.....//Mechanical efficiency
12 ap=70;.....//Percentage of Volume of
    air in he cylinder
13 fr=20;.....//Percentage richness of the
    fuel
14 p1=1.0132;.....//Ambient pressure in bar
15 pc=762;.....//Pressure in the cylinder
    in mm of Hg
16 tc=273+15.5;.....//Temperature in the
    cylinder in Kelvin
17 k=0.5;.....//Four stroke engine
18 //Calculations
19 Vs=(%pi/4)*D*D*L;.....//Swept
    volume in m^3
20 va=(ap/100)*Vs;.....//Volume of air
    drawn in m^3
21 p=(pc/760)*p1;
22 m=(p*(10^5)*va)/(R*tc);.....//Mass of
    air per stroke per cylinder
23 tmau=m*(N/2)*n;.....//Theoretical mass
    of air used per minute in kg
24 tmfu=tmau/afrth;.....//Theoretical mass
    of fyel used per min in kg
25 mf=(tmfu/60)*((100+fr)/100);.....//Mass of
    fuel burnt per second in kg
26 IP=BP/etamech;.....//Indicated
    power in kW

```

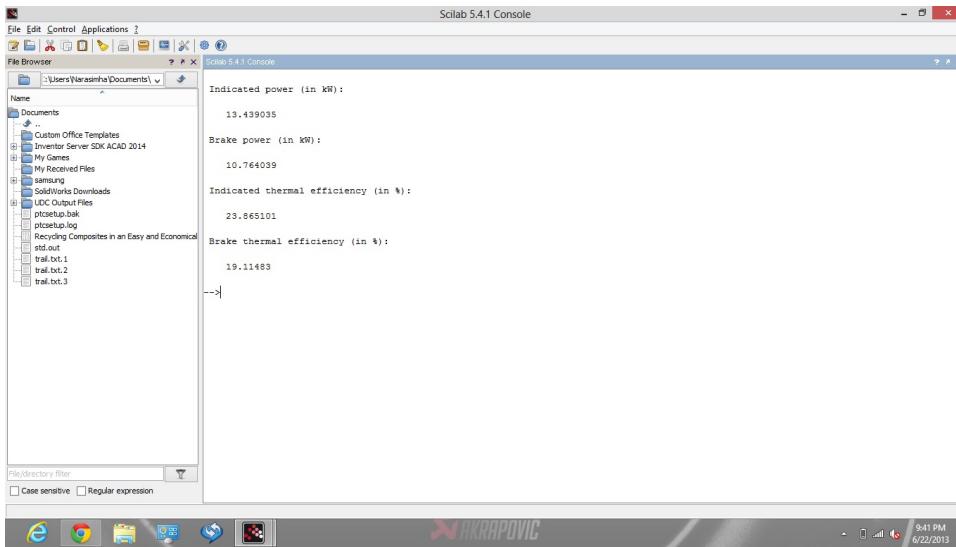


Figure 17.35: Finding all parameters of IC engine

```

27 etaith=IP/(mf*C);.....//Indicated
    thermal efficiency
28 disp(etaith*100," Indicated thermal efficiency (in %)
    :")
29 pmb=(BP*6)/(n*L*D*D*(%pi/4)*N*10*k);.....
    //Mean effective pressure in bar
30 disp(pmb," Mean effective pressure (in bar):")

```

---

### Scilab code Exa 17.35 Finding all parameters of IC engine

```

1 clc;funcprot(0); //EXAMPLE 17.35
2 // Initialisation of Variables
3 n=1;.....//No of cylinders
4 D=0.2;.....//Engine bore in m
5 L=0.4;.....//Engine stroke in m
6 Nt=9400;.....//Total no of revolutions

```

```

7 Ne=4200;.....//Total no of explosions
8 t=40;.....//Duration of testing in min
9 Nk=Ne/t;.....//No of explosions
10 bl=540;.....//Brake load in N
11 Db=1.6;.....//Diameter of brake wheel in
    m
12 d=0.02;.....//Diameter of rope in m
13 gu=8.5;.....//Gas used in m^3/sec
14 C=15900;.....//Calorific value of fuel in
    kJ/kg
15 Vg=(gu/(t*60));.....//Volume of gas used
    in m^3/sec
16 aic=550;.....//Area of indicator
    diagram mm^2
17 l=72;.....//Length of indicator
    diagram in mm
18 s=0.8;.....//Spring number in bar/mm
19 //calculations
20 pmi=(aic*s)/l;.....//Mean effective
    pressure in bar
21 IP=(n*pmi*L*D*D*(%pi/4)*Nk*10)/6;.....//
    Indicated power in kW
22 disp(IP," Indicated power (in kW) :")
23 BP=(bl*%pi*(Db+d)*(Nt/t))/(60*1000);.....
    //Brake power in kW
24 disp(BP," Brake power (in kW) :")
25 etaith=IP/(Vg*C);.....//Indicated thermal
    efficiency
26 disp(etaith*100," Indicated thermal efficiency (in %)
    :")
27 etabth=BP/(Vg*C);.....//Brake thermal
    efficiency
28 disp(etabth*100," Brake thermal efficiency (in %):")

```

---

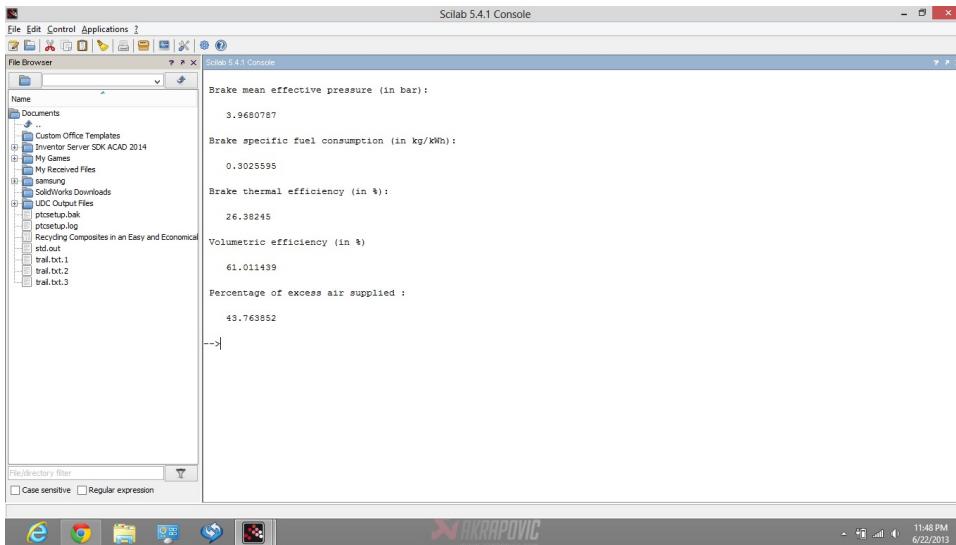


Figure 17.36: Finding all parameters of IC engine

### Scilab code Exa 17.36 Finding all parameters of IC engine

```

1 clc;funcprot(0); //EXAMPLE 17.36
2 // Initialisation of Variables
3 n=6;..... //No of cylinders
4 D=0.125;..... //Engine bore in m
5 L=0.125;..... //Engine stroke in m
6 N=2400;..... //Engine rpm
7 W=490;..... //Load on the dynamometer in N
8 CD=16100;..... //Dynamometer constant
9 d0=0.055;..... //Air orifice diameter
    in m
10 Cd=0.66;..... //Co efficient of
    discharge
11 hw=310;..... //Head causing flow through
    prifice in mm of water
12 br=760;..... //Barometer reading in mm of
    Hg
13 t=298;..... //Ambient temperature in
    Kelvin

```

```

14 fc=22.1;.....//Fuel consumption per
    hour in kg
15 C=45100;.....//Calorific value of fuel
    used in kJ/kg
16 perc=85;.....//Percentage of carbon in
    the fuel
17 perh=15;.....//Percentage of hydrogen
    in the fuel
18 p1=1.013;.....//Pressure of air at
    the end of suction stroke in bar
19 t1=298;.....//Temperature of air
    at the end of suction stroke in Kelvin
20 k=0.5;.....//Four stroke engine
21 R=287;.....//Gas constant in J/kgK
22 //calculations
23 BP=W*(N/CD);.....//Brake power in kW
24 pmb=(BP*6)/(L*D*D*k*10*N*n*(%pi/4));.....
    //Brake mean effective pressure in bar
25 disp(pmb," Brake mean effective pressure (in bar):")
26 bsfc=fc/BP;.....//Brake specific
    fuel consumption in kg/kWh
27 disp(bsfc," Brake specific fuel consumption (in kg/
    kWh):")
28 etathb=BP/((fc/3600)*C);.....//
    Brake thermal efficiency
29 disp(etathb*100," Brake thermal efficiency (in %):")
30 Vst=(%pi/4)*D*D*L;.....//Stroke volume in m
    ^3
31 Val=840*(%pi/4)*d0*d0*Cd*sqrt((hw/10)/((p1*10^5)/(R*
    t1)));.....//Volume of air passing through
    orifice of air box per min
32 Vac=Val/n;.....//Actual volume
    of air per cylinder in m^3/min
33 asps=Vac/(N/2);.....//Air supplied
    per stroke per cylinder in m^3
34 etav=asps/Vst;.....//Volumetric
    efficiency
35 disp(etav*100," Volumetric efficiency (in %)"))

```

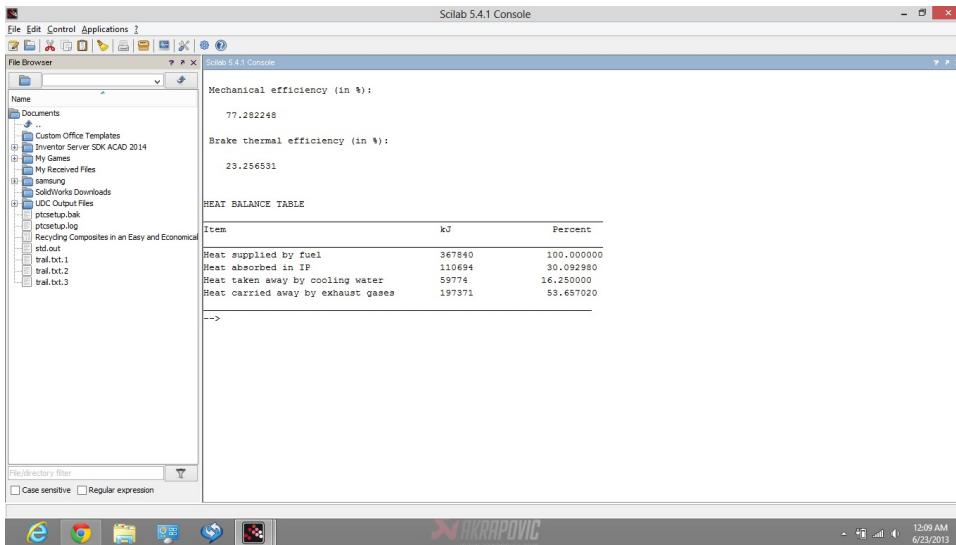


Figure 17.37: Heat balance sheet

```

36 Qa=(100/23)*(((perc/100)*(8/3))+((perh/100)*(8/1)))
;.....//Quantity of air required
     per kg of fuel combustion
37 aqas=Val*((p1*10^5)/(R*t1))*60/fc
;.....//Actual quantity of air
     supplied per kg of fuel
38 pe=(aqas-Qa)/Qa;.....//Fraction of
     excess air supplied to engine
39 disp(pe*100,"Percentage of excess air supplied :")

```

---

### Scilab code Exa 17.37 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.37
2 // Initialisation of Variables
3 n=1;.....//No of cylinders
4 D=0.3;.....//Engine bore in m

```

```

5 L=0.45;.....//Engine stroke in m
6 mf=8.8;.....//Fuel consumption in kg/h
7 C=41800;.....//Calorific value of fuel
    in kJ/kg
8 N=200;.....//Engine rpm
9 pmi=5.8;.....//Mean effective
    pressure in bar
10 bl=1860;.....//Brake load in N
11 Db=1.22;.....//Diameter of brake drum
    in m
12 k=0.5;.....//four stroke engine
13 mw=650;.....//Mass of cooling water
    in kg
14 cpw=4.18;.....//Specific heat
    capacity of water
15 delt=22;.....//Temperature rise
16 //Calculations
17 IP=(n*L*D*D*k*10*pmi*N*(%pi/4))/6;.....//Indicated power in kW
18 BP=(bl*%pi*Db*N)/(60*1000);.....//Brake
    power in kW
19 etamech=BP/IP;.....//Mechanical efficiency
20 disp(etamech*100," Mechanical efficiency (in %):")
21 etathb=BP/((mf/3600)*C);.....//Brake
    thermal efficiency
22 disp(etathb*100," Brake thermal efficiency (in %):")
23 //Heat supplied
24 hip=IP*3600;.....//Heat equivalent of IP in kJ
    /h
25 hcw=mw*cpw*delt;.....//Heat carried away by
    cooling water
26 hf=mf*C;.....//heat supplied by fuel
27 hex=hf-hip-hcw;.....//Heat carried by exhaust
    gasses
28 pf=100; pip=(hip/hf)*100; pcw=(hcw/hf)*100; pex=(hex/hf
    )*100
29 printf("\n\n")
30 printf("HEAT BALANCE\n")

```

```

31 printf("-----\n")
32 printf(" Item Percent\n") kJ
33 printf("-----\n")
34 printf("Heat supplied by fuel %d
          %f\n", hf, pf)
35 printf("Heat absorbed in IP %d
          %f\n", hip, pip)
36 printf("Heat taken away by cooling water %d
          %f\n", hcw, pcw)
37 printf("Heat carried away by exhaust gases %d
          %f\n", hex, pex)
38 printf("-----\n")

```

---

### Scilab code Exa 17.38 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.38
2 // Initialisation of Variables
3 r=15; ..... //Compression ratio
4 n=1; ..... //No of cylinders
5 mf=10.2; ..... //Fuel consumption in kg/h
6 C=43890; ..... //Calorific value of fuel
      in kJ/kg
7 ma=3.8; ..... //Consumption of air in kg/
      min
8 N=1900; ..... //Engine rpm
9 T=186; ..... //Torque on brake drum in

```

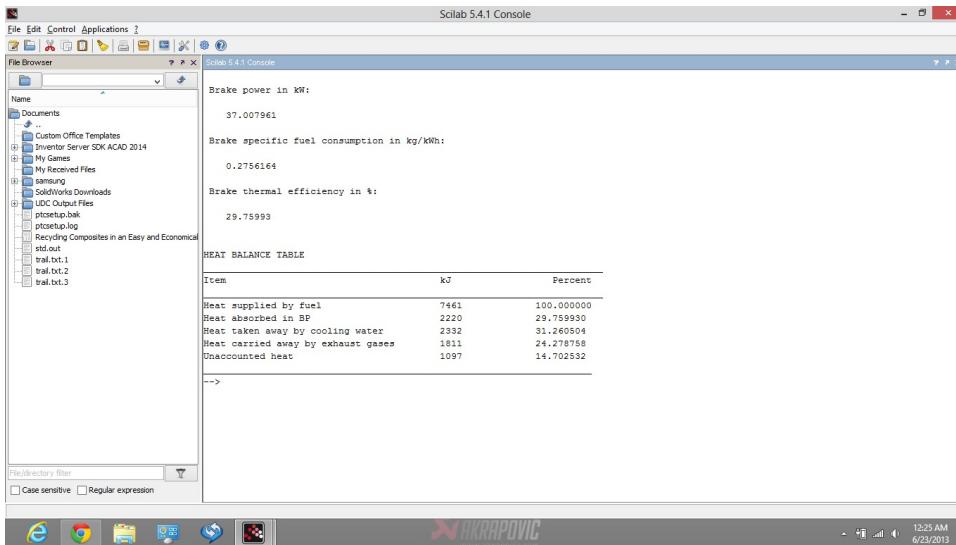


Figure 17.38: Heat balance sheet

Nm

```

10 mw=15.5;.....//Mass of cooling water
    used in kg/min
11 delt=36;.....//temperature rise
12 tg=410;.....//Exhaust gas temperature
    in Celsius
13 tr=20;.....//Room temperature in
    Celsius
14 cp=1.17;.....// Specific heat capacity
    for exhaust gases kJ/kgK
15 cpw=4.18;.....// Specific heat capacity
    for water in kJ/kgK
16 //calculations
17 BP=(2*pi*N*T)/(60*1000);.....//Brake
    power in kW
18 disp(BP,"Brake power in kW:")
19 bsfc=mf/BP;.....//Brake
    specific fuel consumption in kg/kWh
20 disp(bsfc,"Brake specific fuel consumption in kg/kWh
    :")

```

```

21 etabth=BP/((mf/3600)*C);.....//Brake
    thermal efficiency
22 disp(etabth*100," Brake thermal efficiency in %:")
23 //Heat supplied
24 mg=(mf/60)+ma;.....//Mass of exhaust
    gases in kg/min
25 hbp=BP*60;.....//Heat equivalent of BP in kJ/
    min
26 hcw=mw*cpw*delt;.....//Heat carried away by
    cooling water
27 hf=(mf/60)*C;.....//heat supplied by fuel
28 hex=mg*cp*(tg-tr);.....//Heat carried by
    exhaust gasses
29 ha=round(hf)-round(hbp+hex+hcw);.....//  

    Unaccounted heat
30 pf=100;pbp=(hbp/hf)*100;pcw=(hcw/hf)*100;pex=(hex/hf
    )*100;pa=(ha/hf)*100;
31 printf("\n\n")
32 printf("HEAT BALANCE TABLE\n")
33 printf("-----\n")
34 printf(" Item           Percent\n")                                kJ
35 printf("-----\n")
36 printf(" Heat supplied by fuel          %d\n",hf,PF)            %d
37 printf(" Heat absorbed in BP          %d\n",hbp,PBP)            %d
38 printf(" Heat taken away by cooling water      %d\n",hcw,PCW)        %d
39 printf(" Heat carried away by exhaust gases    %d\n",hex,PEX)        %d
40 printf(" Unaccounted heat          %d\n",ha,PA)                %d
41 printf("-----\n")

```

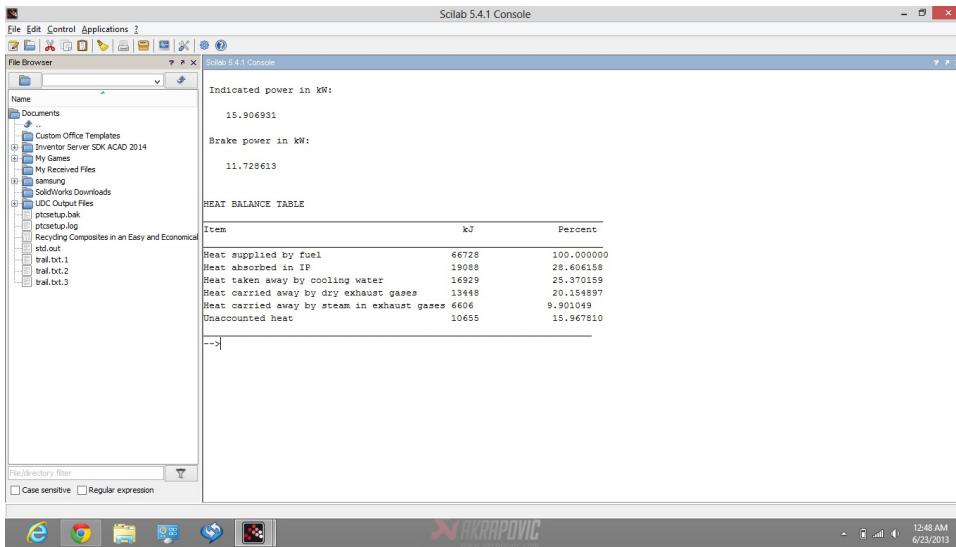


Figure 17.39: heat balance sheet

### Scilab code Exa 17.39 heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.39
2 // Initialisation of Variables
3 CpW=4.18;.....//Specific heat of water in
   kJ/kgK
4 n=1;.....//No of cylinders
5 N=350;.....//Engine rpm
6 pmi=3.1;.....//Mean effective pressure in bar
7 bl=640;.....//Brake load in N
8 mf=1.52;.....//Fuel consumption in kg
9 mw=162;.....//Mass of cooling water
10 tw1=30;.....//Water inlet temperature in C

```

```

11 tw2=55;.....//Water outlet temperature in
   C
12 ma=32;.....//Mass of air used per kg of
   fuel in kg
13 tr=25;.....//Room temperature in C
14 tg=305;.....//Exhaust temperature in C
15 D=0.2;.....//Engine bore in m
16 L=0.28;.....//Engine stroke in m
17 Db=1;.....//Brake drum diameter in
   m
18 ms=1.4;.....//Mass of steam formed
   per kg of fuel exhaust in kg
19 C=43900;.....//Calorific value of
   fuel in kJ/kg
20 Cps=2.09;.....//Specific heat of steam
   in exhaust in kJ/kgK
21 Cpg=1.0;.....//Specific heat of dry
   exhaust gases in kJ/kgK
22 k=1;.....//Two stroke engine
23 t=20;.....//Duration of testing in
   min
24 //Calculations
25 IP=(n*pri*N*D*D*L*k*10*(%pi/4))
   /6;.....//Indicated power in kW
26 disp(IP," Indicated power in kW:")
27 BP=(bl*%pi*Db*N)/(60*1000);.....//
   Brake power in kW
28 disp(BP," Brake power in kW:")
29 //Heat supplied
30 hf=mf*C;.....//heat supplied by fuel
31 hip=IP*60*t;.....//Heat equivalent of BP in kJ
   /min
32 hcw=mw*Cpw*(tw2-tw1);.....//Heat carried away
   by cooling water
33 mg=mf+(ma*mf);.....//Mass of exhaust
   gases in kg/min
34 mst=mf*ms;.....//Mass of steam formed
35 hg=(mg-mst)*Cpg*(tg-tr);.....//Heat carried by

```

```

        exhaust gasses
36 hst=mst*(417.5+2257.9+(Cps*(305-99.6)))
    ; ..... //Heat carried by exhaust
    steam, the obtained values are from steam table
    and hence are constants at NTP
37 ha=round(hf)-round(hip+hg+hst+hcw);.....// 
    Unaccounted heat
38 pf=100; pip=(hip/hf)*100; pcw=(hcw/hf)*100; pg=(hg/hf)
    *100; pa=(ha/hf)*100; pst=(hst/hf)*100;
39 printf("\n\n")
40 printf("HEAT BALANCE TABLE\n")
41 printf("-----\n")
42 printf("Item
                kJ
                Percent\n")
43 printf("-----\n")
44 printf("Heat supplied by fuel
            %d          %f\n",hf,pf)
45 printf("Heat absorbed in IP
            %d          %f\n",hip,pip)
46 printf("Heat taken away by cooling water
            %d          %f\n",hcw,pcw)
47 printf("Heat carried away by dry exhaust gases
            %d          %f\n",hg,pg)
48 printf("Heat carried away by steam in exhaust gases
            %d          %f\n",hst,pst)
49 printf("Unaccounted heat
            %d          %f\n",ha,pa)
50 printf("-----\n")

```

---



Figure 17.40: Finding the parameters for IC engine

### Scilab code Exa 17.40 Finding the parameters for IC engine

```

1 clc;funcprot(0); //EXAMPLE 17.40
2 // Initialisation of Variables
3 n=6; ..... //No of cylinders
4 D=0.1; ..... //Engine bore in m
5 L=0.14; ..... //Engine stroke in m
6 N=2500; ..... //Engine rpm
7 k=0.5; ..... //Four stroke
8 bl=480; ..... //Brake load in N
9 br=76; ..... //Barometer reading in cm of
               Hg
10 d0=3.3/100; ..... //Orifice diameter in m
11 Cd=0.62; ..... //Co efficient of discharge
                  of orifice

```

```

12 pd=14;.....// Pressure drop across
   orifice in cm of Hg
13 tr=25;.....//Room temperature in C
14 mf=0.32;.....//Fuel consumption in kg/min
15 rhohg=13600;.....//Density of Hg in kg/m
   ^3
16 R=0.287;.....//gas constant in kJ/kgK
17 g=9.81;.....//Acceleration due to
   gravity in m/s^2
18 CD=17000;.....//dynamometer constant
19 //Calculations
20 Vs=(%pi/4)*D*D*L*(N/2)*(n/60);.....//Swept
   volume in m^3
21 br1=(br/100)*rhohg*g*(10^-3);.....//
   Barometer reading into kN/m^2
22 rhoa=br1/(R*(tr+273));.....//Density of
   air
23 pd1=(pd/100)*rhohg*g;.....//
   Conversion of pd into N/m^2
24 ha=pd1/(rhoa*g);.....//Head of air
   causing flow in m
25 Va=Cd*(%pi/4)*d0*d0*sqrt(2*g*ha);.....//
   Volume of air passing through orifice of air box
   per min
26 etav=Va/Vs;.....//Volumetric
   efficiency
27 disp(etav*100," Volumetric efficiency in %:")
28 BP=bl*(N/CD);.....//Brake power in kW
29 pmb=(BP*6)/(L*D*D*k*10*N*n*(%pi/4));.....
   //Brake mean effective pressure in bar
30 disp(pmb," Brake mean effective pressure (in bar):")
31 T=(BP*60*1000)/(2*%pi*N);.....//
   Engine torque in N-m
32 disp(T," Engine torque in N-m:")
33 bsfc=(mf*60)/BP;.....//Brake
   specific fuel consumption in kg/kWh
34 disp(bsfc," Brake specific fuel consumption in kg/kWh
   :")

```

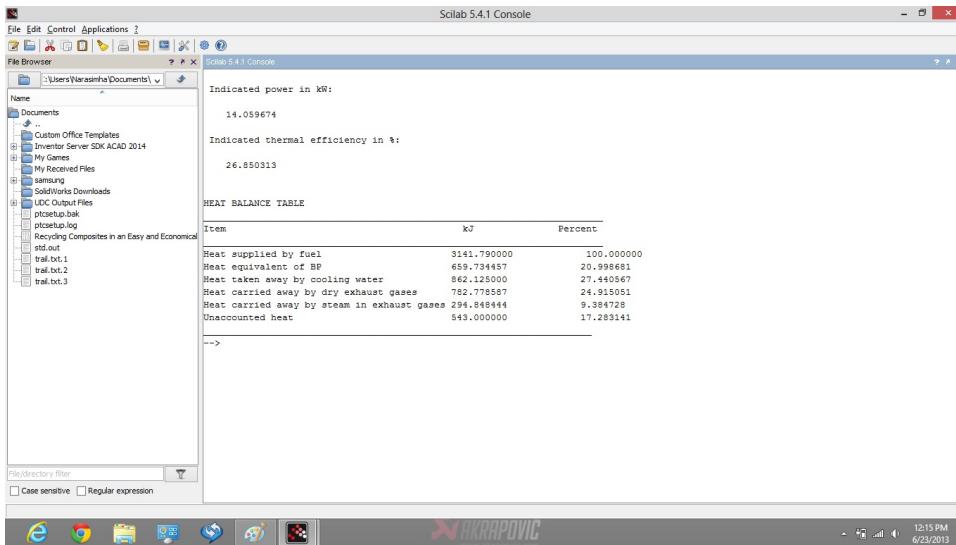


Figure 17.41: Heat balance sheet

### Scilab code Exa 17.41 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.41
2 // Initialisation of Variables
3 Cpw=4.18;.....//Specific heat of water in
   kJ/kgK
4 n=1;.....//No of cylinders
5 N=350;.....//Engine rpm
6 pmi=2.74;.....//Mean effective pressure in bar
7 bl=600;.....//Brake load in N
8 mf=4.22;.....//Fuel consumption in kg
9 mw=495;.....//Mass of cooling water
10 tw1=13;.....//Water inlet temperature in C
11 tw2=38;.....//Water outlet temperature in
   C

```

```

12 ma=135;..... //Mass of air used in kg/h
13 tr=20;..... //Room temperature in C
14 tg=370;..... //Exhaust temperature in C
15 D=0.2;..... //Engine bore in m
16 L=0.28;..... //Engine stroke in m
17 Db=1;..... //Brake drum diameter in
   m
18 C=44670;..... //Calorific value of
   fuel in kJ/kg
19 Cps=2.093;..... //Specific heat of
   steamm in exhaust in kJ/kgK
20 Cpg=1.005;..... //Specific heat of dry
   exhaust gases in kJ/kgK
21 k=1;..... //Two stroke engine
22 t=60;..... //Duration of testing in
   min
23 perh=15;..... //Percentage of H2 in the
   fuel
24 //Calculations
25 IP=(n*pni*N*D*D*L*k*10*(%pi/4))
   /6;..... //Indicated power in kW
26 disp(IP," Indicated power in kW:")
27 BP=(bl*%pi*Db*N)/(60*1000);..... //
   Brake power in kW
28 etaith=(IP)/((mf/3600)*C);..... //
   Indicated thermal efficiency
29 disp(etaith*100," Indicated thermal efficiency in %:")
30 //Heat supplied
31 hf=(mf/t)*C;..... //heat supplied by fuel
32 hbp=BP*t;..... //Heat equivalent of BP in kJ/
   min
33 hcw=(mw/60)*Cpw*(tw2-tw1);..... //Heat carried
   away by cooling water
34 mg=(mf+ma)/t;..... //Mass of exhaust
   gases in kg/min
35 mst=9*(perh/100)*(mf/60);..... //Mass of
   steam formed

```

```

36 mdg=mg-mst;.....//Mass of
    dry exhaust gases per min
37 hg=(mdg)*Cpg*(tg-tr);.....//Heat carried by
    exhaust gasses
38 hst=mst*(417.5+2257.9+(Cps*(305-99.6)))
    ;.....//Heat carried by exhaust
    steam, the obtained values are from steam table
    and hence are constants at NTP
39 ha=round(hf)-round(hbp+hg+hst+hcw);.....//  

    Unaccounted heat
40 pf=100;pbp=(hbp/hf)*100;pcw=(hcw/hf)*100;pg=(hg/hf)
    *100;pa=(ha/hf)*100;pst=(hst/hf)*100;
41 printf("\n\n")
42 printf("HEAT BALANCE TABLE\n")
43 printf("-----\n")
44 printf("Item
                kJ
                Percent\n")
45 printf("-----\n")
46 printf("Heat supplied by fuel
            %f          %f\n",hf,pf)
47 printf("Heat equivalent of BP
            %f          %f\n",hbp,pbp)
48 printf("Heat taken away by cooling water
            %f          %f\n",hcw,pcw)
49 printf("Heat carried away by dry exhaust gases
            %f          %f\n",hg,pg)
50 printf("Heat carried away by steam in exhaust gases
            %f          %f\n",hst,pst)
51 printf("Unaccounted heat
            %f          %f\n",ha,pa)
52 printf("-----\n")

```

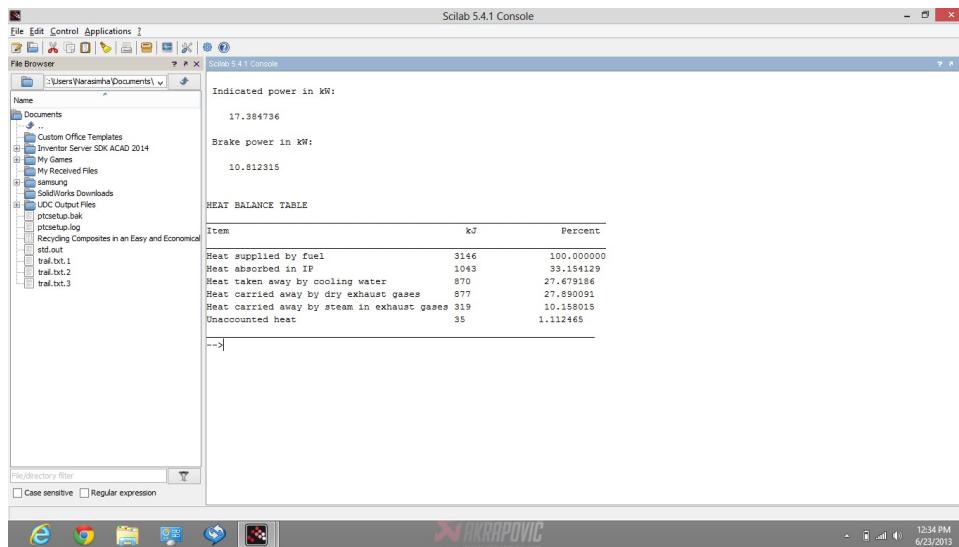


Figure 17.42: Heat balance sheet

### Scilab code Exa 17.42 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.42
2 // Initialisation of Variables
3 Cpw=4.18;.....//Specific heat of water in
   kJ/kgK
4 n=1;.....//No of cylinders
5 N=350;.....//Engine rpm
6 pmi=2.8;.....//Mean effective pressure in bar
7 bl=590;.....//Brake load in N
8 mf=4.3;.....//Fuel consumption in kg
9 mw=500;.....//Mass of cooling water
10 tw1=25;.....//Water inlet temperature in C
11 tw2=50;.....//Water outlet temperature in
   C

```

```

12 ma=33;.....//Mass of air used per kg of
   fuel in kg
13 tr=25;.....//Room temperature in C
14 tg=400;.....//Exhaust temperature in C
15 D=0.22;.....//Engine bore in m
16 L=0.28;.....//Engine stroke in m
17 Db=1;.....//Brake drum diameter in
   m
18 C=43900;.....//Calorific value of
   fuel in kJ/kg
19 Cps=2.09;.....//Specific heat of steam
   in exhaust in kJ/kgK
20 Cpg=1.0;.....//Specific heat of dry
   exhaust gases in kJ/kgK
21 k=1;.....//Two stroke engine
22 perh=15;.....//Percentage of hydrogen
23 //Calculations
24 IP=(n*pri*N*D*D*L*k*10*(%pi/4))
   /6;.....//Indicated power in kW
25 disp(IP," Indicated power in kW:")
26 BP=(bl*%pi*Db*N)/(60*1000);.....//
   Brake power in kW
27 disp(BP," Brake power in kW:")
28 //Heat supplied
29 hf=(mf/60)*C;.....//heat supplied by fuel
30 hip=IP*60;.....//Heat equivalent of BP in kJ/
   min
31 hcw=(mw/60)*Cpw*(tw2-tw1);.....//Heat carried
   away by cooling water
32 mg=(mf+(mf*ma))/60;.....//Mass of
   exhaust gases in kg/min
33 mst=9*(perh/100)*(mf/60);.....//Mass of
   steam formed
34 mdg=mg-mst;.....//Mass of
   dry exhaust gases per min
35 hg=(mdg)*Cpg*(tg-tr);.....//Heat carried by
   exhaust gasses
36 hst=mst*(417.5+2257.9+(Cps*(400-99.6)))

```

```

;.....//Heat carried by exhaust
steam, the obtained values are from steam tables
at NTP
37 mg=mf+(ma*mf);.....//Mass of exhaust
gases in kg/min
38 ha=round(hf)-round(hip+hg+hst+hcw);.....//  

Unaccounted heat
39 pf=100; pip=(hip/hf)*100; pcw=(hcw/hf)*100; pg=(hg/hf)
*100; pa=(ha/hf)*100; pst=(hst/hf)*100;
40 printf("\n\n")
41 printf("HEAT BALANCE TABLE\n")
42 printf("-----\n")
43 printf("Item
          kB
          Percent\n")
44 printf("-----\n")
45 printf("Heat supplied by fuel
          %d          %f\n",hf,pf)
46 printf("Heat absorbed in IP
          %d          %f\n",hip,pip)
47 printf("Heat taken away by cooling water
          %d          %f\n",hcw,pcw)
48 printf("Heat carried away by dry exhaust gases
          %d          %f\n",hg,pg)
49 printf("Heat carried away by steam in exhaust gases
          %d          %f\n",hst,pst)
50 printf("Unaccounted heat
          %d          %f\n",ha,pa)
51 printf("-----\n")

```

---

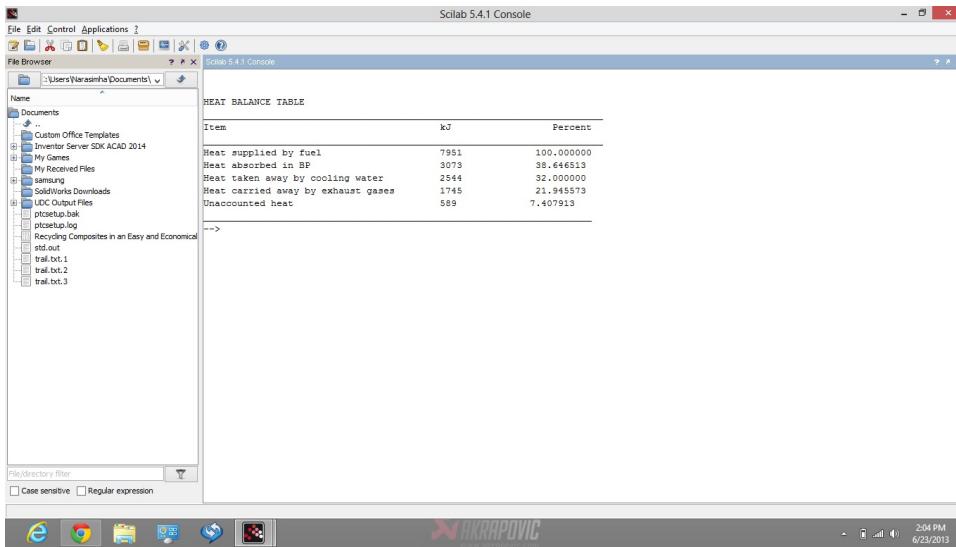


Figure 17.43: Heat balance sheet

### Scilab code Exa 17.43 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.43
2 // Initialisation of Variables
3 I=210;.....//Output of generator in
A
4 V=200;.....//Generator voltage in V
5 etag=0.82;.....//Generator efficiency
6 mf=11.2;.....//Fuel used in kg/h
7 C=42600;.....//Calorific value of
fuel in kJ/kg
8 afr=18;.....//Air fuel ratio
9 mc=580;.....//Mass of water through
calorimeter in kg/h
10 delt=36;.....//Temperature raise in C

```

```

11 tg=98;.....//Temperature of
   exhaust in C
12 ta=20;.....//Ambient temperature
   in C
13 phcw=0.32;.....//Heat lost to
   cooling jacket is 32% of heat supplied
14 cpe=1.05;.....//Specific heat of
   exhaust gases in kJ/kgK
15 cpw=4.18;.....//Specific heat of water
   in kJ/kgK
16 //Calculations
17 pow=V*I;.....//Total power
   generated in W
18 BP=(pow/1000)/etag;.....//Brake power
   in kW
19 hf=(mf/60)*C;.....//Heat supplied to
   the engine
20 hbp=BP*60;.....//Heat equivalent
   of BP
21 mg=(mf/60)*(afr+1);.....//Mass of exhaust
   gases formed per min in kg
22 hg=((mc/60)*cpw*(delt))+(mg*cpe*(tg-ta));.....
   //Heat carried by exhaust gases per min
23 hcw=phcw*hf;.....//Heat lost to
   cooling jacket
24 ha=hf-(hcw+hg+hbp);.....//Unaccounted
   heat
25 pf=100;pbp=(hbp/hf)*100;pcw=(hcw/hf)*100;pg=(hg/hf)
   *100;pa=(ha/hf)*100
26 printf("\n\n")
27 printf("HEAT BALANCE TABLE\n")
28 printf(
   -----
   \n")
29 printf(" Item           kJ
   Percent\n")
30 printf(
   -----

```

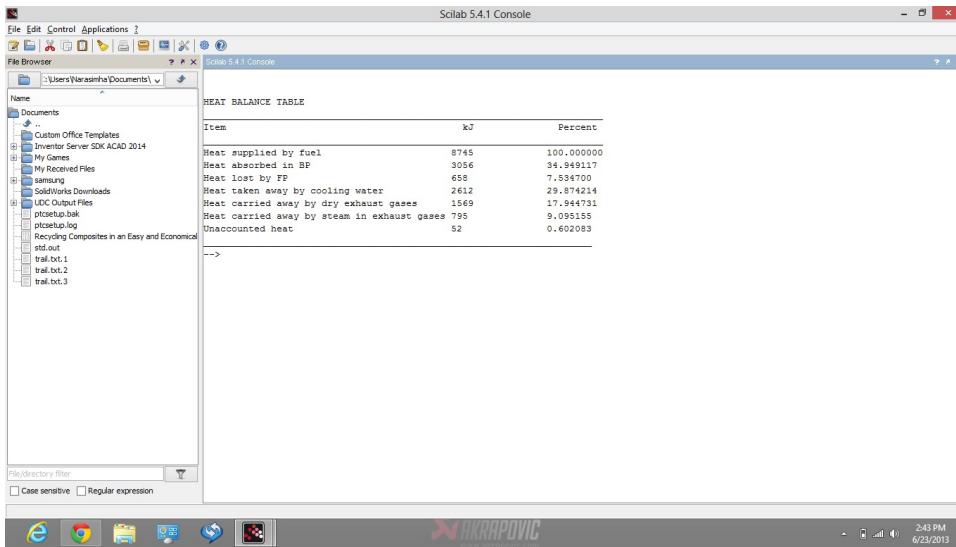


Figure 17.44: Heat balance sheet

```

    \n")
31 printf("Heat supplied by fuel %d
            %f\n",hf,pf)
32 printf("Heat absorbed in BP %d
            %f\n",hbp,pbp)
33 printf("Heat taken away by cooling water %d
            %f\n",hcw,pcw)
34 printf("Heat carried away by exhaust gases %d
            %f\n",hg,pg)
35 printf("Unaccounted heat %d
            %f\n",ha,pa)
36 printf("-----\n")

```

### Scilab code Exa 17.44 Heat balance sheet

```

1 clc;funcprot(0); //EXAMPLE 17.44
2 // Initialisation of Variables
3 D=0.34;.....//Engine bore in m
4 k=0.5;.....//Four stroke engine
5 n=1;.....//No of cylinders
6 L=0.44;.....//Engine stroke in m
7 Ne=400;.....//Engine rpm
8 aic=465;.....//Area of indicator diagram in
     mm^2
9 l=60;.....//Length of diagram in mm
10 s=0.6;.....//Spring constant in bar/mm
11 W=950;.....//Load of dynamometer in N
12 CD=7460;.....//Dynamometer constant
13 mf=10.6;.....//Fuel used in kg/h
14 Ca=49500;.....//Calorific value of fuel
     in kJ/kg
15 mw=25;.....//Cooling water circulated
     in kg/min
16 cpw=4.18;.....//Specific heat capacity
     of water in kJ/kgC
17 delt=25;.....//Rise in temperature of
     water
18 //Mass analysis of fuel
19 C=84;.....//Percentage of carbon
20 H=15;.....//Percentage of hydrogen
21 In=1;.....//Percentage of incombustible
22 //Volume analysis of exhaust gases
23 CO2=9;.....//Percentage of carbon
     dioxide
24 O=10;.....//Percentage of oxygen
25 N=81;.....//Percentage of nitrogen
26 tg=400;.....//Temperature of exhaust
     gases in C
27 cpg=1.05;.....//Specific heat of exhaust
     gases in kJ/kgC
28 tr=25;.....//Temperature of room in C
29 ppst=0.03;.....//Partial pressure of steam
     in exhaust gases in bar

```

```

30 cpst=2.1;.....// Specific heat of
superheated steam in kJ/kgC
31 //Calculations
32 pmi=(aic*s)/l;.....//Mean effective
pressure in bar
33 IP=(n*pmi*L*D*D*k*10*Ne*(%pi/4))/6;.....//
Indicated power in kW
34 BP=(W*Ne)/CD;.....//Brake power in
kW
35 FP=IP-BP;.....//Frictional
power in kW
36 hf=(mf/60)*Ca;.....//Heat supplied in
kJ per min
37 hbp=BP*60;.....//Heat equivalent of
Brake power in kW
38 hfp=FP*60;.....//heat equivalent of
frictional power in kW
39 hcw=mw*cpw*delt;.....//Heat carried
away by cooling water
40 ma1=(N*C)/(33*(C02));.....//Mass of air
supplied per kg of fuel
41 mg1=ma1+1;.....//Mass of exhaust
gases per kg of fuel
42 mg=mg1*(mf/60);.....//Mass of exhaust
gas formed per min
43 mst1=9*(H/100);.....//Mass of steam
formed per kg of fuel
44 mst=mst1*(mf/60);.....//Mass of steam
formed per min
45 mdg=mg-mst;.....//Mass of dry
exhaust gas
46 hex=mdg*cpg*(tg-tr);.....//Heat carried by
exhaust gases
47 hst=(2545.5+(cpst*(tg-24.1)))*mst;.....//
Heat carried by steam in exhaust gases in kJ/kg
.....The values are from steam tables
corresponding to the partial pressure 0.03 and
temperature 400 Celsius

```

```

48 ha=hf-(hbp+hfp+hcw+hex+hst);.....//  

     Unaccounted heat  

49 pf=100;pbp=(hbp/hf)*100;pfp=(hfp/hf)*100;pcw=(hcw/hf)  

     *100;pex=(hex/hf)*100;pa=(ha/hf)*100;pst=(hst/hf)  

     *100;  

50 printf("\n\n")  

51 printf("HEAT BALANCE TABLE\n")  

52 printf(  

     -----  

     \n")  

53 printf("Item  

          kJ  

          Percent\n")  

54 printf(  

     -----  

     \n")  

55 printf("Heat supplied by fuel  

     %d           %f\n",hf,pf)  

56 printf("Heat absorbed in BP  

     %d           %f\n",hbp,pbp)  

57 printf("Heat lost by FP  

     %d           %f\n",hfp,pfp)  

58 printf("Heat taken away by cooling water  

     %d           %f\n",hcw,pcw)  

59 printf("Heat carried away by dry exhaust gases  

     %d           %f\n",hex,pex)  

60 printf("Heat carried away by steam in exhaust gases  

     %d           %f\n",hst,pst)  

61 printf("Unaccounted heat  

     %d           %f\n",ha,pa)  

62 printf(  

     -----  

     ")

```

---

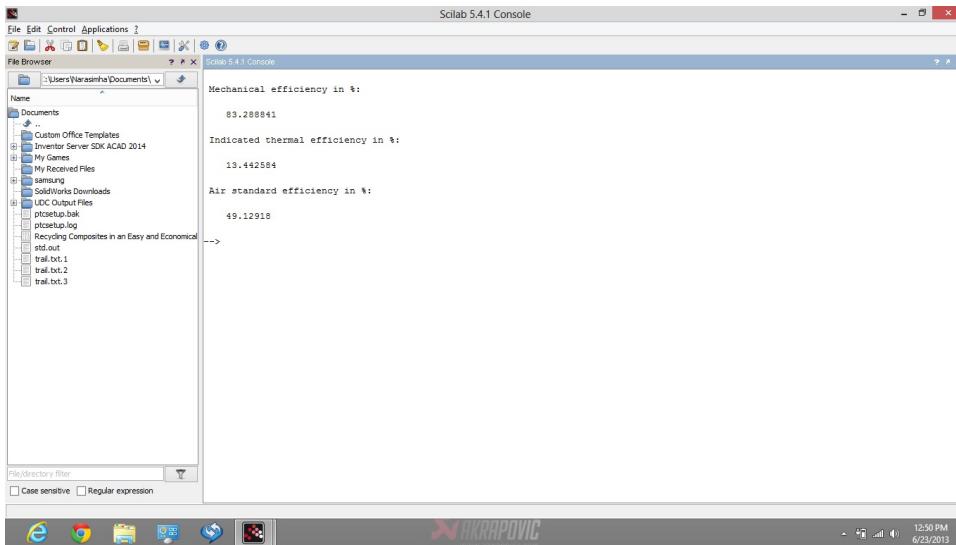


Figure 17.45: Morse test

### Scilab code Exa 17.45 Morse test

```

1 clc;funcprot(0); //EXAMPLE 17.45
2 // Initialisation of Variables
3 n=4; ..... //No of cylinders
4 ga=1.4; ..... //Degree of freedom
5 D=0.075; ..... //Engine bore in m
6 L=0.1; ..... //Engine stroke in m
7 mf=6; ..... //Fuel consumption in kg
    /h
8 C=83600; ..... //Calorific value of fuel
    used
9 Vc=0.0001; ..... //Clearence volume in m^3
10 BP=15.6; ..... //Brake power wilh all
    cylinder working in kW
11 BP1=11.1; ..... //Brake power wilh
    cylinder no 1 cutout in kW
12 BP2=11.03; ..... //Brake power wilh
    cylinder no 2 cutout in kW
13 BP3=10.88; ..... //Brake power wilh

```

```

    cylinder no 3 cutout in kW
14 BP4=10.66;.....//Brake power wilh
    cylinder no 4 cutout in kW
15 //Calculations
16 IP1=BP-BP1;.....//Indicated
    power produced in cylinder 1 in kW
17 IP2=BP-BP2;.....//Indicated
    power produced in cylinder 2 in kW
18 IP3=BP-BP3;.....//Indicated
    power produced in cylinder 3 in kW
19 IP4=BP-BP4;.....//Indicated
    power produced in cylinder 4 in kW
20 IP=IP1+IP2+IP3+IP4;.....//Total Indicated power produced in kW
21 etamech=BP/IP;.....//Mechanical efficiency
22 disp(etamech*100,"Mechanical efficiency in %:")
23 etaith=IP/((mf/3600)*C);.....//Indicated thermal efficiency
24 disp(etaith*100,"Indicated thermal efficiency in %:")
25 Vs=(%pi/4)*D*D*L;.....//Stroke volume in m^3
26 r=(Vs+Vc)/Vc;.....//Compression ratio
27 etast=1-(1/(r^(ga-1)));.....//Air standard efficiency
28 disp(etast*100,"Air standard efficiency in %:")

```

---

### Scilab code Exa 17.46 Morse test

```

1 clc;funcprot(0); //EXAMPLE 17.46
2 // Initialisation of Variables

```

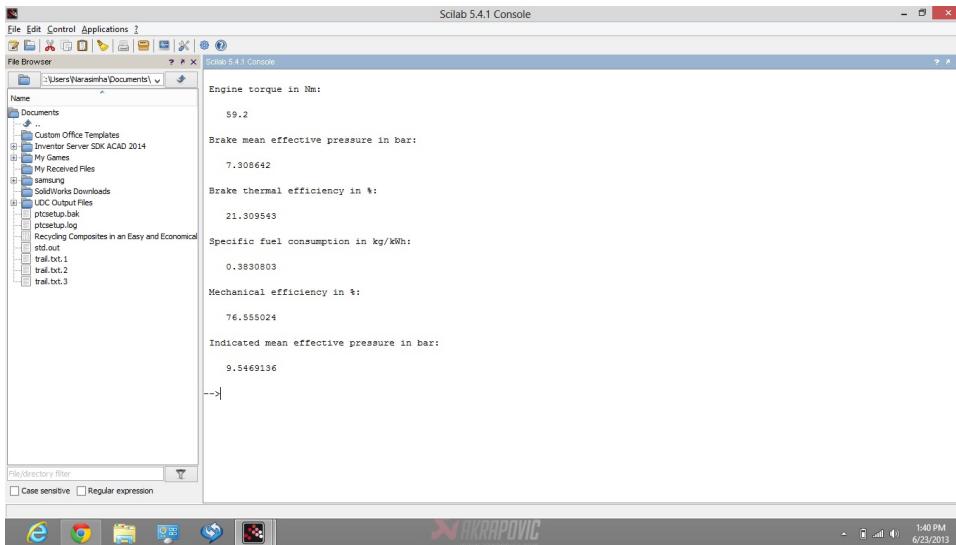


Figure 17.46: Morse test

```

3 n=4; ..... //No of cylinders
4 D=0.06; ..... //Engine bore in m
5 L=0.09; ..... //Engine stroke in m
6 N=2800; ..... //Engine rpm
7 Ta=0.37; ..... //Length of torque
    arm in m
8 spgr=0.74; ..... // Specific graviy of
    fuel
9 fc=8.986; ..... //Fuel consumption in
    ltrs/h
10 mf=fc*spgr; ..... //Fuel consumed in
    kg/h
11 C=44100; ..... //Calorific value of
    fuel in kJ/kg
12 BPnl=160; ..... //Net brake load in N
13 BP1=110; ..... //Brake load with
    cylinder no 1 cutout in N
14 BP2=107; ..... //Brake load with
    cylinder no 2 cutout in N
15 BP3=104; ..... //Brake load with

```

```

    cylinder no 3 cutout in N
16 BP4=110;.....//Brake load with
    cylinder no 4 cutout in N
17 k=0.5;.....//Four stroke engine
18 //Calculations
19 T=BPnl*Ta;.....//Engine torque in
    N-m
20 disp(T,"Engine torque in Nm:")
21 BP=(2*pi*N*T)/(60*1000);.....
    //Brake power in kW
22 pmb=(BP*6)/(n*D*D*L*N*10*(pi/4)*k)
    ;.....//Brake mean effective
    pressure in bar
23 disp(pmb,"Brake mean effective pressure in bar:")
24 etabth=BP/((mf/3600)*C);.....
    //Brake thermal efficiency
25 disp(etabth*100,"Brake thermal efficiency in %:")
26 sfc=mf/BP;.....//Specific fuel
    consumption in kg/kWh
27 disp(sfc,"Specific fuel consumption in kg/kWh:")
28 IP1=BPnl-BP1;.....//Indicated
    power produced in cylinder 1 in kW
29 IP2=BPnl-BP2;.....//Indicated
    power produced in cylinder 2 in kW
30 IP3=BPnl-BP3;.....//Indicated
    power produced in cylinder 3 in kW
31 IP4=BPnl-BP4;.....//Indicated
    power produced in cylinder 4 in kW
32 IP=IP1+IP2+IP3+IP4;.....//Total Indicated power produced in kW
33 etamech=BPnl/IP;.....//Mechanical efficiency
34 disp(etamech*100,"Mechanical efficiency in %:")
35 pmi=pmb/etamech;.....//Indicated mean effective pressure in bar
36 disp(pmi,"Indicated mean effective pressure in bar:")

```

---

# Chapter 20

## Air Compressors

Scilab code Exa 20.1 Single stage reciprocating compressor

```
1 clc;funcprot(0); //EXAMPLE 20.1
2 // Initialisation of Variables
3 v1=1;.....//Volume of air taken in m^3/min
4 p1=1.013;.....//Intake pressure in bar
5 t1=288;.....//Intake temperature in K
6 p2=7;.....//Delivery pressure in
   bar
7 n=1.35;.....//Adiabatic index
8 R=287;.....//Gas constant in kJ/kgK
9 //Calculations
10 m=(p1*v1*10^5)/(R*t1);.....//Mass of air
    delivered per min in kg
11 t2=t1*((p2/p1)^((n-1)/n));.....//Delivery
    temperature in K
12 iw=(n/(n-1))*m*R*(t2-t1);.....//Indicated
    work in kJ/min
13 IP=iw/(60*1000);.....//Indicated
    power
14 disp(IP," Indicated power in kW: ")
```

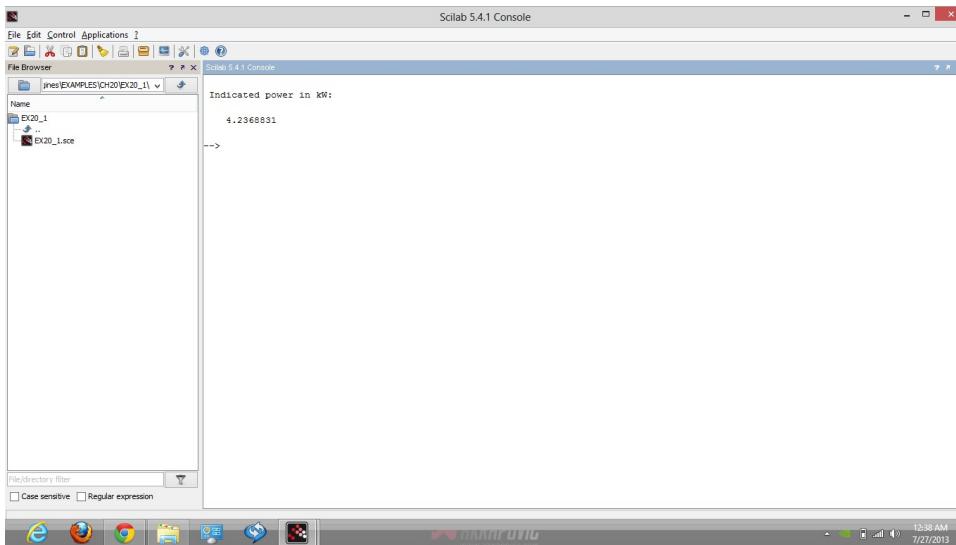


Figure 20.1: Single stage reciprocating compressor

---

### Scilab code Exa 20.2 Motor power and bore of single stage compressor

```
1 clc;funcprot(0); //EXAMPLE 20.2
2 // Initialisation of Variables
3 N=300;.....//Compressor rpm
4 afr=15;.....//Air fuel ratio
5 etamech=0.85;....//Mechanical efficiency
6 etamt=0.9;.....//Motor transmission efficiency
7 v=1;.....//Volume dealt with per min at inlet
    in m^3/min
8 rld=1.5;.....//Ratio of stroke to diameter
9 v1=1;.....//Volume of air taken in m^3/min
10 p1=1.013;.....//Intake pressure in bar
11 t1=288;.....//Intake temperature in K
```

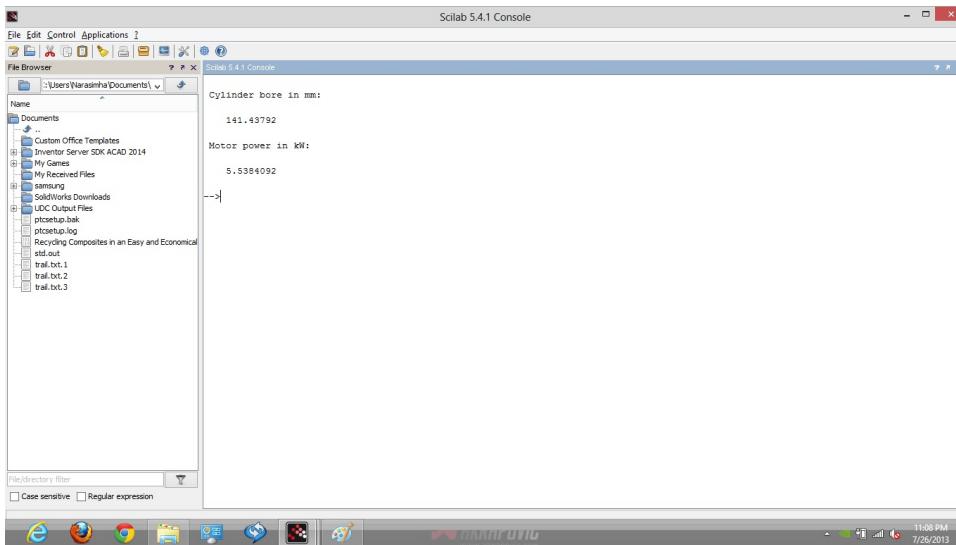


Figure 20.2: Motor power and bore of single stage compressor

```

12 p2=7; ..... // Delivery pressure in
   bar
13 n=1.35; ..... // Adiabatic index
14 R=287; ..... // Gas constant in kJ/kgK
15 // Calculations
16 m=(p1*v1*10^5)/(R*t1); ..... // Mass of air
   delivered per min in kg
17 t2=t1*((p2/p1)^((n-1)/n)); ..... // Delivery
   temperature in K
18 iw=(n/(n-1))*m*R*(t2-t1); ..... // Indicated
   work in kJ/min
19 IP=iw/(60*1000); ..... // Indicated
   power in kW
20 vdc=v/N; ..... // Volume drawn in per cycle in m^3
21 D=(vdc/((%pi/4)*rld))^(1/3); ..... // Cylinder
   bore in m
22 disp(D*1000,"Cylinder bore in mm:")
23 pc=IP/etamech; ..... // Power input to the
   compressor in kW
24 mp=pc/etamt; ..... // Motor power in kW

```

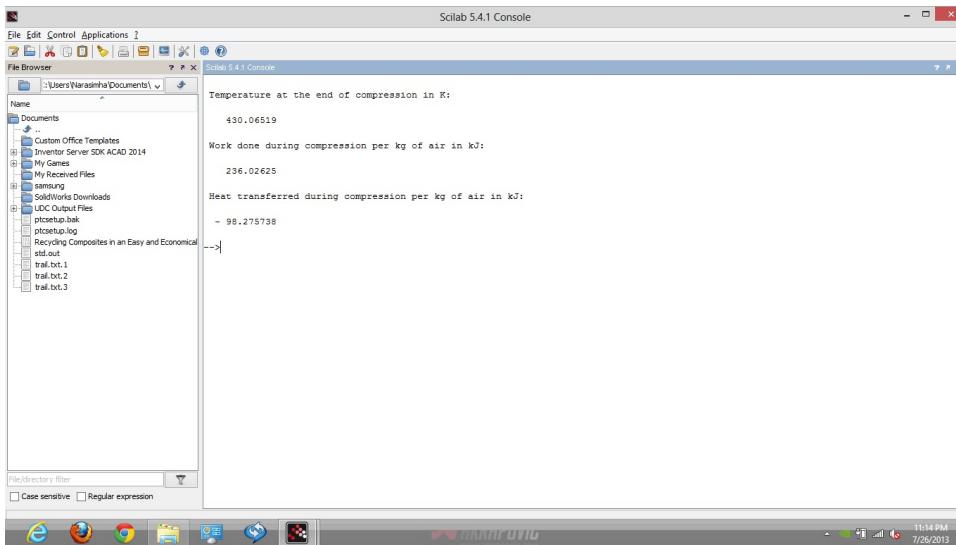


Figure 20.3: Work done and heat transferred during single stage compression

---

25 ***disp(mp,"Motor power in kW:")***

**Scilab code Exa 20.3** Work done and heat transferred during single stage compression

```

1 clc;funcprot(0); //EXAMPLE 20.3
2 // Initialisation of Variables
3 p1=1;.....//Suction pressure in bar
4 t1=293;.....//Suction temperature in K
5 n=1.2;.....//Compression index
6 p2=10;.....//Delivery pressure in bar
7 R=0.287;....//Gas constant in kJ/kgK
8 cv=0.718;...//Specific heat at constant volume in kJ
      /kgK
9 //Calculations

```

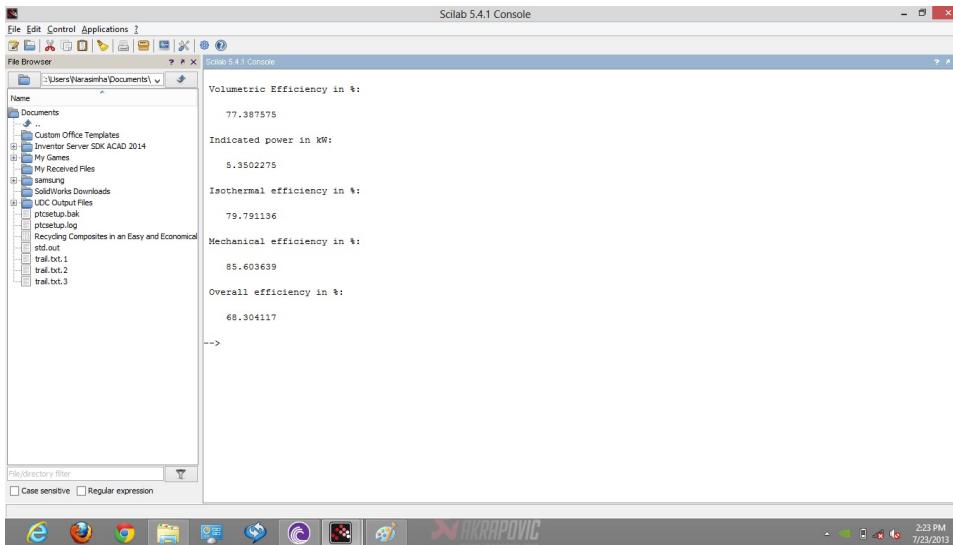


Figure 20.4: Single stage compressor

```

10 t2=t1*((p2/p1)^((n-1)/n));.....//Temperature at the
   end of compression in K
11 disp(t2,"Temperature at the end of compression in K:
   ")
12 W=1*R*t1*(n/(n-1))*(((p2/p1)^((n-1)/n))-1);.....// 
   Work done during compression of air in kJ
13 disp(W,"Work done during compression per kg of air
   in kJ:")
14 Q=(t2-t1)*(cv-(R)/(n-1));.....//Heat
   transferred during compression of air in kJ/kg
15 disp(Q,"Heat transferred during compression per kg
   of air in kJ:")

```

---

### Scilab code Exa 20.4 Single stage compressor

```
1 clc;funcprot(0); //EXAMPLE 20.4
```

```

2 // Initialisation of Variables
3 p1=1;.....//Suction pressure in bar
4 t1=293;.....//Suction temperature in K
5 p2=6;.....//Discharge pressure in bar
6 t2=453;.....//Discharge temperature in K
7 N=1200;.....//Compressor rpm
8 Ps=6.25;.....//Shaft power in kW
9 ma=1.7;.....//Mass of air delivered in kg/min
10 D=0.14;.....//Engine bore in m
11 L=0.10;.....//Engine stroke in m
12 R=287;.....//Gas constant in kJ/kgK
13 //Calculations
14 Vd=(%pi/4)*D*D*L*N;.....// Displlacement volume
   in m^3/min
15 FAD=ma*R*t1/(p1*10^5);.....//Free air delivered
16 etav=FAD/Vd;.....//Volumetric efficiency
17 disp(etav*100," Volumetric Efficiency in %:")
18 n=1/(1-((log(t2/t1))/(log(p2/p1))));.....//Index
   of compression
19 IP=(n/(n-1))*(ma/60)*(R/1000)*t1*((p2/p1)^((n-1)/n)
   )-1);.....//Indicated power in kW
20 disp(IP," Indicated power in kW:")
21 Piso=((ma/60)*(R/1000)*t1*(log(p2/p1)));.....///
   Isothermal power
22 etaiso=Piso/IP;.....//Isothermal efficiency
23 disp(etaiso*100," Isothermal efficiency in %:")
24 etamech=IP/Ps;.....//Mechanical efficiency
25 disp(etamech*100," Mechanical efficiency in %:")
26 etao=Piso/Ps;.....//Overall efficiency
27 disp(etao*100," Overall efficiency in %:")

```

---

**Scilab code Exa 20.5** Low pressure water jacketed rotary compressor

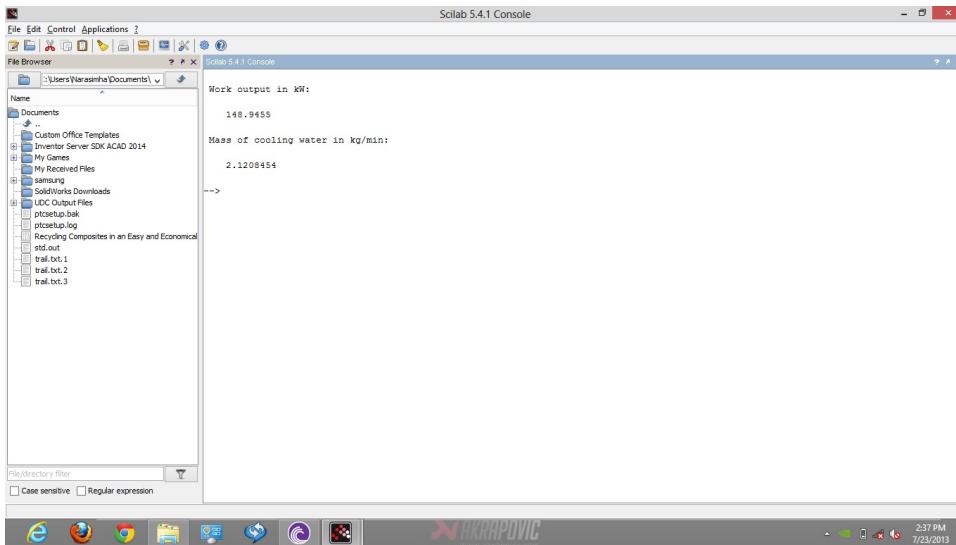


Figure 20.5: Low pressure water jacketed rotary compressor

```

1 clc;funcprot(0); //EXAMPLE 20.5
2 // Initialisation of Variables
3 ma=6.75;.....//Mass of air compressed in kg/min
4 p1=1;.....//Initial pressure in atm
5 cp=1.003;.....//Specifc heat at constant
   vpressure in kJ/kgK
6 t1=21;.....//Initial temperature in Celsius
7 t2=43;.....//Final temperature in Celsius
8 rp=1.35;.....//Pressure ratio
9 ga=1.4;.....//Ratio os specific heats
10 delt=3.3;.....//Change in temperature
11 cpw=4.18;.....// Specific heat for water in kJ/kgK
12 //Calculations
13 W=ma*cp*(t2-t1);.....//Work output in kJ
14 disp(W,"Work output in kW:")
15 t21=(t1+273)*(rp^((ga-1)/ga));.....//Final
   temperature if the compression had been
   isentropic
16 Qr=ma*cp*(t21-(t2+273));.....//Heat rejected
   in kJ

```

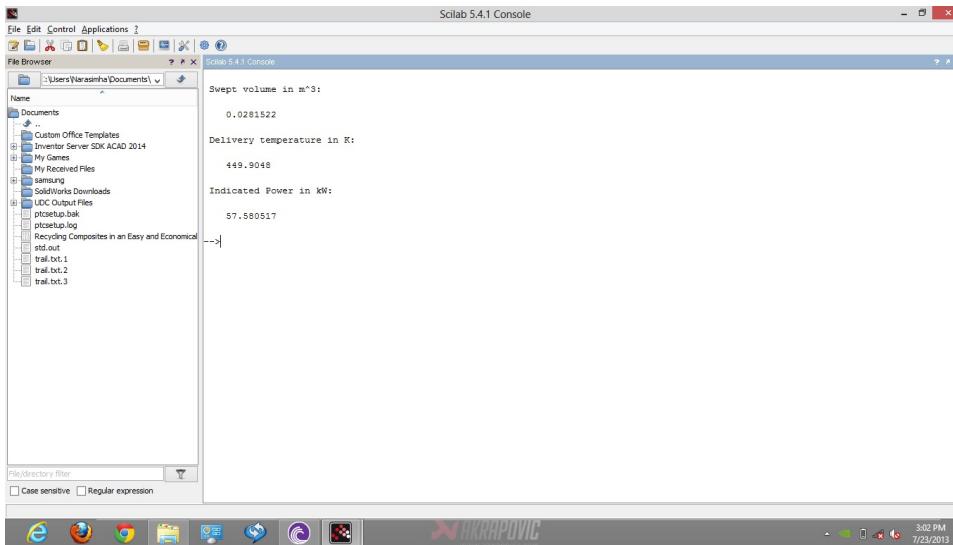


Figure 20.6: Single stage double acting compressor

---

```

17 mw=Qr/(cpw*delt);.....//Mass of cooling water in
   kg/min
18 disp(mw,"Mass of cooling water in kg/min:")

```

---

### Scilab code Exa 20.6 Single stage double acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.6
2 // Initialisation of Variables
3 ma=14;.....//Quantity of air delivered in kg/min
4 p1=1.013;.....//Intake pressure in bar
5 t1=288;.....//Intake temperature in K
6 p2=7;.....//Delivery pressure in bar
7 N=300;.....//Compressor rpm
8 pervc=0.05;.....//Percentage of clearance volume
   in the total stroke volume
9 n=1.3;.....//Compressor and expansion index

```

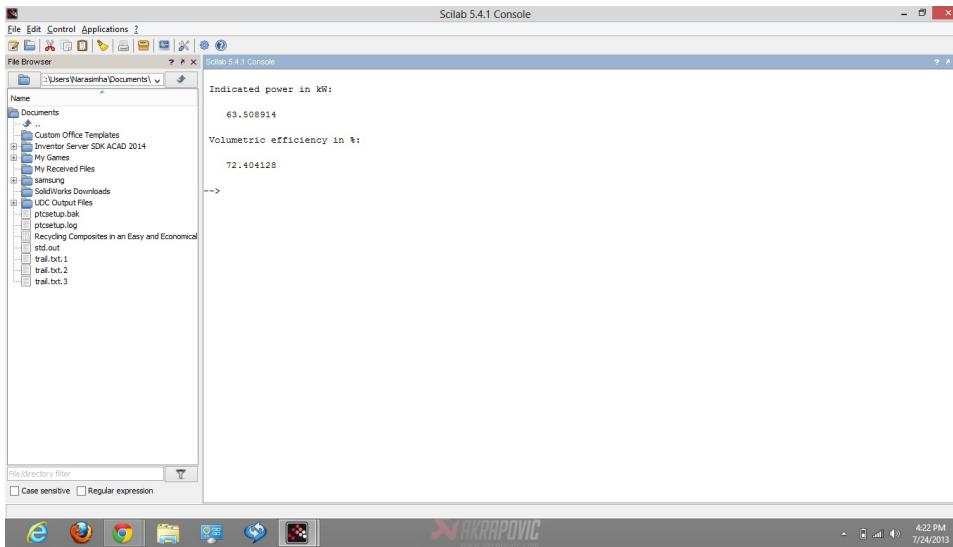


Figure 20.7: Single stage double acting compressor

```

10 // Calculations
11 V1byVs=pervc+1;
12 v1minv4=ma/(N*2); v4byv3=((p2/p1)^(1/n)); v4byvs=
    v4byv3*pervc; Vs=v1minv4/(V1byVs-v4byvs); .....//  

    Swept volume in m^3
13 disp(Vs,"Swept volume in m^3:")
14 t2=t1*((p2/p1)^((n-1)/n)); .....// Delivery  

    Temperature in K
15 disp(t2,"Delivery temperature in K:")
16 IP=((n)/(n-1))*p1*(10^5)*((ma)/(60*1000))*(((p2/p1)
    ^((n-1)/n))-1);
17 disp(IP,"Indicated Power in kW:")

```

---

### Scilab code Exa 20.7 Single stage double acting compressor

```
1 clc;funcprot(0); //EXAMPLE 20.7
```

```

2 // Initialisation of Variables
3 FAD=14;.....//Free air delivered in m^3/min
4 p1=0.95;.....//Induction pressure in bar
5 t1=305;.....//Induction temperature in K
6 p2=7;.....//Delivery pressure in bar
7 n=1.3;.....//Adiabatic index
8 VcbyVs=0.05;.....//Ratio of clearance volume and
    swept volume
9 R=287;.....//Gas constant in J/kgK
10 t=288;.....//free air temperature in K
11 p=1.013;.....//free air pressure in bar
12 //Calculations
13 m=(p*100000*FAD)/(R*t);.....//Mass delivered
    per min in kg
14 t2=t1*((p2/p1)^(n-1/n));
15 IP=((n/(n-1))*m*(R/1000)*(t2-t1))/60;.....//
    Indicated power in kW
16 disp(IP," Indicated power in kW:")
17 v4byv3=(p2/p1)^(1/n);v4byvs=v4byv3*VcbyVs;v1minv4
    =(1+VcbyVs)-v4byvs;
18 Vbyvs=v1minv4*(t/t1)*(p1/p);
19 etav=Vbyvs/1;.....//Volumetric efficiency
20 disp(etav*100," Volumetric efficiency in %:")

```

---

### Scilab code Exa 20.8 Single stage double acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.8
2 // Initialisation of Variables
3 FAD=16;.....//Free air delivered in m^3/min
4 p1=0.96;.....//Suction pressure in bar
5 t1=303;.....//Suction temperature in K
6 n=1.3;.....//Compression index
7 k=0.04;.....//Clearance ratio

```

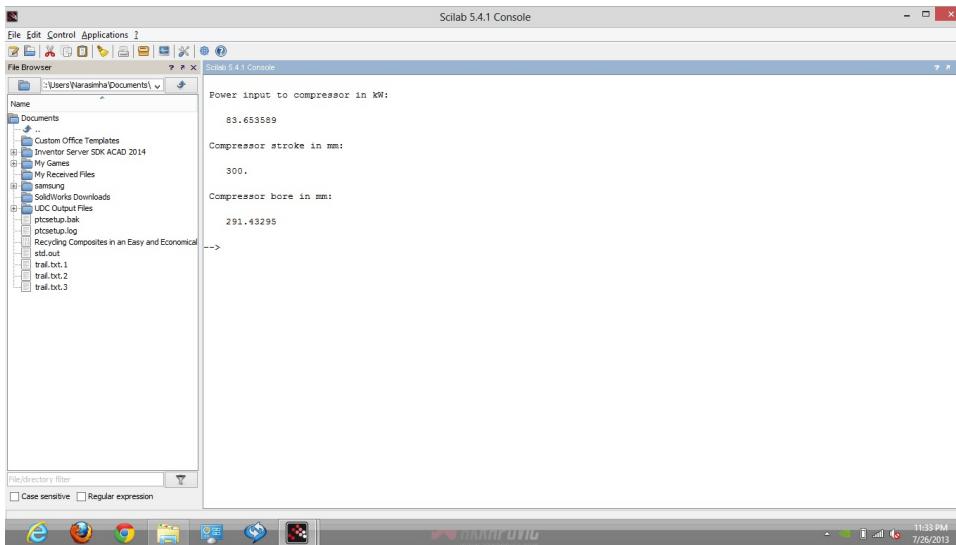


Figure 20.8: Single stage double acting compressor

```

8 p2=6;.....//Delivery pressure in bar
9 etamech=0.9;...//Mechanical efficiency
10 vp=300;.....//Piston speed in m/min
11 N=500;.....//Compressor rpm
12 p=1;.....//Ambient pressure in bar
13 t=288;.....//Ambient temperature in K
14 etac=0.85;...//Compressor efficiency
15 R=0.287;.....//Universal gas constant
16 //Calculations
17 m=(p*10^5*FAD)/(R*1000*t);.....//Mass flow
    rate of compressor in kg/min
18 t2=t1*((p2/p1)^((n-1)/n));.....//Temperature at the
    end of compression in K
19 P=(n/(n-1))*(m/60)*R*(t2-t1)*(1/etamech)*(1/etac)
    ;.....//Power input to compressor in kW
20 disp(P,"Power input to compressor in kW:")
21 L=vp/(2*N);.....//Stroke in m
22 disp(L*1000,"Compressor stroke in mm:")
23 etav=((t/t1)*(p1/p)*(1+k-(k*((p2/p1)^(1/n)))))  

    ;.....//Volumetric efficiency

```

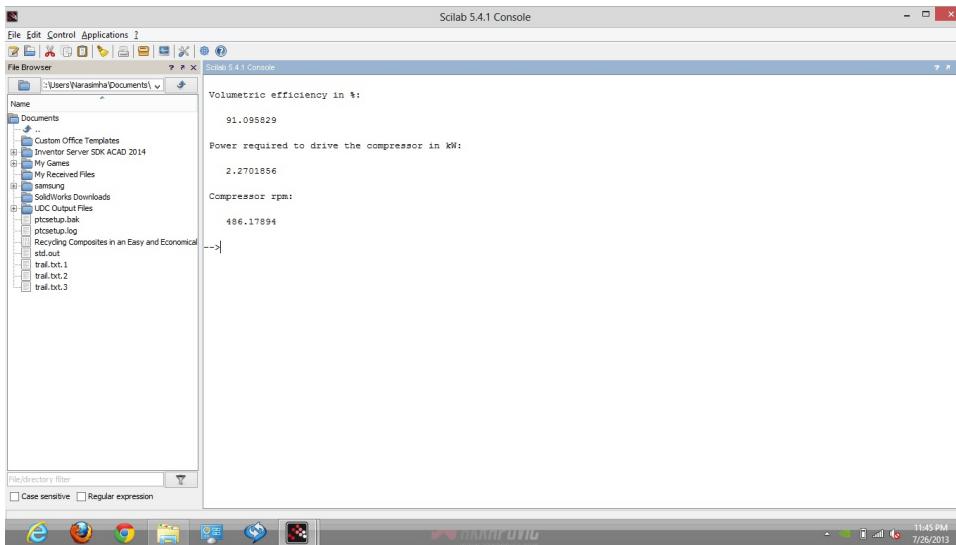


Figure 20.9: Single stage single acting compressor

```

24 D=sqrt(FAD/((%pi/4)*L*N*2*etav));.....//  
Compressor bore in m  
25 disp(D*1000,"Compressor bore in mm:")

```

---

### Scilab code Exa 20.9 Single stage single acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.9  
2 // Initialisation of Variables  
3 m=0.6;.....//Mass of air delivered in kg/min  
4 p2=6;.....//Delivery pressure in bar  
5 p1=1;.....//Induction pressure in bar  
6 t1=303;.....//Induction temperature in K  
7 D=0.1;.....//Compressor bore in m  
8 L=0.15;.....//Compressor stroke in m  
9 k=0.03;.....//Clearance ratio  
10 etamech=0.85;....//Mechanical efficiency

```

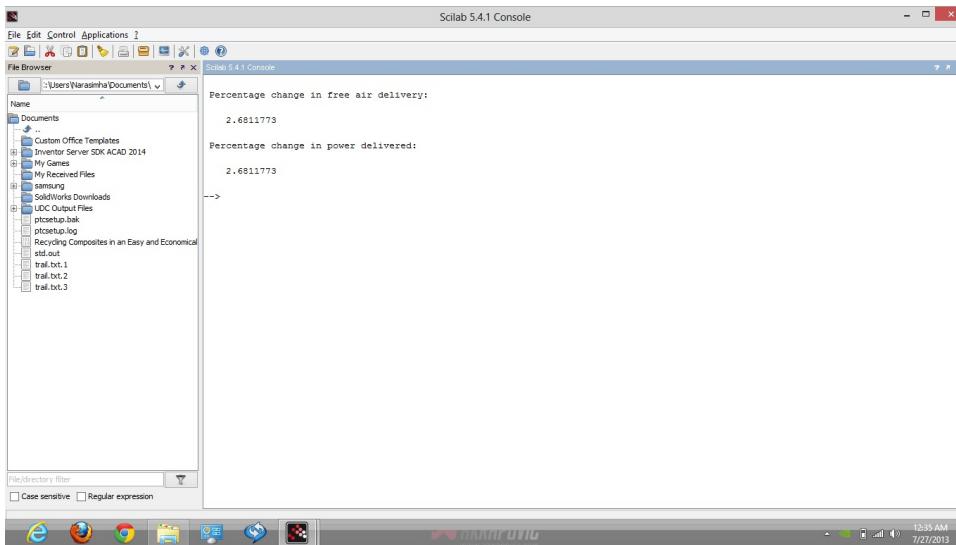


Figure 20.10: Percentage change in volume and power

```

11 R=0.287;.....//Gas constant in kJ/kgK
12 n=1.3;.....//Compression index
13 //Calculations
14 etav=(1+k)-(k*((p2/p1)^(1/n)));.....//  
Volumetric efficiency
15 disp(etav*100,"Volumetric efficiency in %:")
16 IP=(n/(n-1))*(m/60)*R*t1*((p2/p1)^((n-1)/n))-1  
;.....//Indicated power in kW
17 P=IP/etamech;.....//Power required to drive  
the compressor in kW
18 disp(P,"Power required to drive the compressor in kW  
:")
19 FAD=(m*R*t1*1000)/(p1*10^5);.....//Free air  
delivery in m^3/min
20 Vd=FAD/etav;.....//Displacement volume in m^3/min
21 N=Vd/((pi/4)*D*D*L);.....//Compressor rpm
22 disp(N,"Compressor rpm:")

```

---

**Scilab code Exa 20.10** Percentage change in volume and power

```
1 clc;funcprot(0); //EXAMPLE 20.10
2 // Initialisation of Variables
3 L=88;.....//Compressor stroke in cm
4 k=0.02;.....//Clearance ratio
5 p3=8.2;.....//Delivery pressure in bar
6 p4=1.025;.....//Suction pressure in bar
7 p1=p4;.....//Suction pressure in bar
8 n=1.3;.....//Compression index
9 lo=0.55;....//Length of distance piece fitted after
               overhaul in cm
10 //Calculations
11 pcfa=((((L+(L*k))-((L*k)*((p3/p4)^(1/n))))-(((k*L)+lo
           +L)-((k*L)+lo)*((p3/p4)^(1/n))))) / ((L+L*k)-((L*k
           )*((p3/p4)^(1/n))))
12 disp(pcfa*100," Percentage change in free air
           delivery:")
13 pcpa=pcfa;.....//Percentage change in power
               delivered
14 disp(pcpa*100," Percentage change in power delivered:
           ")
```

---

**Scilab code Exa 20.11** Single stage double acting compressor

```
1 clc;funcprot(0); //EXAMPLE 20.11
2 // Initialisation of Variables
3 v=30;.....//Suction volume in m^3/min
4 p1=1;.....//Suction pressure in bar
5 t1=300;.....//Suction temperature in K
```

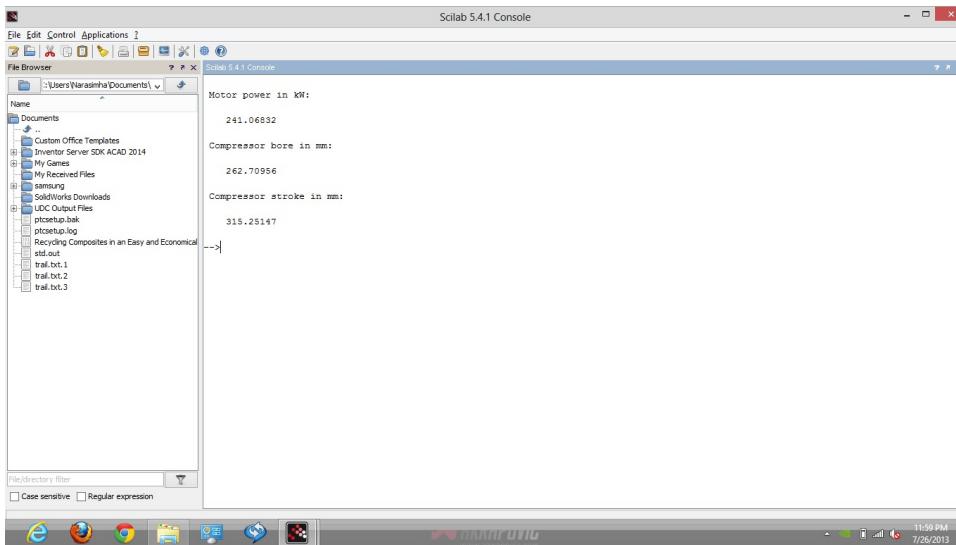


Figure 20.11: Single stage double acting compressor

```

6 p2=16;.....//Delivery pressure in bar
7 N=320;.....//Compressor rpm
8 k=0.04;.....//Clearance ratio
9 rld=1.2;.....//Ratio of stroke to bore
10 etamech=0.82;....//Mechanical efficiency
11 n=1.32;.....//Compression index
12 ti=39+273;....//Temperature inside the suction
    chamber in K
13 nc=4;.....//No of cylinders
14 //Calculations
15 W=(n/(n-1))*(p1/1000)*10^5*(v/60)*(((p2/p1)^((n-1)/n)
    )-1);.....//Work done in kW
16 mp=W/etamech;.....//Motor power in kW
17 disp(mp,"Motor power in kW:")
18 etav=((1+k)-(k*((p2/p1)^(1/n)))*(t1/ti));.....// 
    Volumetric efficiency
19 Vs=(v/nc)*(1/(2*N))*(1/etav);.....//Swept
    volume of cylinder in m^3
20 D=(Vs/((pi/4)*rld))^(1/3);.....//Compressor
    bore in m

```

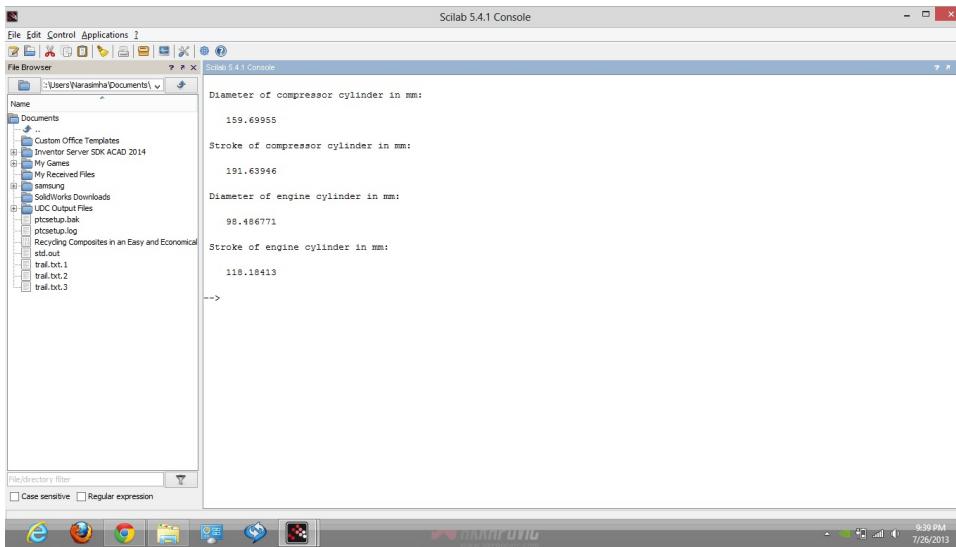


Figure 20.12: Two cylinder single acting compressor

```

21 L=D*rld;.....//Compressor stroke in m
22 disp(D*1000,"Compressor bore in mm:")
23 disp(L*1000,"Compressor stroke in mm:")

```

---

### Scilab code Exa 20.12 Two cylinder single acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.12
2 // Initialisation of Variables
3 n=2;.....//No of cylinders
4 ma=16;.....//Mass of air supplied per min in kg
5 p1=1;.....//Suction pressure in bar
6 t1=288;.....//Suction temperature in K
7 k=0.04;.....//Clearance ratio
8 ni=1.3;.....//Compression index
9 R=0.287;.....//Gas constant in kJ/kgK
10 N=2000;.....//Engine rpm

```

```

11 p3=7;.....//Delivery pressure in bar
12 rld=1.2;.....//Ratio of stroke to bore for
    compressor cylinder and engine cylinder
13 etamech=0.82;.....//Mechanical efficiency of
    engine
14 pmb=5.5;.....//Mean effective pressure in bar
    in engine
15 ne=4;.....//No of engine cylinders
16 //Calculations
17 Vs=(((ma/n)*R*1000*t1)/(p1*10^5*N))/((1+k)-(k*((p3/
    p1)^(1/ni)))); 
18 Dc=(Vs/((%pi/4)*rld))^(1/3);.....//Diameter of
    compressor cylinder in m
19 Lc=rld*Dc;.....//Stroke of the compressor
    cylinder in m
20 disp(Dc*1000,"Diameter of compressor cylinder in mm:")
21 disp(Lc*1000,"Stroke of compressor cylinder in mm:")
22 IP=(ni/(ni-1))*(ma/60)*R*t1*(((p3/p1)^(1/(ni-1)/ni))-1);.....//Indicated power of the compressor in
    kW
23 BP=IP/etamech;.....//Brake power of the
    engine in kW
24 De=((BP*60*1000)/(ne*pmb*10^5*rld*(%pi/4)*N))^(1/3)
    ;.....//Diameter of the engine cylinder in m
25 Le=rld*De;.....//Stroke of the engine cylinder
    in m
26 disp(De*1000,"Diameter of engine cylinder in mm:")
27 disp(Le*1000,"Stroke of engine cylinder in mm:")

```

---

**Scilab code Exa 20.13** Single stage double acting compressor

```
1 clc;funcprot(0); //EXAMPLE 20.13
```

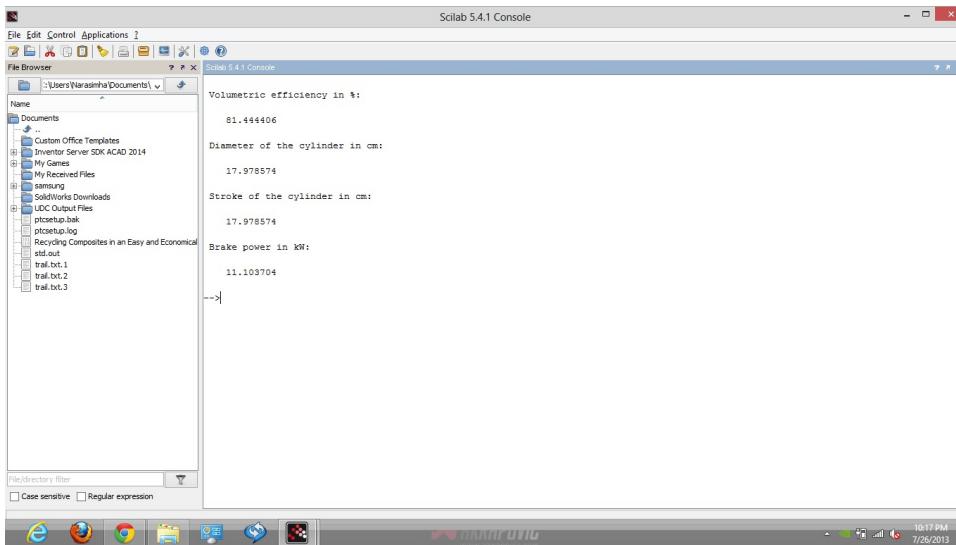


Figure 20.13: Single stage double acting compressor

```

2 // Initialisation of Variables
3 nc=1.25;.....//Index of compression
4 ne=1.3;.....//Index of expansion
5 etamech=0.85;.....//Mechanical efficiency
6 p1=1;.....//Suction pressure in bar
7 p2=7.5;.....//Delivery pressure in bar
8 t1=25+273;....//Suction temperature in bar
9 Vamb=2.2;....//Volume of free air delivered in m^3
10 N=310;.....//Engine rpm
11 k=0.05;.....//Clearance ratio
12 pamb=1.03;....//Ambient pressure in bar
13 tamb=293;....//Ambient temperature in K
14 // Calculations
15 etav=(1+k-(k*((p2/p1)^(1/ne)))).....//Volumetric
     efficiency
16 disp(etav*100,"Volumetric efficiency in %:")
17 v1=(pamb*Vamb*t1)/(p1*tamb);.....//Volume of air
     delivered at suction condition in m^3
18 vs=(v1/(etav*N*2));.....//Swept volume in m^3
19 D=(vs/(%pi/4))^(1/3);.....//Diameter of the

```

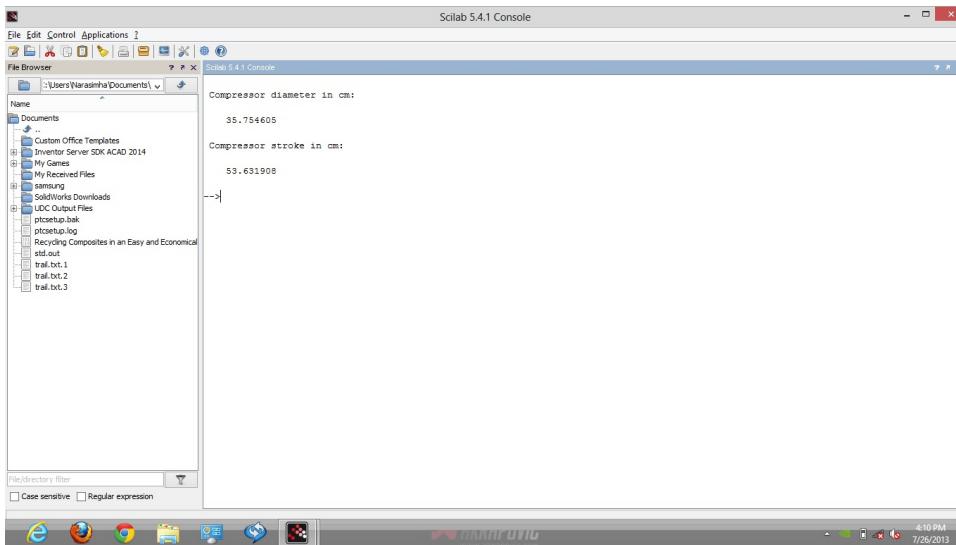


Figure 20.14: Single stage single acting compressor

```

cylinder in m
20 L=D;
21 disp(D*100,"Diameter of the cylinder in cm:")
22 disp(L*100,"Stroke of the cylinder in cm:")
23 W=2*vs*10^5*((nc)/(nc-1))*p1*(1+k)*((p2/p1)^((nc
    -1)/(nc))-1)-((ne)/(ne-1))*p1*(k*((p2/p1)^(1/ne)
    )*((p2/p1)^((ne-1)/(ne))-1));.....//Work
    done per cycle of operation in Nm/cycle
24 IP=W*N/(60*1000);.....//Indicated power in
    kW
25 BP=IP/etamech;.....//Brake power in kW
26 disp(BP,"Brake power in kW:")

```

---

### Scilab code Exa 20.14 Single stage single acting compressor

```
1 clc;funcprot(0); //EXAMPLE 20.14
```

```

2 // Initialisation of Variables
3 v=14;.....//Volume of air delivered in m^3
4 p1=1;.....//Suction pressure in bar
5 p2=7;.....//Delivery pressure in bar
6 N=310;.....//Compressor rpm
7 n=1.35;.....//Compression index
8 k=0.05;.....//Clearance ratio
9 rld=1.5;.....//Ratio of cylinder length and
    diameter
10 //Calculations
11 etav=(1+k)-(k*((p2/p1)^(1/n)));.....//Volumetric efficiency
12 Vs=v/(etav*N);.....//Swept volume in m^3
13 D=((Vs)/((pi/4)*rld))^(1/3);.....//Compressor
    diameter in m
14 L=rld*D;.....//Compressor stroke in
    m
15 disp(D*100,"Compressor diameter in cm:")
16 disp(L*100,"Compressor stroke in cm:")

```

---

### Scilab code Exa 20.15 Double acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.15
2 // Initialisation of Variables
3 D=0.33;.....//Cylinder diameter in m
4 L=0.35;.....//Cylinder stroke in m
5 k=0.05;.....//Clearance ratio
6 N=300;.....//Compressor rpm
7 psuc=0.95;.....//Suction pressure in bar
8 tsuc=298;.....//Suction temperature in K
9 pamb=1.013;.....//Ambient pressure in bar
10 tamb=293;.....//Ambient temperature in K
11 p2=4.5;.....//Delivery pressure in bar

```

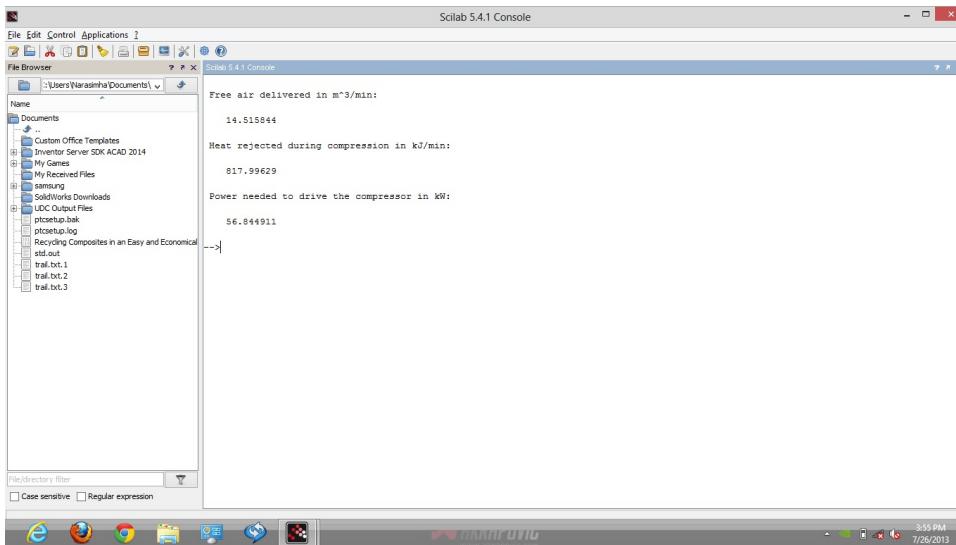


Figure 20.15: Double acting compressor

```

12 n=1.25;.....//Compression index
13 cv=0.717;.....//Specific heat at constant
volume in kJ/kgK
14 ga=1.4;.....//Ratio of specific heats
15 etamech=0.8;.....//Mechanical efficiency
16 R=0.287;.....//Gas constant in kJ/kgK
17 //Calculations
18 Vs=(%pi/4)*D*D*L*N*2;.....//Swept volume in m
^3
19 p1=psuc;etav=1-(k*((p2/p1)^(1/n))-1));.....//Volumetric efficiency
20 Vad=Vs*etav;.....//Actual air drawn per
min in m^3
21 FAD=(psuc/pamb)*(tamb/tsuc)*Vad;.....//Free
air delivered in m^3/min
22 disp(FAD,"Free air delivered in m^3/min:")
23 t1=tsuc;ma=(p1*10^5*Vad)/(R*1000*t1);.....//Mass
of air delivered per min in kg
24 t2=t1*((p2/p1)^((n-1)/n));.....//Delivery
temperature in K

```

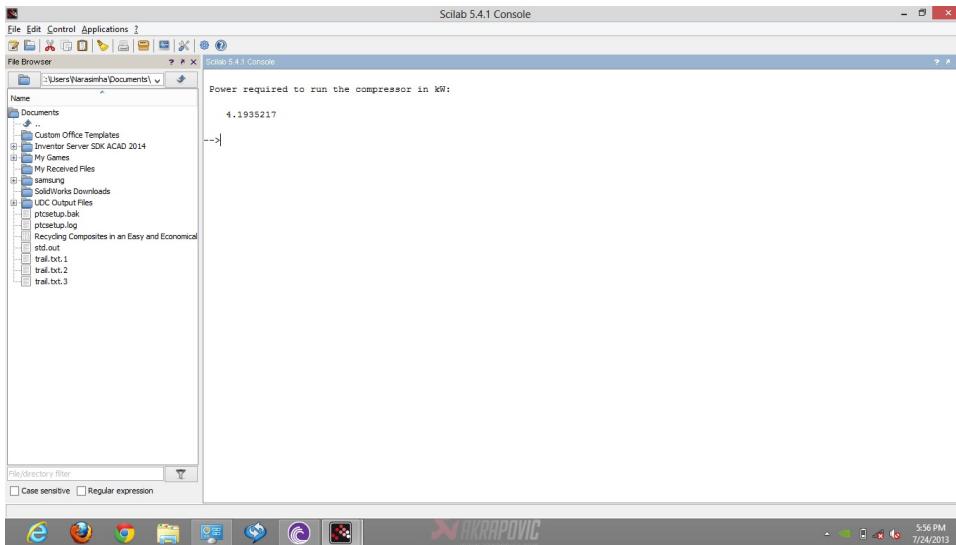


Figure 20.16: Two stage compressor

```

25 Qr=ma*cv*((ga-n)/(n-1))*(t2-t1);.....//Heat
      rejected during compression in kJ/min
26 disp(Qr,"Heat rejected during compression in kJ/min:
      ")
27 P=((n)/(n-1))*R*t1*(ma/60)*(((p2/p1)^((n-1)/(n)))-1)
      *(1/etamech);.....//Power needed to drive
      the compressor in kW
28 disp(P,"Power needed to drive the compressor in kW:")

```

---

### Scilab code Exa 20.16 Two stage compressor

```

1 clc;funcprot(0);...//Example 20.16
2 //Initialisation of variables
3 p1=1.03;.....//Intake pressure in bar
4 t1=300;.....//Intake temperature in K

```

```

5 p2=7;.....//Intake pressure for High
    pressure cylinder in bar
6 t2=310;.....//Temperature of air entering
    high pressure cylinder in K
7 p3=40;.....//Pressure of air after
    compression in bar
8 V=30;.....//volume of air delivered in m^3/h
9 R=0.287;.....//Gas constant for air in kJ/kgK
10 ga=1.4;.....//Ratio of specific heats
11 //Calculations
12 m=p1*10^5*V/(R*1000*t1);.....//Mass of air
    compressed in kg/h
13 t21=t1*((p2/p1)^((ga-1)/ga));.....//Actual
    temperature of air entering high pressure
    cylinder in K
14 t3=t2*((p3/p2)^((ga-1)/ga));.....//Actual
    temperature of air after compression in K
15 W=((ga)/(ga-1))*m*(R/3600)*(t21-t1+t3-t2);.....
    //Power required to run compressor in kW
16 disp(W,"Power required to run the compressor in kW:")
)

```

---

### Scilab code Exa 20.17 Two stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.17
2 // Initialisation of Variables
3 FAD=6;.....//Free air delivered in m^3/min
4 p1=1;.....//suction pressure in bar
5 t1=300;.....//Suction temperature in K
6 p3=40;.....//Delivery pressure in bar
7 p2=6;.....//Intermediate pressure in bar
8 t3=300;.....//Temperature at the inlet to 2nd
    stage in K

```

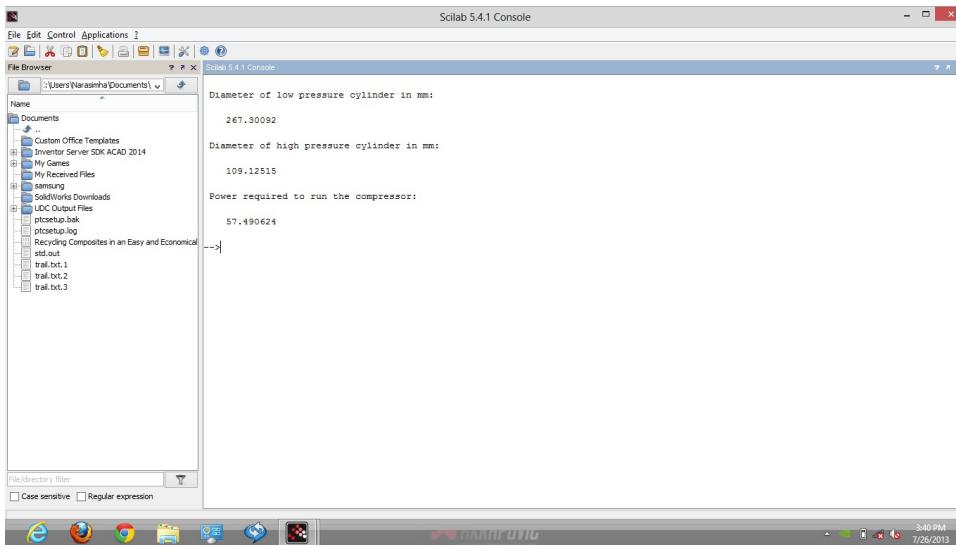


Figure 20.17: Two stage compressor

```

9 n=1.3;.....//Compression index
10 etamech=0.8;.....//Mechanical efficiency
11 N=400;.....//Compressor rpm
12 R=0.287;.....//Gas constant in kJ/kgK
13 //Calculations
14 dlp=(FAD/(N*(%pi/4)))^(1/3);.....//
   Diameter of the low pressure cylinder in m
15 dhp=sqrt(1/(dlp*N*(%pi/4)));.....//Diameter
   of high pressure cylinder in m
16 disp(dlp*1000,"Diameter of low pressure cylinder in
   mm:")
17 disp(dhp*1000,"Diameter of high pressure cylinder in
   mm:")
18 m=(p1*FAD*10^5)/(R*t1*1000*60);.....//Mass flow
   of air in kg/s
19 W=n*(1/(n-1))*m*R*t1*((p2/p1)^((n-1)/n))+((p3/p2)
   ^((n-1)/n))-2);.....//Indicated work in kJ/s
20 P=W/etamech;.....//Power required in kW
21 disp(P,"Power required to run the compressor:")

```

---

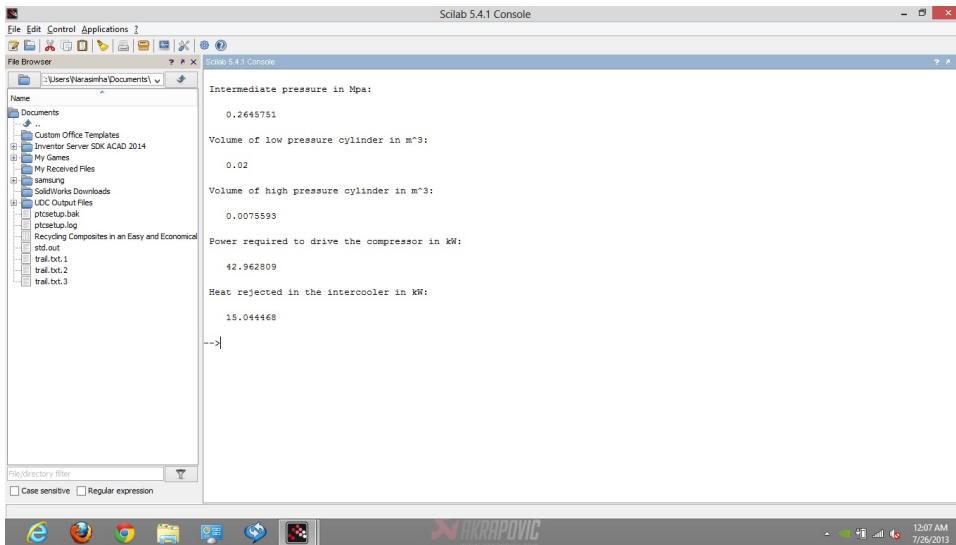


Figure 20.18: Two stage compressor

### Scilab code Exa 20.18 Two stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.18
2 // Initialisation of Variables
3 ns=2;.....//No of stages
4 v1=0.2;.....//Intake volume in m^3/s
5 p1=1;.....//Intake pressure in bar
6 t1=289;.....//Intake temperature in K
7 p3=7;.....//Final pressure in bar
8 n=1.25;.....//Compression index
9 N=600;.....//Compressor rpm
10 cp=1.005;.....// Specific heat at constant pressure
    in kJ/kgK
11 R=0.287;.....//Gas constant in kJ/kgK
12 // Calculations

```

```

13 p2=sqrt(p1*p3);.....//Intermediate pressure in bar
14 disp(p2/10,"Intermediate pressure in Mpa:")
15 vslp=60*v1/N;.....//Volume of low pressure
    cylinder in m^3
16 vshp=p1*vsdp/p2;.....//Volume of high pressure
    cylinder in m^3
17 disp(vsdp,"Volume of low pressure cylinder in m^3:")
18 disp(vshp,"Volume of high pressure cylinder in m^3:")
19 W=(ns*(n/(n-1)))*p1*10^5*(v1/1000)*(((p3/p1)^((n-1)
    /(ns*n))-1);.....//Power required to drive
    the compressor in kW
20 disp(W,"Power required to drive the compressor in kW
    :")
21 m=p1*10^5*v1/(R*t1*1000);.....//Mass of air
    handled in kg/s
22 t2=t1*((p2/p1)^((n-1)/n));.....//Temperature at
    the end of first stage compression in K
23 Qr=m*cp*(t2-t1);.....//Heat rejected in the
    intercooler in kW
24 disp(Qr,"Heat rejected in the intercooler in kW:")

```

---

### Scilab code Exa 20.19 Two stage compressor

```

1 clc,funcprot(0);.....//Example 20.19
2 //initialisation of variables
3 p3=30;.....//delivery pressure in bar
4 p1=1;.....//suction pressure in bar
5 t1=273+15;.....//suction temperature in K
6 n=1.3;.....//adiabatic index
7 //calculation
8 p2=sqrt(p1*p3);....//Pressure before entering High
    pressure cylinder in bar

```

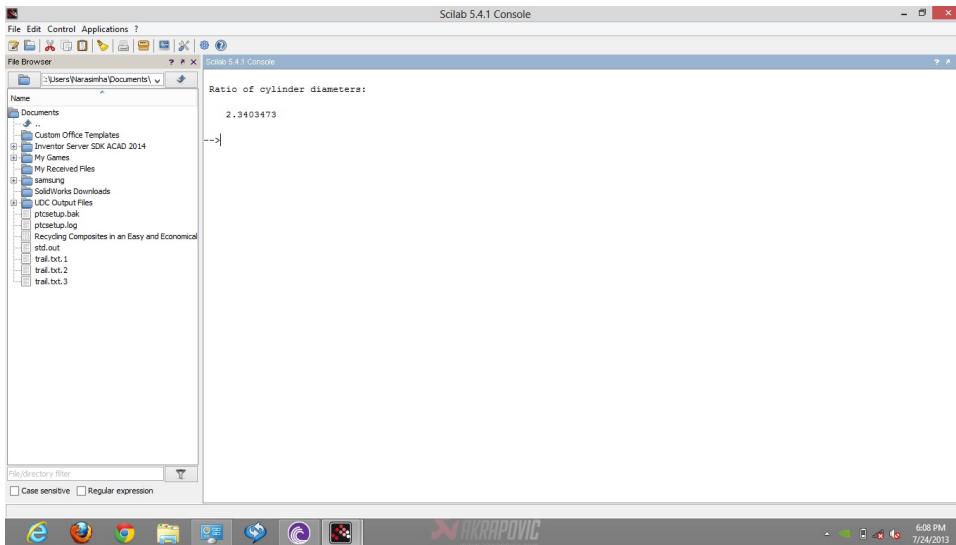


Figure 20.19: Two stage compressor

---

```

9 t21=t1*((p2/p1)^((n-1)/n));.....//Actual
   temperature before entering the high pressure
   turbine in K
10 r=sqrt((p2^(1/n))*(t21/t1));.....//Ratio of
    cylinder diameters
11 disp(r,"Ratio of cylinder diameters:")

```

---

### Scilab code Exa 20.20 Two stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.20
2 // Initialisation of Variables
3 ns=2;.....//No of stages
4 p1=1;.....//Suction pressure in bar
5 p2=7.4;.....//Intercooler pressure in bar
6 p3=42.6;.....//Delivery pressure in bar
7 t1=15+273;.....//Suction temperature in K

```

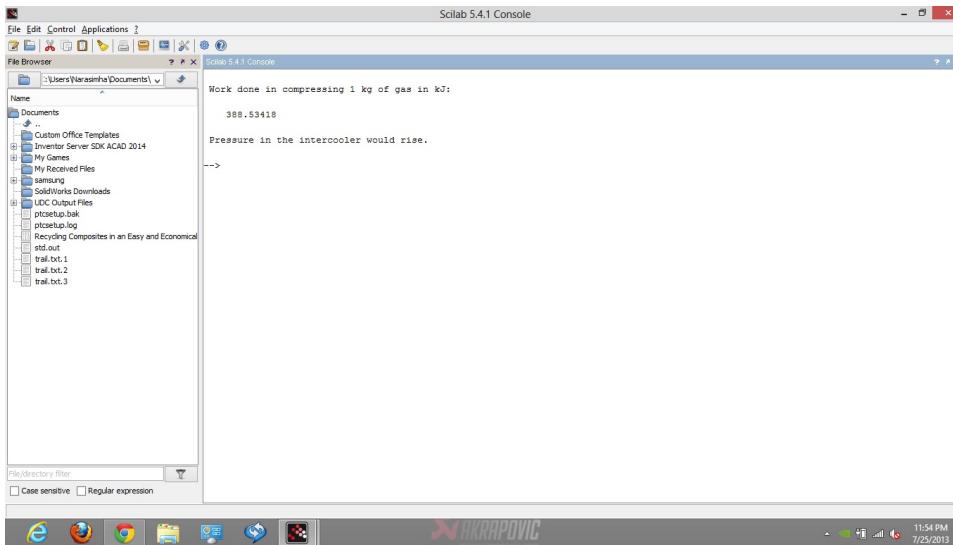


Figure 20.20: Two stage compressor

```

8 n=1.3;..... //Compression index
9 R=0.287;..... //Gas constant in kJ/kgK
10 dlp=0.09;..... //Diameter of low pressure cylinder
    in m
11 dhp=0.03;..... //Diameter of high pressure cylinder
    in m
12 etav=0.9;..... //Volumetric efficiency
13 //Calculations
14 W=n*(1/(n-1))*R*t1*(((p2/p1)^((n-1)/n))+((p3/p2)^((n
    -1)/n))-2);
15 disp(W,"Work done in compressing 1 kg of gas in kJ:")
16 //Given that stroke length is same in both cases
17 rV=p2/p1;..... //Ratio of volumes
18 rECV=((dlp/dhp)^2)*etav;..... //Ratio of
    effective cylinder volumes
19 if (rECV>rV) then disp("Pressure in the intercooler
    would rise.")
20 else if (rECV<rV) then disp("Pressure in the
    intercooler would fall")

```

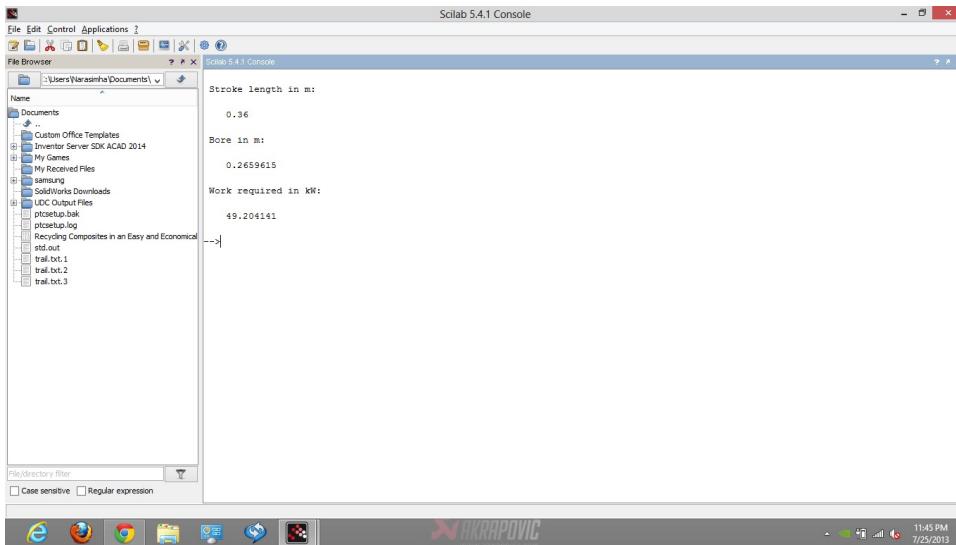


Figure 20.21: Single acting two stage compressor

```

21      end
22 end

```

---

### Scilab code Exa 20.21 Single acting two stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.21
2 // Initialisation of Variables
3 V=4;..... //Volume of air handled in m^3/min
4 p1=1.016;.... //Suction pressure in bar
5 t1=288;..... //Suction temperature in K
6 N=250;..... //Compressor rpm
7 p3=78.65;.... //Delivery pressure in bar
8 vp=3;..... //Piston speed in m/s
9 etamech=0.75;.... //mechanical efficiency
10 etav=0.8;..... //Volumetric efficiency
11 n=1.25;..... //Compression index

```

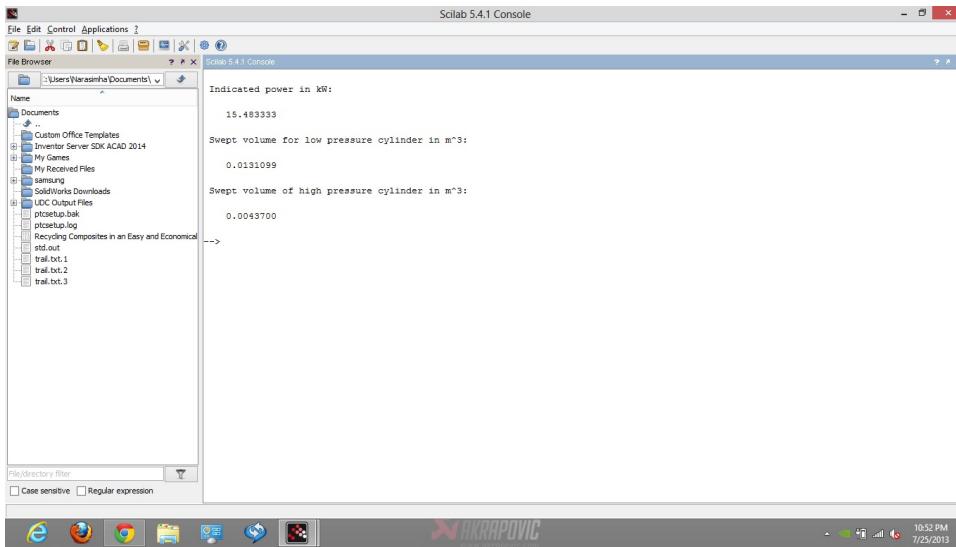


Figure 20.22: Single acting two stage compressor

```

12 R=287;.....//Gas constant in J/kgK
13 ns=2;.....//No of stages
14 //Calculations
15 l=(vp*60)/(2*N);.....//Stroke length in m
16 d=sqrt(V/((pi/4)*l*N*etav));.....//Bore in m
17 disp(l,"Stroke length in m:")
18 disp(d,"Bore in m:")
19 m=(p1*10^5*V)/(R*t1);.....//Mass of air handled by
    the compressor in kg/min
20 p2=sqrt(p1*p3);.....//Intermediate pressure
    in bar
21 t2=t1*((p2/p1)^((n-1)/n));.....//Temperature at
    the end of first stage compression in K
22 W=ns*(n/(n-1))*(m/60)*(R/1000)*(t2-t1)*(1/etamech)
    ;.....//Work required in kW
23 disp(W,"Work required in kW:")

```

---

### Scilab code Exa 20.22 Single acting two stage compressor

```
1 clc;funcprot(0); //EXAMPLE 20.22
2 // Initialisation of Variables
3 m=4.5;.....//Amount of air compressed in kg/min
4 ps=1.013;.....//Suction pressure in bar
5 ts=288;.....//Suction temperature in K
6 rp=9;.....//Pressure ratio
7 n=1.3;.....//Compression index
8 k=0.05;.....//Clearance ratio
9 N=300;.....//Compressor rpm
10 R=287;.....//Gas constant in J/kgK
11 ns=2;.....//No of stages
12 //Calculations
13 ti=round(ts*((sqrt(rp))^(((n-1)/n)));.....//
   Intermediate temperature in K
14 W=round(ns*n*(1/(n-1))*m*(R/1000)*(ti-ts))
   ;.....//Work required per min in kJ
15 IP=W/60;.....//Indicated power in kW
16 disp(IP," Indicated power in kW:")
17 mc=m/N;.....//Mass induced per cycle in kg
18 etav=(1+k)-(k*(sqrt(rp)^(1/n)));.....//Volumetric
   efficiency
19 Vs=(mc*R*ts)/(ps*10^5*etav);.....//Swept volume
   for low pressure cylinder in m^3
20 disp(Vs," Swept volume for low pressure cylinder in m
   ^3:")
21 vdhp=(mc*ts*R)/(sqrt(rp)*ps*10^5);.....//
   Volume of air drawn in high pressure cylinder per
   cycle in m^3
22 vshp=vdhp/etav;.....//Swept volume of high
   pressure cylinder in m^3
23 disp(vshp," Swept volume of high pressure cylinder in
   m^3:")
```

---

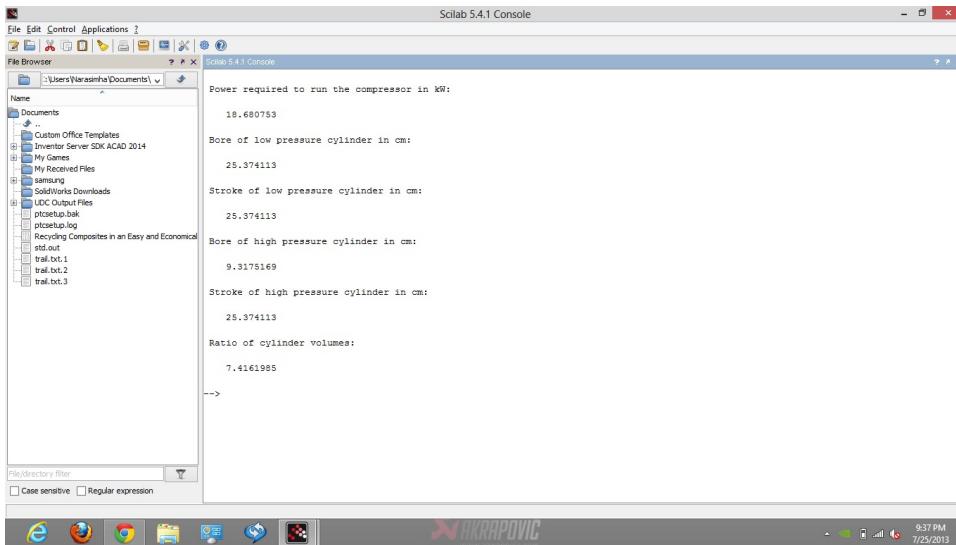


Figure 20.23: Two stage compressor

### Scilab code Exa 20.23 Two stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.23
2 // Initialisation of Variables
3 v1=2.2;.....//free air delivered by the
   compressor in m^3/min
4 p1=1;.....//Suction pressure in bar
5 t1=298;.....//Suction temperature in K
6 pd=55;.....//Delivery pressure in bar
7 N=210;.....//Compressor rpm
8 n=1.3;.....//Compression index
9 k=0.05;.....//Clearance ratio for high pressure
   and low pressure cylinders
10 R=287;.....//Gas constant in J/kgK
11 ns=2;.....//No of stages

```

```

12 // Calculations
13 ps=p1;
14 m =(p1*v1*10^5)/(R*t1);.....//Mass of air
    deivered in m^3/min
15 W=(ns*(n/(n-1)))*m*R*t1*((pd/ps)^((n-1)/(ns*n))-1)
    ;.....//Work done by compressor in Nm/min
16 P=W/(60*1000);.....//Power required to run the
    compressor
17 disp(P,"Power required to run the compressor in kW:")
18 pi=sqrt(ps*pd);.....//Intermediate pressure in
    bar
19 etav1=(1+k)-(k*((pi/p1)^(1/n)));.....//
    Volumetric efficiency of the low pressure
    cylinder
20 Vs=(v1*10^6)/(etav1*N);.....//Swept volume in
    cm^3
21 dlp=(Vs/((%pi/4)))^(1/3);.....//Diameter of low
    pressure cylinder in cm
22 llp=dlp;.....//Stroke of low pressure
    cylinder in cm
23 disp(dlp,"Bore of low pressure cylinder in cm:")
24 disp(llp,"Stroke of low pressure cylinder in cm:")
25 dhp=sqrt(dlp*dlp/pi);.....//Diameter of high
    pressure cylinder in cm
26 lhp=llp;
27 disp(dhp,"Bore of high pressure cylinder in cm:")
28 disp(lhp,"Stroke of high pressure cylinder in cm:")
29 rcv=pi/ps;....//Ratio of cylinder volumes
30 disp(rcv,"Ratio of cylinder volumes:")

```

---

**Scilab code Exa 20.24** Two stage double acting compressor

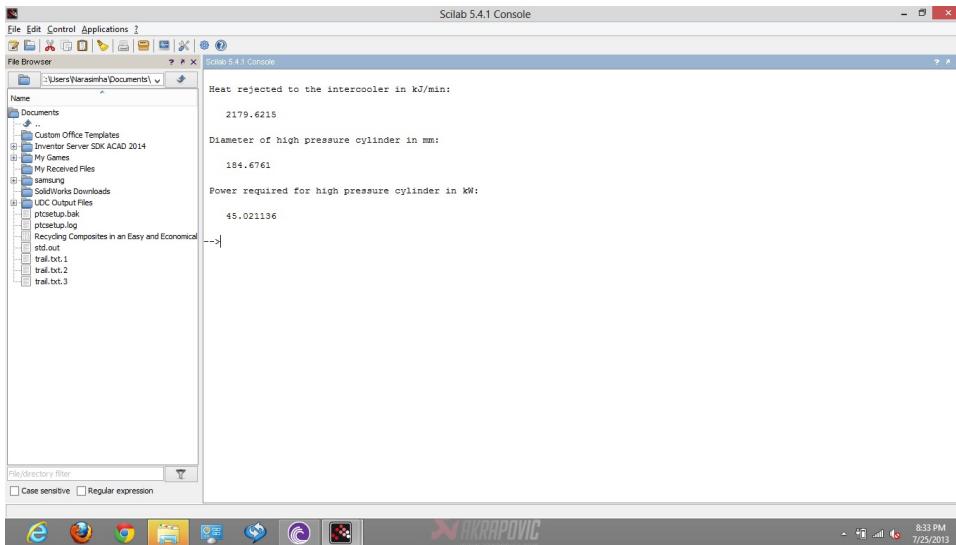


Figure 20.24: Two stage double acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.24
2 // Initialisation of Variables
3 p1=1;.....//Suction pressure in bar
4 p2=4;.....//Intermediate pressure in bar
5 p5=3.8;.....//Pressure of air leaving the
    interooler in bar
6 p6=15.2;.....//Delivery pressure in bar
7 t1=300;.....//Suction temperature in K
8 dlp=0.36;.....//Diameter of low pressure cylinder
    in m
9 llp=0.4;.....//Stroke of low pressure cylinder in
    m
10 N=220;.....//Compressor rpm
11 k=0.04;.....//Clearance ratio
12 cp=1.0035;.....//Specific heat at constant
    pressure in kJ/kgK
13 n=1.3;.....//Compression index
14 R=0.287;.....//Gas constant in kJ/kgK
15 p8=p5;p3=p2;p7=p6;t5=t1;
16 //Calculations

```

```

17 Vslp=(%pi/4)*dlp*dlp*llp*N*2;.....//Swept volume
      in m^3
18 etavlp=(1+k)-(k*((p2/p1)^(1/n)));....//Volumetric
      efficiency
19 valp=Vslp*etavlp;.....//Volume of air
      drawn in low pressure cylinder in m^3
20 m=(p1*10^5*valp)/(R*1000*t1);.....//Mass of air
      drawin in kg/min
21 t2=round(t1*((p2/p1)^((n-1)/n)));
22 Qr=m*cp*(t2-t5);.....//Heat rejected to the
      intercooler in kJ/min
23 disp(Qr,"Heat rejected to the intercooler in kJ/min:
      ")
24 vahp=(m*R*t5*1000)/(p5*10^5);...//Volume of air
      drawn into high pressure cylinder per min in m^3
25 Vshp=vahp/etavlp;.....//Swept volume of high
      pressure cylinder in m^3/min
26 dhp=sqrt(Vshp/((%pi/4)*2*N*llp));.....//
      Diameter of high pressure cylinder in m
27 disp(dhp*1000,"Diameter of high pressure cylinder in
      mm:")
28 P=(n/(n-1))*m*(1/60)*R*(t2-t1);.....//Power
      required for high pressure cylinder in kW
29 disp(P,"Power required for high pressure cylinder in
      kW:")

```

---

### Scilab code Exa 20.25 Two stage single acting compressor

```

1 clc;funcprot(0); //EXAMPLE 20.25
2 // Initialisation of Variables
3 ps=1;.....//Suction pressure in bar
4 pi=4.2;.....//Intermediate pressure in bar
5 pi1=4;.....//Pressure of air leaving the

```

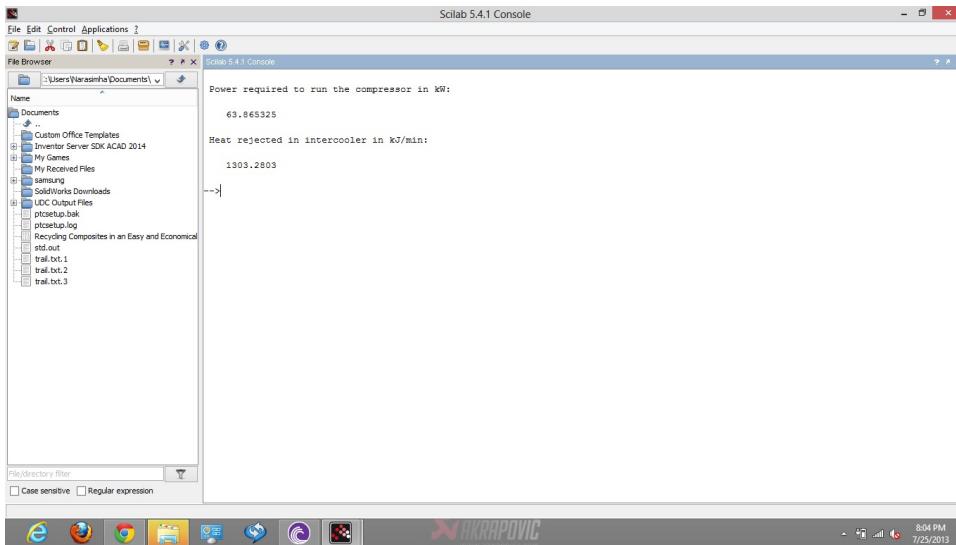


Figure 20.25: Two stage single acting compressor

```

    intercooler in bar
6 pd=18;.....//Delivery pressure in bar
7 t1=298;.....//Suction temperature in K
8 t5=t1;
9 dlp=0.4;.....//Diameter of low pressure cylinder
    in m
10 llp=0.5;.....//Stroke of low pressure cylinder in
    m
11 N=200;.....//Compressor rpm
12 k=0.05;.....//Clearance ratio
13 cp=1.004;.....//Specific heat at constant
    pressure in kJ/kgK
14 n=1.25;.....//Compression index
15 R=0.287;.....//Gas constant in kJ/kgK
16 //Calculations
17 Vs1p=(%pi/4)*dlp*dlp*llp;.....//Swept volume of
    low pressure cylinder in m^3
18 etavlp=(1+k)-(k*((pi/ps)^(1/n)));.....//Volumetric
    efficiency
19 t2=round(t1*((pi/ps)^((n-1)/n)));

```

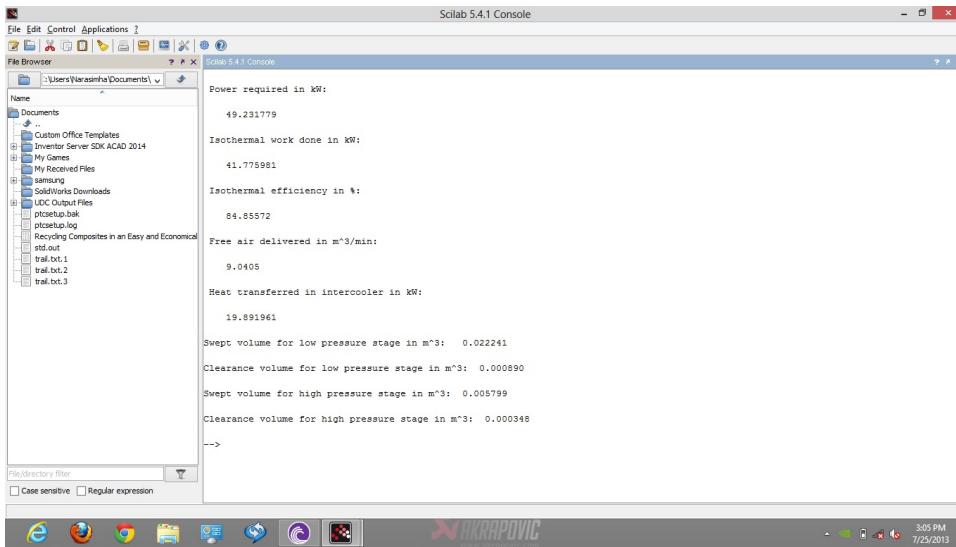


Figure 20.26: Two stage single acting compressor

```

20 m=(ps*10^5*etavlp*Vslp)/(R*1000*t1);... //Mass of air
     in kg
21 wlp=((n)/(n-1))*R*1000*t1*m*((pi(ps)^(n-1)/(n)))
     -1);.....//Work done per min in Nm in low
     pressure cylinder
22 whp=((n)/(n-1))*R*t5*m*1000*((pd/pi1)^(n-1)/(n))
     -1);.....//Work done per min in Nm in high
     pressure cylinder
23 W=wlp+whp;.....//Net work done in Nm
24 IP=(W*N)/(60*1000);.....//Power required to
     run the compressor in kW
25 disp(IP,"Power required to run the compressor in kW:
     ")
26 Qr=m*N*cp*(t2-t1);.....//Heat rejected in
     intercooler in kJ/min
27 disp(Qr,"Heat rejected in intercooler in kJ/min:")

```

---

**Scilab code Exa 20.26** Two stage single acting compressor

```
1 clc;funcprot(0); //EXAMPLE 20.26
2 // Initialisation of Variables
3 p1=1;.....//Intake pressure in bar
4 p2=4;.....//Pressure after first stage in
    bar
5 p3=16;.....//Final pressure in bar
6 ns=2;.....//No of stages
7 t1=300;.....//Intake temperature in K
8 n=1.3;.....//Compression index
9 klp=0.04;.....//Clearance ratio for low pressure
    cylinder
10 khp=0.06;.....//Clearance ratio for high pressure
    cylinder
11 N=440;.....//Engine rpm
12 R=0.287;.....//Gas constant in kJ/kgK
13 m=10.5;.....//Mass of air delivered in kg/
    min
14 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
15 //Calculations
16 rp=sqrt(p1*p3);.....//Pressure ratio per stage
17 P=((ns*n)/(n-1))*R*t1*(m/60)*((p3/p1)^((n-1)/(ns*n))
    )-1);.....//Work done per min in Nm
18 disp(P,"Power required in kW:")
19 isowd=(m/60)*R*t1*log(p3/p1);.....//Isothermal
    work done in Nm
20 disp(isowd,"Isothermal work done in kW:")
21 etaiso=isowd/P;.....//Isothermal
    efficiency
22 disp(etaiso*100,"Isothermal efficiency in %:")
23 FAD=(m*R*t1*1000)/(p1*10^5);.....//Free air
    delivered in m^3/min
```

```

24 disp(FAD,"Free air delivered in m^3/min:")
25 t2=t1*((p2/p1)^((n-1)/n));.....//Temperature at the
   end of compression in K
26 Qt=(m/60)*cp*(t2-t1);.....//Heat
   transferred in intercooler in kW
27 disp(Qt,"Heat transferred in intercooler in kW:")
28 etavlp=(1+klp)-(klp*((p2/p1)^(1/n)));.....//Volumetric efficiency of low pressure stage
29 etavhp=(1+khp)-(khp*((p2/p1)^(1/n)));.....//Volumetric efficiency of high pressure stage
30 vslp=FAD/(N*etavlp);.....//Swept volume for low
   pressure stage in m^3
31 vclp=klp*vsdp;.....//Clearance volume for
   low pressure stage in m^3
32 printf("\nSwept volume for low pressure stage in m
   ^3: %f\n",vsdp)
33 printf("\nClearance volume for low pressure stage in
   m^3: %f\n",vclp)
34 vsdp=FAD/(N*rp*etavhp);.....//Swept volume for high
   pressure stage in m^3
35 vchp=khp*vsdp;.....//Clearance volume for
   high pressure stage in m^3
36 printf("\nSwept volume for high pressure stage in m
   ^3: %f\n",vsdp)
37 printf("\nClearance volume for high pressure stage
   in m^3: %f\n",vchp)

```

---

### Scilab code Exa 20.27 Three stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.27
2 // Initialisation of Variables
3 ns=3;.....//No of stages
4 p1=1.05;.....//Intake pressure in bar

```

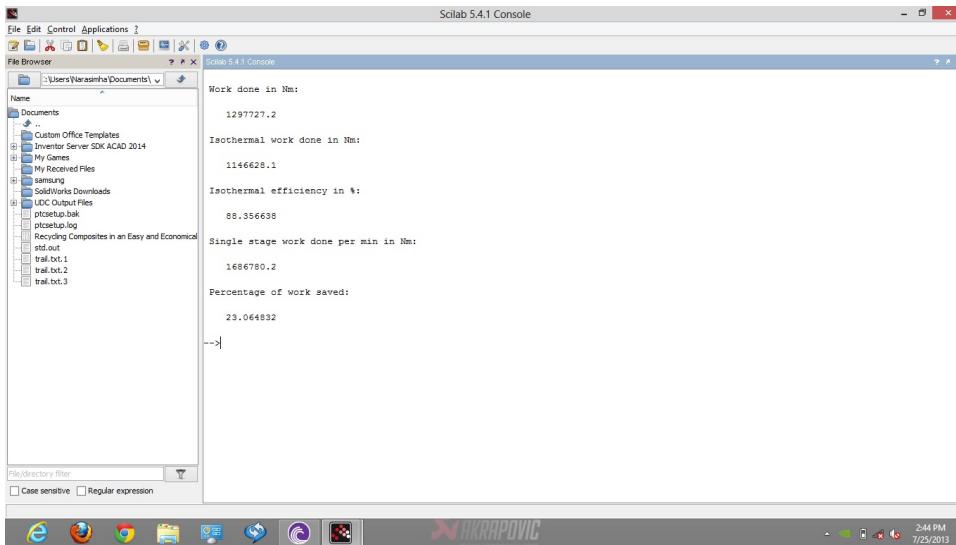


Figure 20.27: Three stage compressor

```

5 pd=40;.....//Delivery pressure in bar
6 V=3;.....//Volume of air xupplied per min in m
^3
7 n=1.25;.....//Compression index
8 //Calculations
9 Wd=((ns*n)/(n-1))*p1*V*10^5*((pd/p1)^((n-1)/(ns*n))
    )-1;.....//Work done per min in Nm
10 disp(Wd,"Work done in Nm:")
11 isoWd=10^5*p1*V*log(pd/p1);.....//Isothermal
    work done in Nm
12 disp(isoWd,"Isothermal work done in Nm:")
13 etaiso=isoWd/Wd;.....//Isothermal
    efficiency
14 disp(etaiso*100,"Isothermal efficiency in %:")
15 wdss=((n)/(n-1))*p1*V*10^5*((pd/p1)^((n-1)/(n)))-1
    ;.....//Single stage Work done per min in Nm
16 disp(wdss,"Single stage work done per min in Nm:")
17 perws=(wdss-Wd)/wdss;.....//Percentage of work
    saved
18 disp(perws*100,"Percentage of work saved:")

```

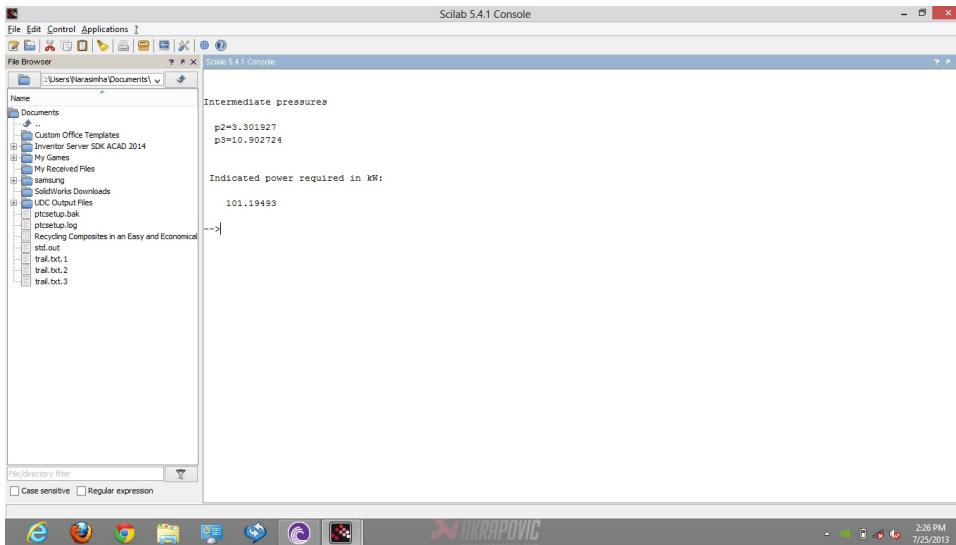


Figure 20.28: Three stage compressor

### Scilab code Exa 20.28 Three stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.28
2 // Initialisation of Variables
3 p1=1; ..... //Intake pressure in bar
4 p4=36; ..... //Final pressure in bar
5 n=1.25; ..... //Compression index
6 R=0.287; ..... //Gas constant in kJ/kgK
7 t1=300; ..... //Intake temperature in K
8 ns=3; ..... //No of stages
9 v=15; ..... //Volume of air delivered in m^3
10 //Calculations
11 p2=p1*((p4/p1)^(1/ns));
12 p3=p2*((p4/p1)^(1/ns));
13 printf("\n\nIntermediate pressures\n\n    p2=%f\n    p3=%f\n"

```

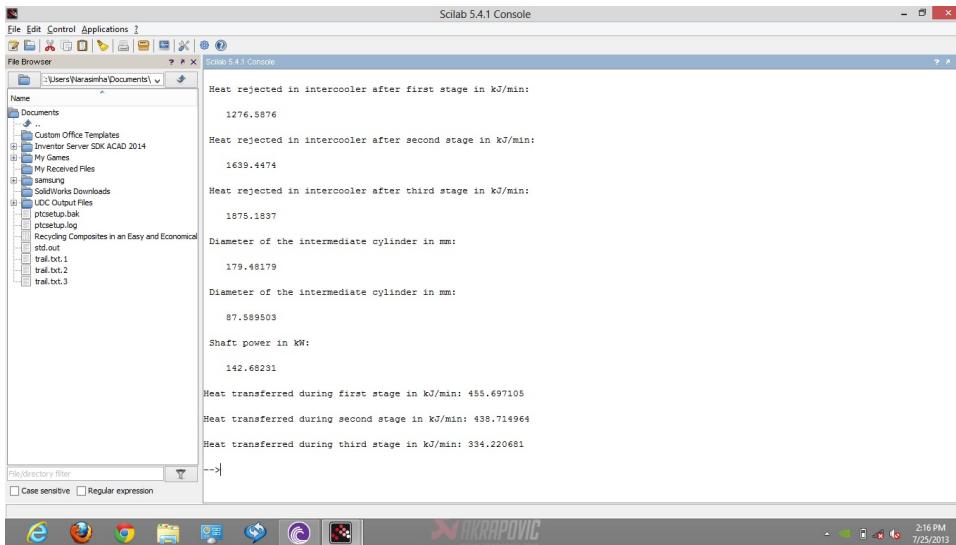


Figure 20.29: Three stage compressor

```

%f\n\n",p2,p3)
14 t2=t1*((p4/p1)^(((n-1)/n)*(1/ns)));..... // Delivery
      temperature in K
15 m=p1*10^5*v/(R*1000*t1);..... //Mass of air
      handled per min in kg
16 Wt=((n/(n-1))*m*R*(1/60)*(t2-t1)*ns);..... //Total
      work done in three stages
17 disp(Wt," Indicated power required in kW:")

```

---

### Scilab code Exa 20.29 Three stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.29
2 // Initialisation of Variables
3 ns=3;..... //No of stages
4 N=200;..... //Compressor rpm
5 p1=1;..... //Intake pressure in bar

```

```

6 t1=20+273;.....//Intake temperature in K
7 D=0.35;.....//Engine bore in m
8 L=0.4;.....//Engine stroke in m
9 p2=4;.....//Discharge pressure from first stage
   in bar
10 p6=16;.....//Discharge pressure from second stage
    in bar
11 p10=64;.....//Discharge pressure from third stage
    in bar
12 pd=0.2;.....//Loss of pressure between
    intercoolers in bar
13 R=0.287;.....//Gas constant in kJ/kgK
14 k=0.04;.....//Clearence volume in 4% of the stroke
    volume
15 n1=1.2;.....//Compressor index for first stage
16 n2=1.25;.....//Compressor index for second stage
17 n3=1.3;.....//Compressor index for third stage
18 cp=1.005;.....//Specific heat at constant pressure
    in kJ/kgK
19 etamech=0.8;.....//Mechanical efficiency
20 //Calculations
21 p5=p2-pd;p9=p6-pd;t5=t1;t9=t1;
22 Vs=(%pi/4)*D*D*L*N*2;.....//Swept volume of
    low pressure cylinder per min in m^3
23 etav1=(1+k)-(k*((p2/p1)^(1/n1)));.....//Volumetric
    efficiency in first stage
24 etav2=(1+k)-(k*((p6/p5)^(1/n2)));.....//Volumetric
    efficiency in second stage
25 etav3=(1+k)-(k*((p10/p9)^(1/n3)));.....//Volumetric
    efficiency in third stage
26 vain1=Vs*etav1;.....//Volume of air
    taken in first stage in m^3/min
27 m=(p1*10^5)*vain1/(R*t1*1000);.....//Mass of
    air intake in kg/min in first stage
28 t2=round(t1*((p2/p1)^((n1-1)/n1)));
29 t6=t5*((p6/p5)^((n2-1)/n2));
30 t10=t9*((p10/p9)^((n3-1)/n3));
31 Qr1=m*cp*(t2-t5);.....//Heat rejected in

```

```

        intercooler after first stage in kJ/min
32  Qr2=m*cp*(t6-t9);.....//Heat rejected in
        intercooler after second stage in kJ/min
33  Qr3=m*cp*(t10-t1);.....//Heat rejected in
        intercooler after third stage in kJ/min
34  disp(Qr1,"Heat rejected in intercooler after first
        stage in kJ/min:")
35  disp(Qr2,"Heat rejected in intercooler after second
        stage in kJ/min:")
36  disp(Qr3,"Heat rejected in intercooler after third
        stage in kJ/min:")
37  vainip=m*R*t5*1000/(p5*10^5);.....//Volume drawn
        in intermediate pressure cylinder/min
38  Vsip=vainip/etav2;.....//Swept volume of
        intermediate cylinder in m^3/min
39  Dip=sqrt(Vsip/(2*N*L*(%pi/4)));.....//
        Diameter of the intermediate cylinder in m
40  disp(Dip*1000,"Diameter of the intermediate cylinder
        in mm:")
41  vainhp=m*R*t9*1000/(p9*10^5);.....//Volume drawn
        in high pressure cylinder/min
42  Vshp=vainhp/etav3;.....//Swept volume of
        high pressure cylinder in m^3/min
43  Dhp=sqrt(Vshp/(2*N*L*(%pi/4)));.....//
        Diameter of the intermediate cylinder in m
44  disp(Dhp*1000,"Diameter of the intermediate cylinder
        in mm:")
45  Ps=[{(n1/(n1-1))*m*R*(t2-t1)}+{(n2/(n2-1))*m*R*(t6-
        t5)}+{(n3/(n3-1))*m*R*(t10-t9)}]*(1/(60*etamech))
        ;...//Shaft power in kW
46  disp(Ps,"Shaft power in kW:")
47  cv=cp-R;.....//Specific heat at constant volume
        in kJ/kgK
48  ga=cp/cv;.....//Ratio of specific heats
49  Qt1=cv*((ga-n1)/(ga-1))*(t2-t1)*m;.....//Heat
        transfer during first stage in kJ/min
50  Qt2=cv*((ga-n2)/(ga-1))*(t6-t1)*m;.....//Heat
        transfer during second stage in kJ/min

```

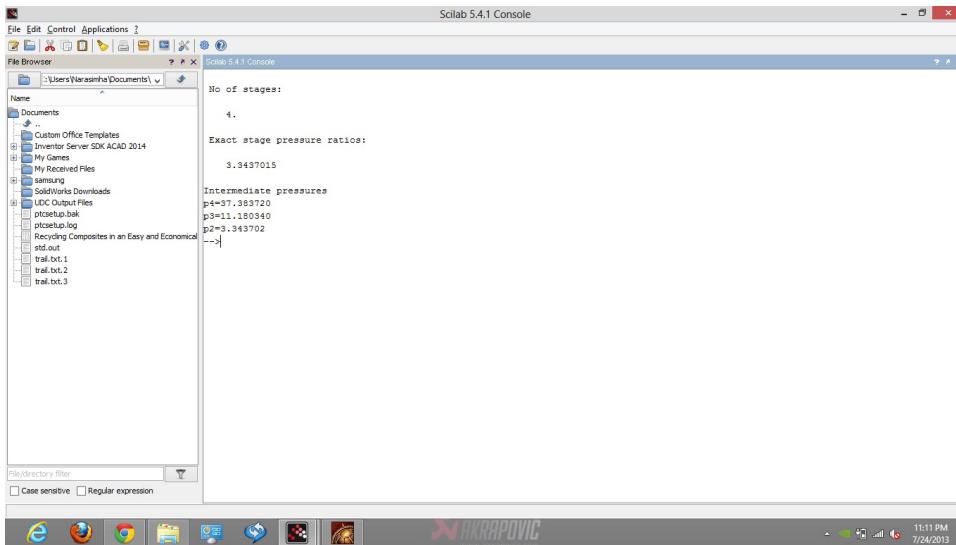


Figure 20.30: Multi stage compressor

```

51 Qt3=cv*((ga-n3)/(ga-1))*(t10-t1)*m;.....//  

     Heat transfer during third stage in kJ/min  

52 printf("\nHeat transferred during first stage in kJ/  

     min: %f\n",Qt1)  

53 printf("\nHeat transferred during second stage in kJ  

     /min: %f\n",Qt2)  

54 printf("\nHeat transferred during third stage in kJ/  

     min: %f\n",Qt3)

```

---

### Scilab code Exa 20.30 Multi stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.30
2 // Initialisation of Variables
3 p1=1;.....//Intake pressure in bar
4 p5=125;.....//Pressure of the compressed air in bar
5 rpr=4;.....//Pressure ratio is restricted to 4

```

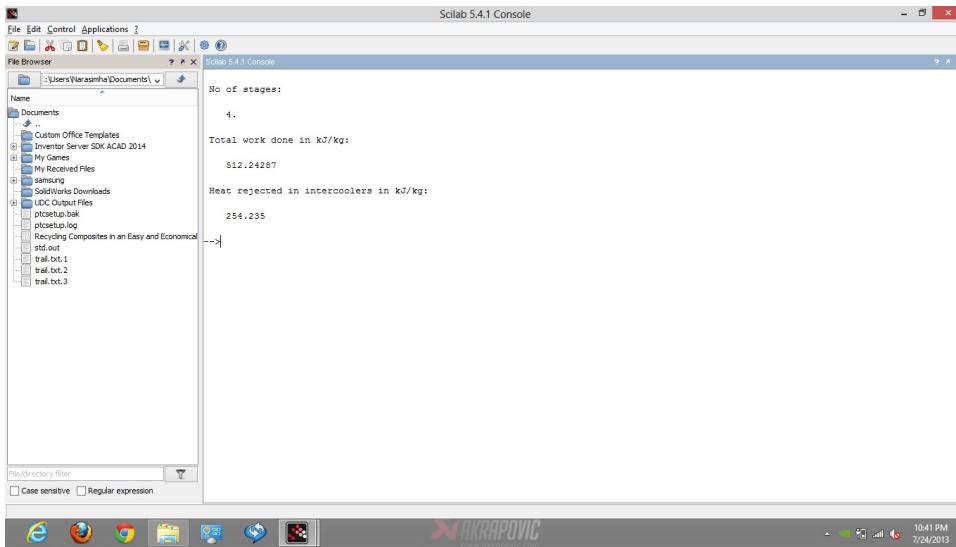


Figure 20.31: Multi stage compressor

```

6 // Calculations
7 X=(log(p5/p1)/log(rpr));
8 if(X>round(X))
9 x=round(X)+1;
10 else
11     x=round(X);
12 end
13 disp(x,"No of stages:")
14 esrp=(p5/p1)^(1/x);
15 disp(esrp,"Exact stage pressure ratios:")
16 p4=p5/esrp;p3=p4/esrp;p2=p3/esrp;.....//  

    Intermediate pressures in bar
17 printf("\nIntermediate pressures\np4=%f\np3=%f\np2=%f",p4,p3,p2)

```

---

### Scilab code Exa 20.31 Multi stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.31
2 // Initialisation of Variables
3 ps=1;.....//Suction pressure in bar
4 t1=273+125;.....//Delivery temperature in K
5 pd=160;.....//Delivery pressure in bar
6 tm=40+273;.....//Min temperature
7 ts=298;.....//Suction temperature in K
8 n=1.25;.....//Adiabatic index
9 cv=0.71;.....// Specific heat at constant volume in
   kJ/kgK
10 R=0.287;.....//Gas constant in kJ/kgK
11 ns=3;.....//No of stages
12 //Calculations
13 p1=ps*((t1/ts)^(n/(n-1)));
14 x=(log(pd/p1))/(((n/(n-1))*(log(t1/tm))));
15 disp(round(x)+1,"No of stages:")
16 rp1=p1;.....//Pressure ratio in 1st stage
17 rp=(pd/rp1)^(1/ns);.....//Pressure ratio in the
   following stage
18 W=(n/(n-1))*R*ts*((rp1)^((n-1)/n))-1);.....//
   Work done in first stage in kJ
19 Wf=ns*(n/(n-1))*R*tm*((rp)^((n-1)/n))-1);.....
   //Work done in next three stages in kJ
20 wt=W+Wf;.....//Total work done per kg in kJ
21 disp(wt," Total work done in kJ/kg:")
22 cp=cv+R;.....// Specific heat at constant
   pressure in kJ/kgK
23 Qr=ns*cp*(t1-tm);.....//Heat rejected in
   intercoolers in kJ/kg
24 disp(Qr," Heat rejected in intercoolers in kJ/kg:")

```

---

**Scilab code Exa 20.32** Three stage compressor

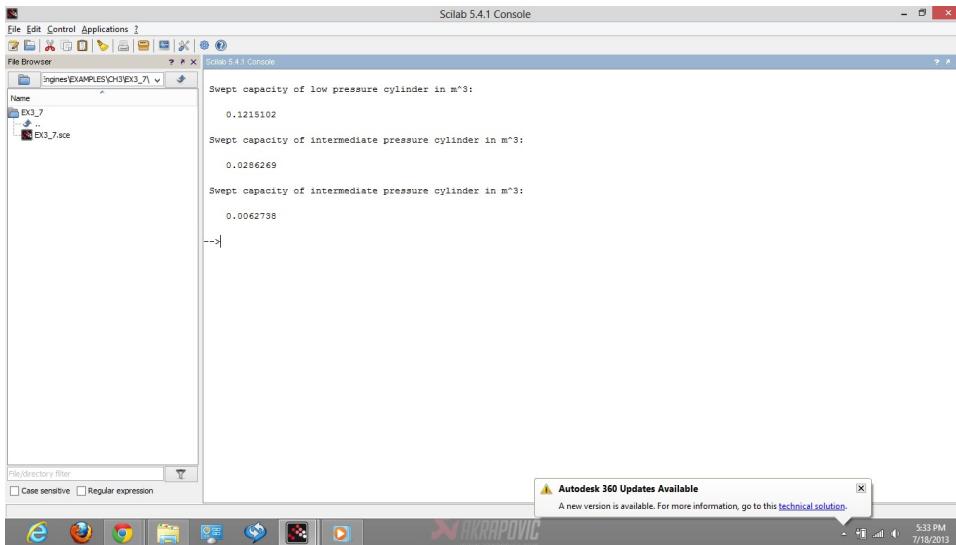


Figure 20.32: Three stage compressor

```

1 clc;funcprot(0); //EXAMPLE 20.32
2 // Initialisation of Variables
3 Vamb=10.5;.....//Free air volume in m^3
4 Pamb=1.013;.....//Free air presssure in bar
5 Tamb=273+15;.....//Free air temperature in K
6 T1=(273+25);.....//Temperature at the end of
    suction in all cylinders in K
7 P1=1;.....//Pressure at the suction in bar
8 pd=95;.....//Delivery presssure in bar
9 N=100;.....//Compressor rpm
10 n=1.25;.....//Adiabatic index
11 k=0.04;.....//Fractional clearances for LP
12 k1=0.07;.....//Fractional clearances for HP
13 //Calculations
14 z=(pd/P1)^(1/3);.....// Pressure ratio
15 pi1=z*P1;
16 pi2=z*pi1;
17 etavollp=1+k-(k*(z^(1/n)));
18 etavolhp=1+k1-(k1*(z^(1/n)));
19 v1=(Pamb*Vamb*T1)/(Tamb*P1);

```

```

20 sclp=(round(v1))/(etavolpp*N);.....//Swept
    capacity of LP cylinder in m^3
21 disp(sclp,"Swept capacity of low pressure cylinder
    in m^3:")
22 vip=(Pamb*Vamb*T1)/(pi1*Tamb);.....//Volume of
    free air reduced to suction conditions of IP
    cylinder
23 scip=vip/(etavolhp*N);.....//Swept capacity of
    IP cylinder in m^3
24 disp(scip,"Swept capacity of intermediate pressure
    cylinder in m^3:")
25 vhp=(Pamb*Vamb*T1)/(pi2*Tamb);.....//Volume of
    free air reduced to suction conditions of HP
    cylinder
26 schp=vhp/(etavolhp*N);.....//Swept capacity of
    HP cylinder in m^3
27 disp(schp,"Swept capacity of intermediate pressure
    cylinder in m^3:")

```

---

**Scilab code Exa 20.34** Indicated power and air supplied per minute

```

1 clc;funcprot(0); //EXAMPLE 20.34
2 // Initialisation of Variables
3 D=0.0635;.....//Engine bore in m
4 L=0.114;.....//Engine stroke in m
5 p1=6.3;.....//Supply pressure in bar
6 t1=273+24;.....//Supply temperature in K
7 p4=1.013;.....//Exhaust pressure in bar
8 cv=0.05;.....//Clearance volume is 5% of the
    swept volume
9 cr=0.5;.....//Cut off ratio
10 n=1.3;.....//Adiabatic index
11 R=287;.....//gas constant in kJ/kgK

```

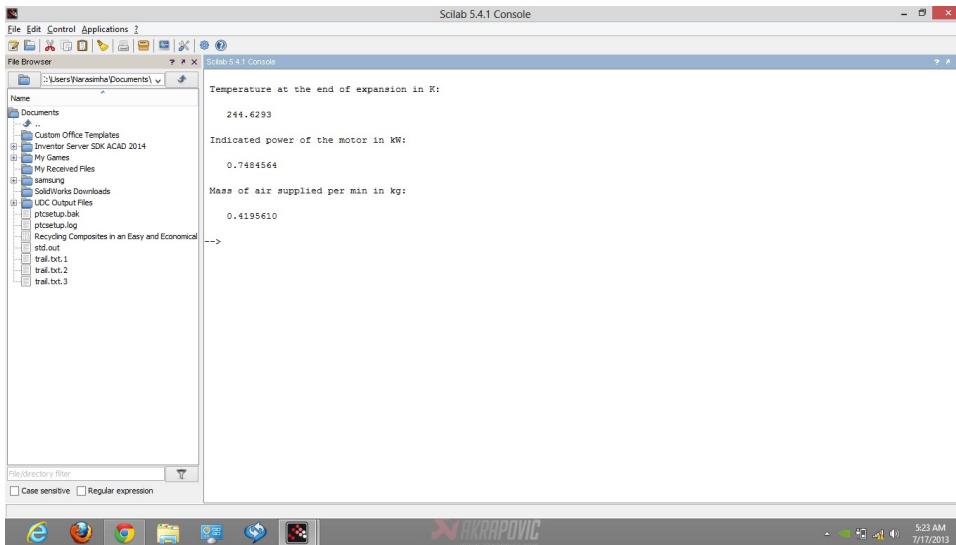


Figure 20.33: Indicated power and air supplied per minute

```

12 N=300;..... //Engine rpm
13 ga=1.4;..... //Ratio of specific heats
14 //Calculations
15 Vs=(%pi*D*D*L)/4;..... //Swept volume in m^3
16 Vc=cv*Vs;..... //Clearance volume in m^3
17 v6=Vc;v5=v6;
18 v1=(Vs/2)+Vc;v2=Vs+Vc;v3=v2;p3=p4;v4=v5+(cv*Vs);
19 p2=p1*((v1/v2)^n);..... //Pressure at the end of
    expansion
20 t2=t1*((v1/v2)^(n-1));..... //Temperature at the
    end of expansion in K
21 disp(t2,"Temperature at the end of expansion in K:")
22 p5=p4*((v4/v5)^n);
23 w=((p1*(v1-v6))+(((p1*v1)-(p2*v2))/(n-1))-(p3*(v3-v4))
    )-(((p5*v5)-(p4*v4))/(n-1))*10^5;..... //Workk
        done per cycle in Nm
24 IP=(w*N)/(60*1000);..... //Indicated power in kW
25 disp(IP,"Indicated power of the motor in kW:")
26 t3=t2*((p3/p2)^((ga-1)/ga));
27 t4=t3;m4=(p4*v4*10^5)/(R*t4);m1=(p1*v1*10^5)/(R*t1);

```

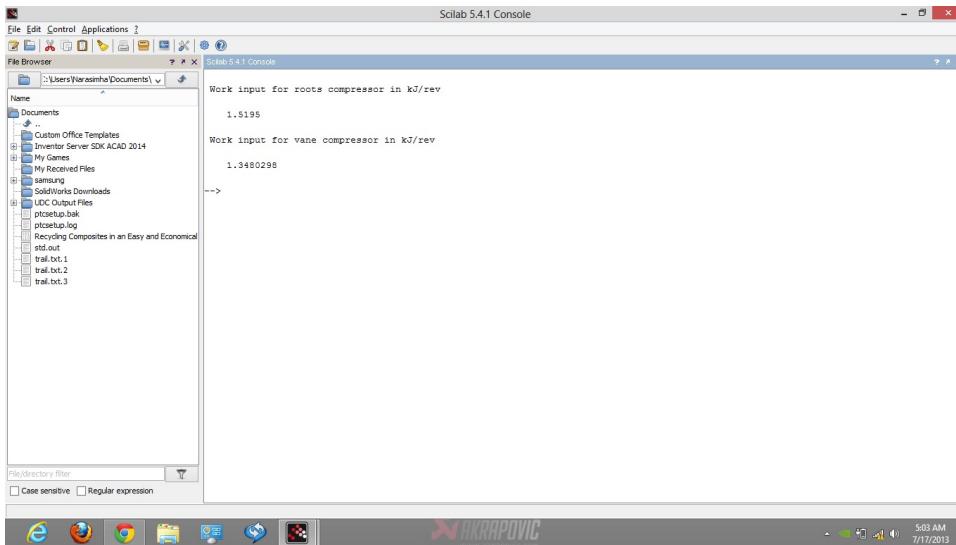


Figure 20.34: Comparison of roots blower and vane type compressor

---

```

28 ma=(m1-m4)*N; ..... //Mass of air supplied per
min
29 disp(ma,"Mass of air supplied per min in kg:")

```

---

**Scilab code Exa 20.35** Comparison of roots blower and vane type compressor

```

1 clc;funcprot(0); //EXAMPLE 20.35
2 // Initialisation of Variables
3 v=0.03; ..... //Induced volume in m^3/rev
4 p1=1.013; ..... //Inlet pressure in bar
5 rp=1.5; ..... //Pressure ratio
6 ga=1.4; ..... //Ratio of specific heats
7 //Calculations
8 p2=rp*p1;

```

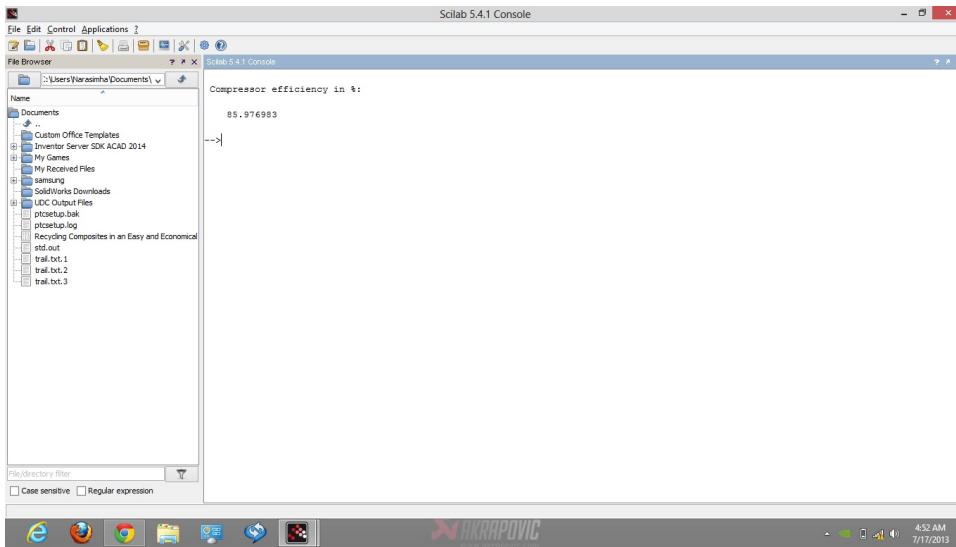


Figure 20.35: Roots blower

```

9 wr=(p2-p1)*(10^5)*v/1000;..... //Work input for roots
      compressor in kJ
10 disp(wr,"Work input for roots compressor in kJ/rev")
11 pi=(p2+p1)/2;
12 wv=((p2-pi)*(10^5)*v*((p1/pi)^(1/ga))*(1/1000))+((ga
      /(ga-1))*p1*(10^5)*(v/1000)*(((pi/p1)^(ga-1/ga)
      )-1));... //Work input required for vane type in
      kJ/rev
13 disp(wv,"Work input for vane compressor in kJ/rev")

```

---

### Scilab code Exa 20.36 Roots blower

```

1 clc;funcprot(0); //EXAMPLE 20.36
2 // Initialisation of Variables
3 v=0.08;.....//Volume of air compressed in m^3
4 p1=1;.....//Intake pressure in bar

```

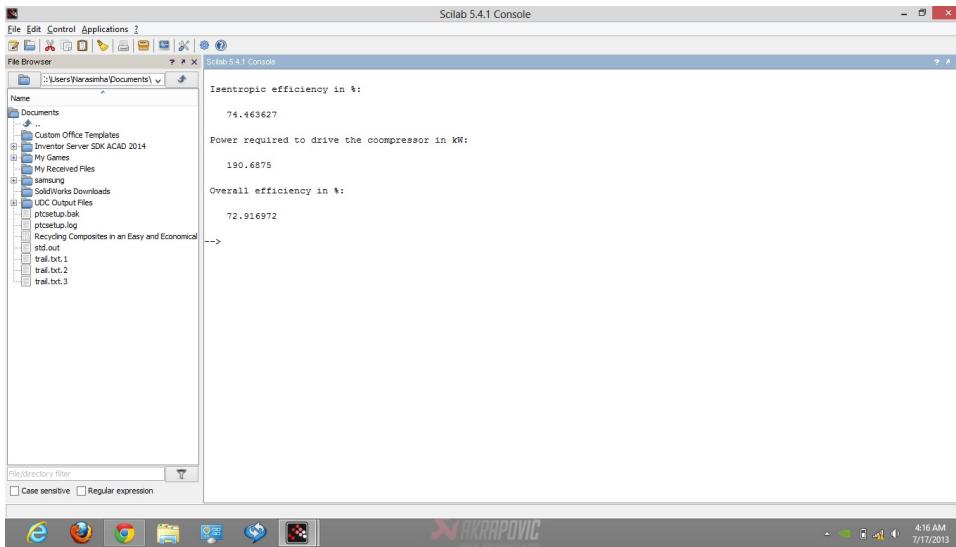


Figure 20.36: Centrifugal compressor

```

5 p2=1.5;.....// Pressure after compression in in
   bar
6 ga=1.4;.....// Ratio of specific heats
7 //Calculations
8 wac=v*(p2-p1)*10^5;.....// Actual work done in Nm
9 wid=(ga/(ga-1))*p1*v*(10^5)*(((p2/p1)^((ga-1)/ga))
   -1);.....// Ideal work done per revolution
   in Nw
10 etac=wid/wac;.....// Compressor efficiency
11 disp(etac*100,"Compressor efficiency in %:")

```

---

### Scilab code Exa 20.37 Centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.37
2 // Initialisation of Variables
3 m=2.5;.....// Air flow rate in kg/s

```

```

4 p1=1;.....//Inlet pressure in bar
5 t1=290;.....//Inlet temperature in bar
6 C1=80;.....//Inlet Velocity in m/s
7 p2=1.5;.....//pressure after compression in bar
8 t2=345;.....//temperature after compression
    in bar
9 C2=220;.....//Velocity after compression in m/s
10 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
11 ga=1.4;.....//Ratio of specific heats
12 R=287;.....//Gas constant for air in kJ/kgK
13 //Calculations
14 t21=t1*((p2/p1)^((ga-1)/ga));
15 wisen=cp*(t21-t1)+((C2*C2)-(C1*C1))/(2*1000);....//
    Isentropic work done in kJ/kg
16 w=cp*(t2-t1)+((C2*C2)-(C1*C1))/(2*1000);....//
    Actual work done (in impeller) in kJ/kg
17 etaisen=wisen/w;.....//Isentropic
    efficiency
18 disp(etaisen*100,"Isentropic efficiency in %:")
19 P=m*w;.....//Power required to drive the
    coompressor in kW
20 disp(P,"Power required to drive the coompressor in
    kW:")
21 t3=(((C2*C2)-(C1*C1))/(2*1000*cp))+t2;....//
    Temperature of air after leaving the diffuser in
    K
22 p3=p2*((t3/t2)^(ga/(ga-1)));.....//Pressure of
    air after leaving the diffuser in bar
23 t31=t1*((p3/p1)^((ga-1)/ga));.....//Delivery
    temperature from diffuser in K
24 etao=(t31-t1)/(t3-t1);.....//Overall
    efficiency
25 disp(etao*100,"Overall efficiency in %:")

```

---

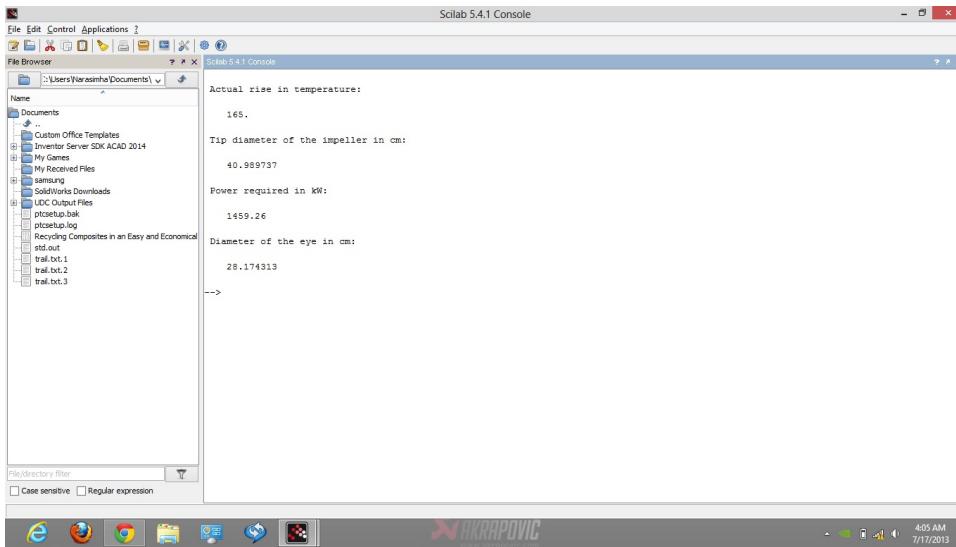


Figure 20.37: Single inlet type centrifugal compressor

### Scilab code Exa 20.38 Single inlet type centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.38
2 // Initialisation of Variables
3 ma=528;.....//Air flow in kg/min
4 m=ma/60;.....//Air flow in kg/s
5 p1=1;.....//Inlet pressure in bar
6 t1=293;.....//Inlet temperature in bar
7 N=20000;.....//Compressor rpm
8 etaisen=0.8;.....//Isentropic efficiency
9 po1=1;.....//Static pressure in bar
10 p02=4;.....//Final total pressure in bar
11 C1=145;.....//Velocity of air when entering the
    impeller in m/s
12 rwt=0.9;.....//Ratio of whirl speed to tip
    speed
13 dh=0.12;.....//Hub diameter in m

```

```

14 cp=1.005;.....// Specific heat at constant
    pressure in kJ/kgK
15 ga=1.4;.....//Ratio of specific heats
16 R=287;.....//Gas constant for air in kJ/kgK
17 //Calculations
18 t01=t1+((C1*C1)/(2*cp*1000));.....//Stagnation
    temperature at the inlet to the machine in K
19 p01=p1*((t01/t1)^(ga/(ga-1)));....//Stagnation
    pressure at the inlet to the machine in bar
20 t021=t01*((p02/p01)^((ga-1)/ga));
21 deltisen=t021-t01;.....//Isentropic rise in
    temperature in K
22 delt=round(deltisen/etaisen);.....//Actual rise
    in temperature
23 disp(delt,"Actual rise in temperature:")
24 wc=cp*delt;.....//Work consumed by compressor in
    kJ/kg
25 Cb12=sqrt(wc*1000/rwt);
26 d2=Cb12*60/(%pi*N);.....//Tip diameter of the
    impeller in m
27 disp(d2*100,"Tip diameter of the impeller in cm:")
28 P=m*wc;.....//Power required in kW
29 disp(P,"Power required in kW:")
30 rho1=(p1*10^5)/(R*t1);.....//Density at entry in
    kg/m^3
31 d1=sqrt(((m*4)/(C1*rho1*%pi))+(dh^2));.....//Eye
    diameter in m
32 disp(d1*100,"Diameter of the eye in cm:")

```

---

### Scilab code Exa 20.39 Centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.39
2 // Initialisation of Variables

```

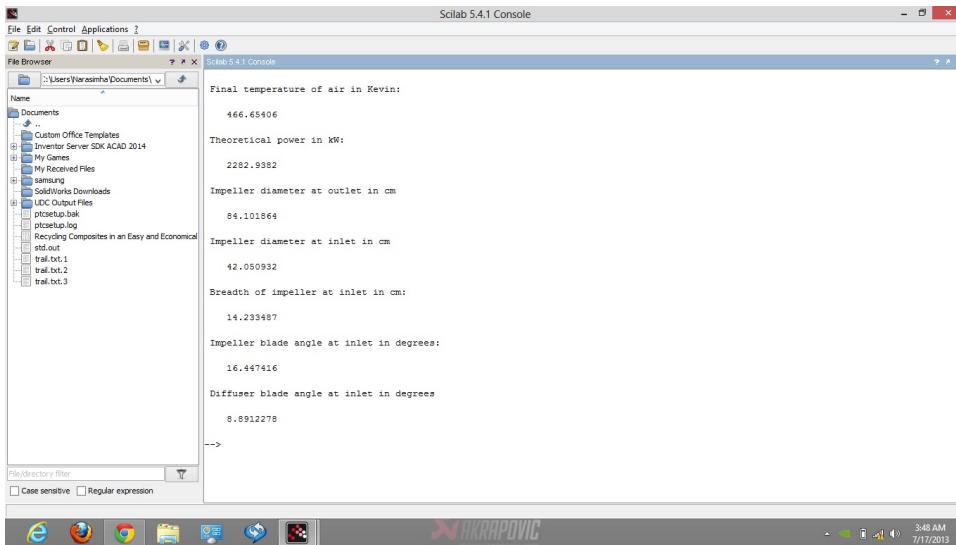


Figure 20.38: Centrifugal compressor

```

3 N=10000;..... //Compressor rpm
4 v=660;..... //Volume of air delivered in m^3/
               min
5 p1=1;..... //Inlet pressure in bar
6 t1=293;..... //Inlet temperature in K
7 rp=4;..... //Pressure ratio
8 etaisen=0.82;..... //Isentropic efficiency
9 Cf2=62;..... //Flow velocity in m/s
10 rr=2;..... //Ratio of outer radius of
                impeller to inner radius of impeller
11 ka=0.9;..... //Blade area co efficient
12 fis=0.9;..... //Slip factor
13 cp=1.005;..... //Specific heat at constant
                  pressure in kJ/kgK
14 ga=1.4;..... //Ratio of specific heats
15 R=287;..... //Gas constant for air in kJ/kgK
16 //Calculations
17 t21=t1*(rp^((ga-1)/ga));Cf1=Cf2;
18 t2=t1+((t21-t1)/etaisen);..... //Final
               temperature of air

```

```

19 m=(p1*10^5*v/60)/(R*t1);..... //Mass flow
    rate in m^3/s
20 P=m*cp*(t2-t1);..... //Theoretical power in kW
21 disp(t2,"Final temperature of air in Kevin:")
22 disp(P,"Theoretical power in kW:")
23 Cbl2=sqrt(1000*cp*(t2-t1)/fis);
24 d2=60*Cbl2/(%pi*N);..... //Impeller diameter at
    outlet in m
25 d1=d2/rr;..... //Impeller diameter at inlet
    in m
26 disp(d2*100,"Impeller diameter at outlet in cm")
27 disp(d1*100,"Impeller diameter at inlet in cm")
28 b1=(v/60)/(2*%pi*(d1/2)*Cf1*ka);..... //Breadth
    of impeller at inlet in m
29 disp(b1*100,"Breadth of impeller at inlet in cm:")
30 Cbl1=Cbl2/rr;
31 beta1=(atan(Cf1/Cbl1))*180/%pi;
32 al2=(atan(Cf2/(fis*Cbl2)))*180/%pi;
33 disp(beta1,"Impeller blade angle at inlet in degrees
    :")
34 disp(al2,"Diffuser blade angle at inlet in degrees")

```

---

### Scilab code Exa 20.40 Centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.40
2 // Initialisation of Variables
3 v1=4.8;..... //Volume of air compressed in m^3/s
4 p1=1;.... //Inlet pressure in bar
5 t1=293;..... //Inlet pressure in K
6 n=1.5;..... //Compression index
7 Cf1=65;..... //Air flow velocity at inlet in m/s
8 Cf2=Cf1;..... //Flow velocity is same at inlet and
    outlet

```

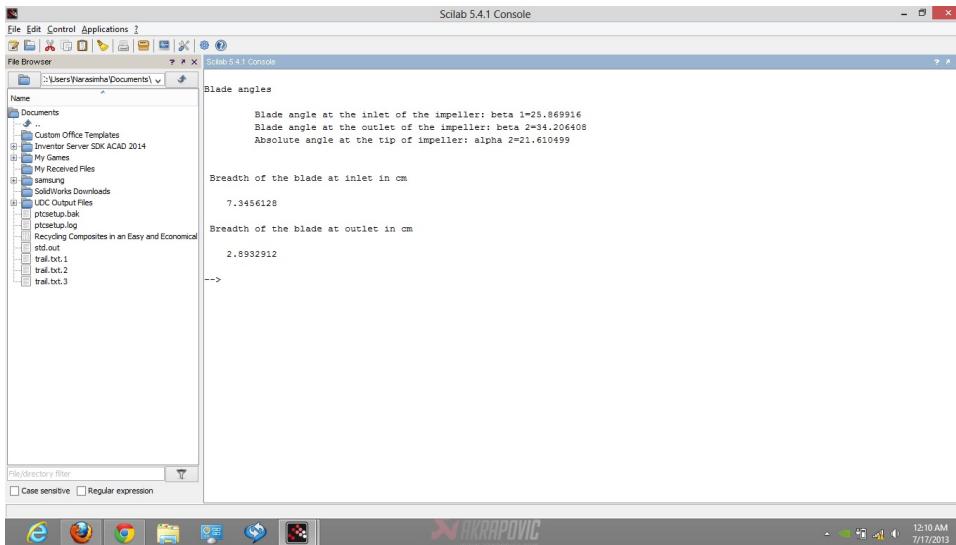


Figure 20.39: Centrifugal compressor

```

9 d1=0.32;.....//Inlet impeller diameter in m
10 d2=0.62;.....//Outlet impeller diameter in m
11 N=8000;.....//Blower rpm
12 cp=1.005;.....//Specific heat at constant pressure
    in kJ/kgK
13 //Calculations
14 t21=t1*((n/p1)^((n-1)/n));....//Temperature at the
    outlet of compressor in K
15 Cb11=(%pi*d1*N)/60;.....//Peripheral velocity at
    inlet in m/s
16 Cb12=(%pi*N*d2)/60;.....//Tip peripheral velocity
    at outlet in m/s
17 Cw2=(cp*(t21-t1)*1000)/Cb12;
18 be1=(atan(Cf1/Cb11))*180/%pi;be2=(atan(Cf2/(Cb12-Cw2
    )))*180/%pi;.....//Blade angles at the tip of
    the impeller
19 al2= (atan(Cf2/Cw2))*180/%pi;
20 printf("\nBlade angles \n\n\t Blade angle at the
    inlet of the impeller: beta 1=%f \n\t Blade angle
    at the outlet of the impeller: beta 2=%f \n\t

```

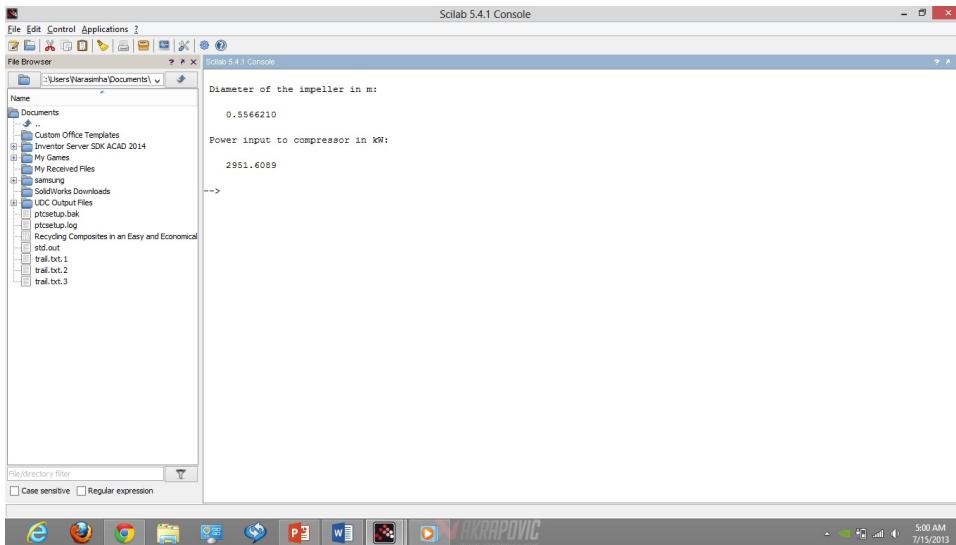


Figure 20.40: Centrifugal compressor

```

Absolute angle at the tip of impeller: alpha 2=%f
\n\n",be1,be2,a12)
21 b1=v1/(2*pi*(d1/2)*Cf1);.....//Breadth of blade
    at inlet in m
22 disp(b1*100,"Breadth of the blade at inlet in cm")
23 v2=(v1*t21*p1)/(n*t1);.....//Discharge at
    the outlet in m^3/s
24 b2=v2/(2*pi*(d2/2)*Cf2);.....//Breadth of blade
    at outlet in m
25 disp(b2*100,"Breadth of the blade at outlet in cm")

```

---

### Scilab code Exa 20.41 Centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.41
2 // Initialisation of Variables
3 m=16.5;.....//Air flow in kg/s

```

```

4 rp=4;..... // Pressure ratio
5 N=15000;..... // Compressor rpm
6 t01=293;..... // Inlet head temperature
7 fis=0.9;..... // Slip factor
8 fiw=1.04;..... // Power input factor
9 etaisen=0.8;..... // Isentropic efficiency
10 cp=1.005;..... // Specific heat at constant
    pressure in kJ/kgK
11 ga=1.4;..... // Ratio of specific heats
12 // Calculations
13 t021=t01*(rp^((ga-1)/ga));
14 delt=(t021-t01)/etaisen;Cbl2=sqrt((1000*cp*delt)/(
    fiw*fis));
15 D=(60*Cbl2)/(%pi*N);..... // Diameter of
    impeller
16 disp(D,"Diameter of the impeller in m:")
17 P=m*cp*delt;
18 disp(P,"Power input to compressor in kW:")

```

---

### Scilab code Exa 20.42 Centrifugal compressor

```

1 clc;funcprot(0); //EXAMPLE 20.42
2 // Initialisation of Variables
3 rp=3.6;..... // Pressure ratio
4 die=0.35;..... // Diameter of inlet eye of
    compressor in m
5 Cf=140;..... // Axial velocity in m/s
6 m=12;..... // Mass flow in kg/s
7 Cbl2=120;..... // Velocity in the delivery duct in
    m/s
8 Ci=460;..... // The tip speed of the impeller in
    m/s
9 N=16000;..... // Speed of impeller in rpm

```

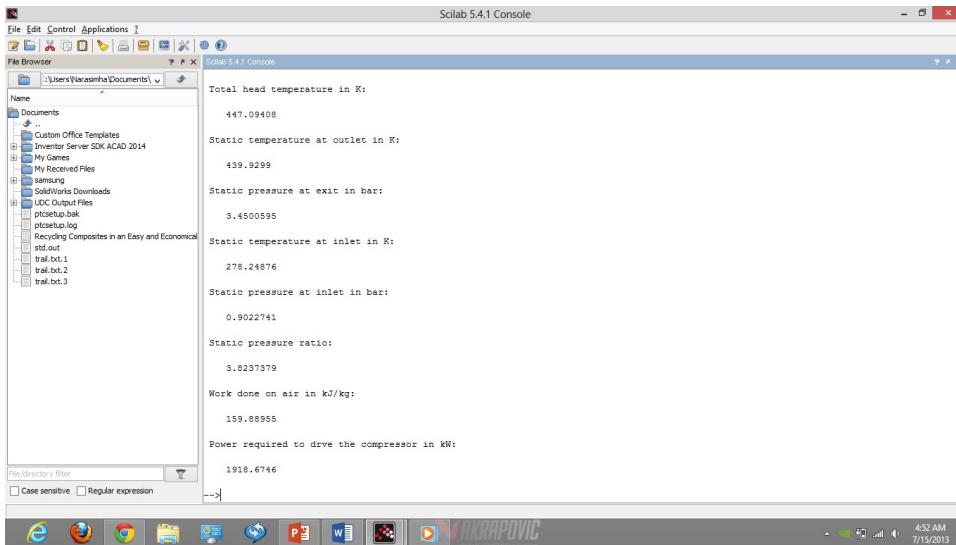


Figure 20.41: Centrifugal compressor

```

10 etaisen=0.8;.....//Isentropic efficiency
11 pc=0.73;.....//Pressure co efficient
12 pa=1.013;.....//Ambient pressure in bar
13 ta=273+15;.....//Ambient temperature in K
14 ga=1.4;.....//Ratio of specific heats
15 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
16 R=0.287;.....//Gas constant in kJ/kgK
17 //Calculations
18 delt=((ta*((rp^((ga-1)/ga))-1))/etaisen);.....//
    Rise in temperature
19 t02=ta+delt;.....//Total head temperature in
    K
20 disp(t02,"Total head temperature in K:")
21 t2=t02-((Cbl2*Cbl2)/(2*cp*1000));.....//Static
    temperature at outlet in K
22 disp(t2,"Static temperature at outlet in K:")
23 p02=pa*rp;
24 p2=p02/(1+((Cbl2*Cbl2)/(2*R*t2*1000)));.....//
    Static pressure at exit in bar

```

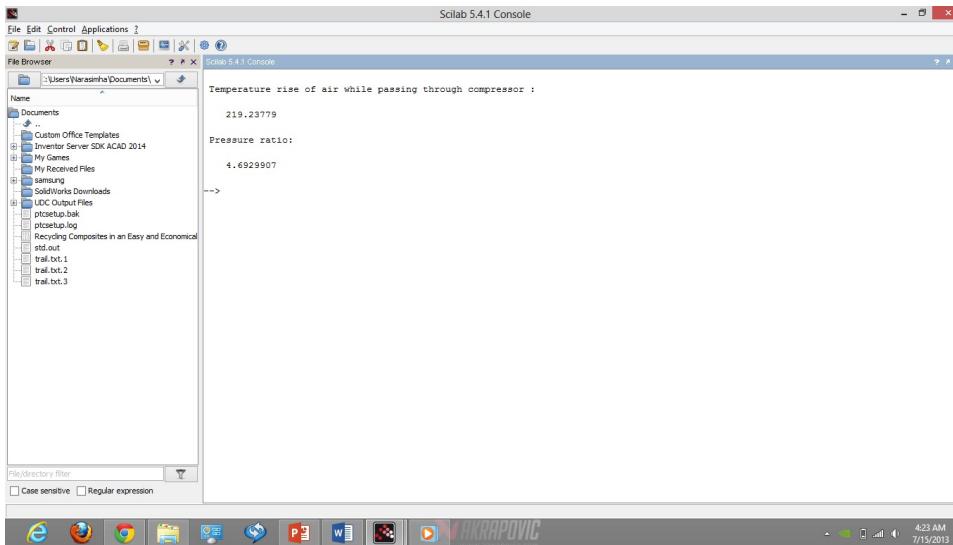


Figure 20.42: Centrifugal compressor

```

25 disp(p2," Static pressure at exit in bar:")
26 t1=ta-((Cf*Cf)/(2*cp*1000));.....//Static
    temperature at inlet in K
27 disp(t1," Static temperature at inlet in K:")
28 p1=pa/(1+((Cf*Cf)/(2*R*t1*1000)));.....// 
    Static pressure at inlet in bar
29 disp(p1," Static pressure at inlet in bar:")
30 rp=p2/p1;....//Static pressure ratio
31 disp(rp," Static pressure ratio:")
32 W=cp*delt;.....//Work done on air in kJ/kg of
    air
33 disp(W,"Work done on air in kJ/kg:")
34 P=m*cp*delt;.....//Power required to drive the
    compressor in kW
35 disp(P,"Power required to drve the compressor in kW:
    ")

```

---

### Scilab code Exa 20.43 Centrifugal compressor

```
1 clc;funcprot(0); //EXAMPLE 20.43
2 // Initialisation of Variables
3 t1=300;.....// Inlet temperature in K
4 N=18000;.....// Compressor rpm
5 etaisen=0.76;.....// Isentropic efficiency
6 od=0.55;.....//Outer diameter of blade tip
7 sf=0.82;.....//Slip factor
8 cp=1.005;.....// Specific heat capacity at
    constant pressure in kJ/kgK
9 ga=1.4;.....//Ratio of specific heats
10 // Calculations
11 Cbl2=(%pi*od*N)/60;W=Cbl2*Cbl2*sf/1000;.....//
    Work done per kg of air in kW
12 delt=W/cp;.....//Temperature rise of air
    while passing through compressor
13 disp(delt,"Temperature rise of air while passing
    through compressor :")
14 t21=(etaisen*delt)+t1;rp=((t21/t1)^(ga/(ga-1)))
    ;.....// Pressure ratio
15 disp(rp,"Pressure ratio:")
```

---

### Scilab code Exa 20.44 Axial flow compressor

```
1 clc;funcprot(0); //EXAMPLE 20.44
2 // Initialisation of Variables
3 Cbl=240;.....//Mean blade velocity in m/s
4 Cf=190;.....//Air flow velocity in m/s
5 a11=45;a12=14;.....//Blade angels in degrees
```

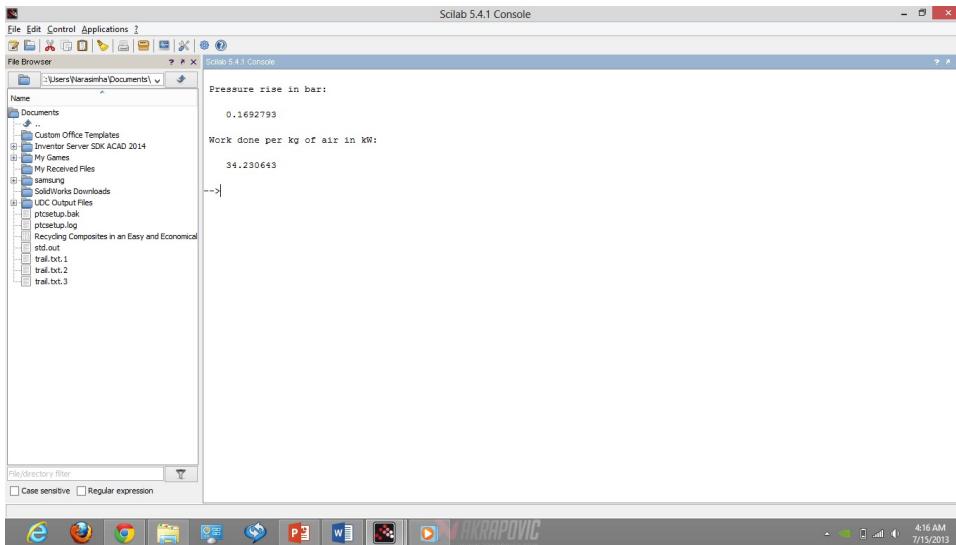


Figure 20.43: Axial flow compressor

```

6 rho=1;.....//Density of air in kg/m^3
7 //Calculations
8 pr=(1/2)*(rho*Cf*Cf/(10^5))*(((tan(al1*pi/180))^2)
-((tan(al2*pi/180))^2));.....//Pressure rise
in bar
9 disp(pr,"Pressure rise in bar:")
10 W=Cb1*Cf/1000*((tan(al1*pi/180))-(tan(al2*pi/180)))
);.....//Work done per kg of air in kW
11 disp(W,"Work done per kg of air in kW:")

```

---

### Scilab code Exa 20.45 Axial flow compressor

```

1 clc;funcprot(0); //EXAMPLE 20.45
2 // Initialisation of Variables
3 etaisen=0.82;.....//Overall isentropic efficiency
4 N=8;.....//No of stages

```

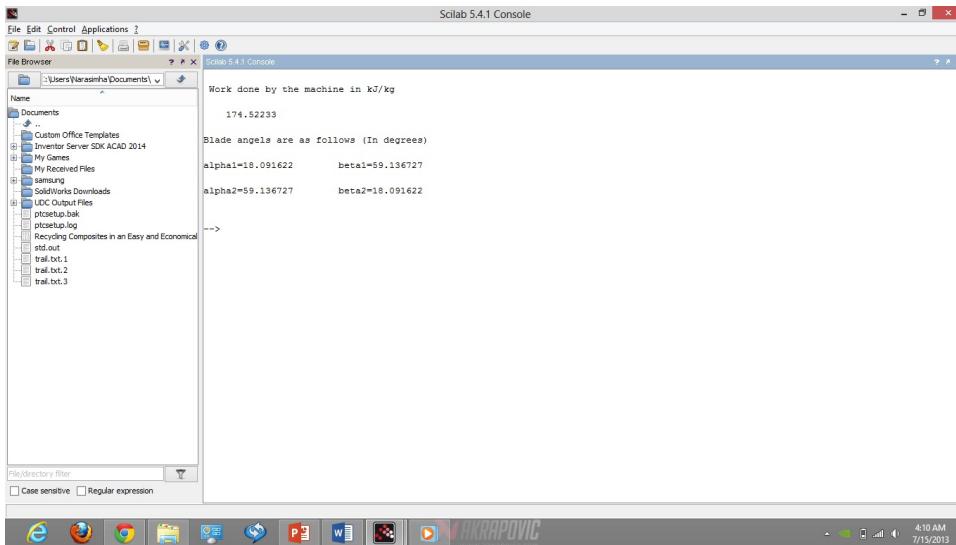


Figure 20.44: Axial flow compressor

```

5 t1=293;.....//Inlet temperature in K
6 ga=1.4;.....//Ratio of specific heats
7 rp=4;.....//Pressure ratio
8 Rd=0.5;.....//Reaction factor
9 Cbl=180;.....//Mean blade speed in m/s
10 Cf=90;.....//Air flow velocity in m/s
11 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
12 //Calculations
13 t21=t1*(rp^((ga-1)/ga));
14 t2=((t21-t1)/etaisen)+t1;
15 wrt=cp*(t2-t1);.....//Work done by the machine
    in kJ/kg
16 disp(wrt,"Work done by the machine in kJ/kg")
17 be1=atan(((cp*(t2-t1)*1000/(Cf*Cbl*N))+(Cbl/Cf))/2)
    *180/%pi;
18 al1=atan((Cbl/Cf)-tan(be1*%pi/180))*180/%pi;
19 printf("\nBlade angels are as follows (In degrees)\n"
    "\nalpha1=%f\beta1=%f\nalpha2=%f\beta2=%f\n",al1,be1,be1,al1)

```

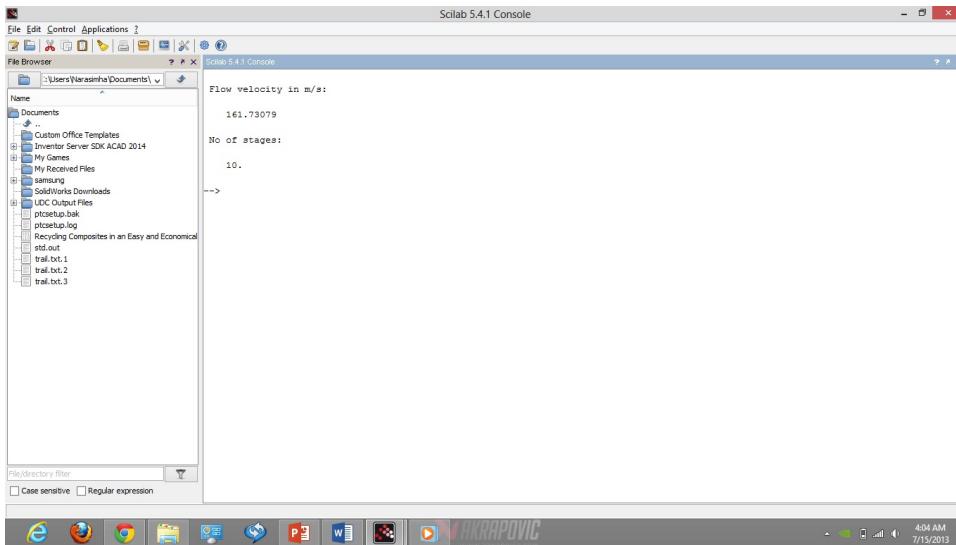


Figure 20.45: Axial flow compressor

### Scilab code Exa 20.46 Axial flow compressor

```

1 clc;funcprot(0); //EXAMPLE 20.46
2 // Initialisation of Variables
3 etaisen=0.85;.....//Overall isentropic efficiency
4 t1=293;.....//Inlet temperature in K
5 rp=4;.....//Pressure ratio
6 Rd=0.5;.....//Reaction factor
7 Cbl=180;.....//Mean blade speed in m/s
8 wip=0.82;.....//Work input factor
9 al1=12;be1=42;....//Blade angels in degrees
10 ga=1.4;.....//Ratio of specific heats
11 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
12 // Calculations

```

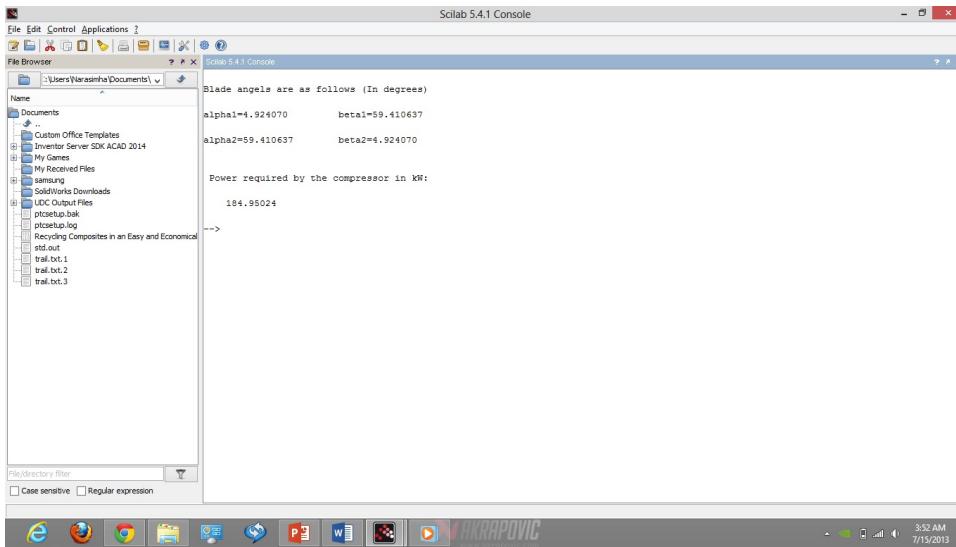


Figure 20.46: Eight stage axial flow compressor

```

13 t21=t1*(rp^((ga-1)/ga));
14 t2=((t21-t1)/etaisen)+t1;
15 wrt=cp*(t2-t1);..... //Theoretical work required
    in kJ/kg
16 Cf=Cbl/(tan(al1*pi/180)+tan(be1*pi/180));
17 Cw1=Cf*tan(al1*pi/180);Cw2=Cf*tan(be1*pi/180);
18 wcps=Cbl*(Cw2-Cw1)*wip/1000;..... //Work
    consumed per stage in kJ/kg
19 N=round(wrt/wcps);...//No of stages
20 disp(Cf,"Flow velocity in m/s:")
21 disp(N,"No of stages:")

```

---

### Scilab code Exa 20.47 Eight stage axial flow compressor

```

1 clc;funcprot(0); //EXAMPLE 20.47
2 // Initialisation of Variables

```

```

3 rp=5;.....//Stagnation pressure ratio ga
4 etaisen=0.92;.....//Overall isentropic efficiency
5 t1=290;.....//Inlet stagnation temperature
   in K
6 p1=1;.....//Inlet stagnation pressure in
   bar
7 Cbl=160;.....//Mean blade speed in m/s
8 ga=1.4;.....//Ratio of specific heats
9 Rd=0.5;.....//Degree of reaction
10 Cf=90;.....//Axial velocity of air
    through compressor in m/s
11 N=8;.....//No of stages
12 m=1;.....//Mass flow in kg/s
13 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
14 //Calculations
15 tN1=t1*(rp^((ga-1)/ga));.....//Temperature at the
    end of compression stage due to isentropic
    expansion in K
16 tN=((tN1-t1)/etaisen)+t1;
17 be1=atan(((cp*(tN-t1)*1000/(Cf*Cbl*N))+(Cbl/Cf))/2)
    *180/%pi;
18 al1=atan((Cbl/Cf)-tan(be1*%pi/180))*180/%pi;
19 printf("\nBlade angels are as follows (In degrees)\n
    \nalpha1=%f\t\beta1=%f\n\nalpha2=%f\t\beta2=%f\n\
    \n",al1,be1,al1)
20 P=m*cp*(tN-t1);.....//Power required by the
    compressor in kW
21 disp(P,"Power required by the compressor in kW:")

```

---

### Scilab code Exa 20.48 Axial flow compressor

```
1 clc;funcprot(0); //EXAMPLE 20.48
```

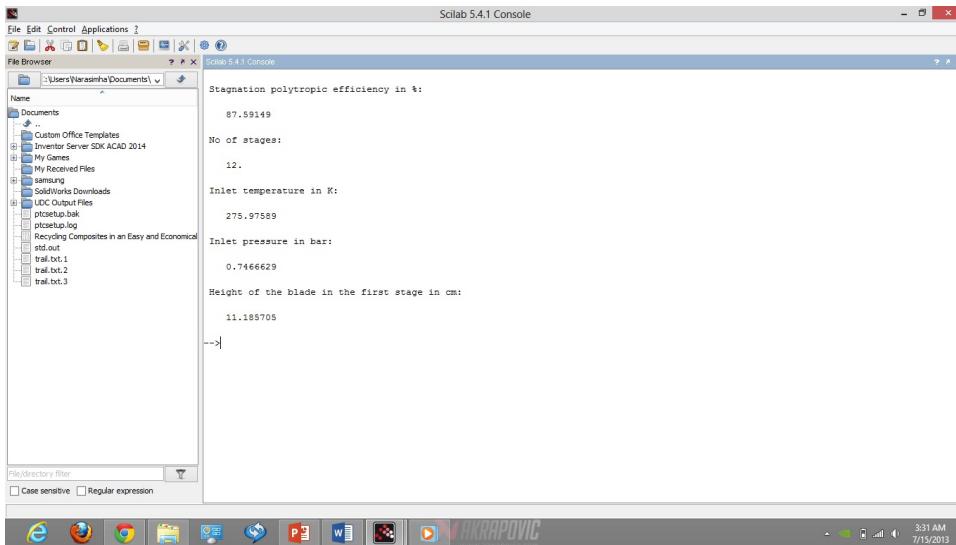


Figure 20.47: Axial flow compressor

```

2 // Initialisation of Variables
3 rp=4;.....//Stagnation pressure ratio
4 etaisen=0.85;.....//Stagnation isentropic efficiency
5 p1=1;.....//Inlet stagnation pressure in bar
6 t1=300;.....//Inlet stagnation temperature in
   K
7 Rd=0.5;.....//Degree of reaction
8 Cu=180;.....//Mean blade speed in m/s
9 Wd=0.9;.....//Work done factor
10 htr=0.42;.....//Hub tip ratio
11 al1=12;be2=al1;.....//Relative air angle at rotor
   inlet in degrees
12 al2=32;be1=al2;.....//Relative air angle at rotor
   at outlet in degrees
13 ga=1.4;.....//Ratio of specific heats
14 cp=1.005;.....//Specific heat capacity at
   constant pressure in kJ/kgK
15 R=287;.....//Gas constant in J/kgK
16 m=19.5;.....//Mass flow in kg/s
17 // Calculations

```

```

18 tN1=t1*(rp^((ga-1)/ga));.....//Temperature at the
   end of compression stage due to isentropic
   expansion in K
19 tN=((tN1-t1)/etaisen)+t1;
20 etap=log(rp^((ga-1)/ga))/log(tN/t1);.....//  

   Stagnation polytropic efficiency
21 disp(etap*100,"Stagnation polytropic efficiency in %  

   :")
22 Cf=Cu/ (tan(al1*pi/180)+tan(be1*pi/180));
23 Cw1=Cf*tan(al1*pi/180);Cw2=Cf*tan(al2*pi/180);
24 wcps=Cu*(Cw2-Cw1)*Wd/1000;.....//Work  

   consumed per stage in kJ/kg
25 wc=cp*(tN-t1);.....//Work consumed by  

   compressor in kJ/kg
26 N=round(wc/wcps);.....//No of stages
27 disp(N,"No of stages:")
28 C1=Cf/cos(al1*pi/180);.....//Absolute velocity at  

   exit from guide vanes in m/s
29 ti=t1-((C1*C1)/(2*cp*1000));.....//Inlet  

   temperature in K
30 disp(ti,"Inlet temperature in K:")
31 pi=p1*((ti/t1)^(ga/(ga-1)));.....//Inlet pressure  

   in bar
32 disp(pi,"Inlet pressure in bar:")
33 rho1=(pi*10^5)/(R*ti);.....//Density of air  

   approaching the first stage
34 r1=sqrt(m/(rho1*pi*Cf*(1-(ht^2))));rh=r1*ht;
35 l=r1-rh;.....//Height of the blade in the  

   first stage in m
36 disp(l*100,"Height of the blade in the first stage  

   in cm:")

```

---

**Scilab code Exa 20.49** Multi stage axial flow compressor

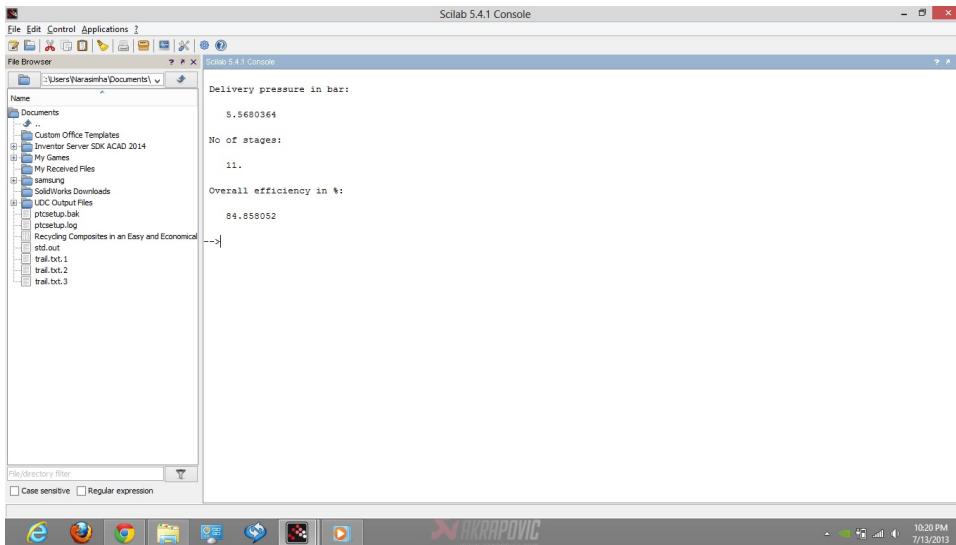


Figure 20.48: Multi stage axial flow compressor

```

1 clc;funcprot(0); //EXAMPLE 20.49
2 // Initialisation of Variables
3 ma=20;.....//Air flow rate in kg/s
4 p1=1;.....//Inlet stagnation pressure in bar
5 t1=290;.....//Inlet stagnation temperature in
   Kelvin
6 t2=305;.....//Temperature at the end of first
   stage in K
7 etapc=0.88;....//Polytropic efficiency of
   compression
8 P=4350;.....//Power consumed by compressor in kW
9 ga=1.4;....//Ratio of specific heats
10 cp=1.005;....//Specific heat at constant pressure
11 //Calculations
12 p2byp1=(%e^(etapc*log(t2/t1)))^(ga/(ga-1));
13 tN=(P/(ma*cp))+t1;
14 pN=p1*((tN/t1)^((etapc*ga)/(ga-1)));.....//Delivery
   pressure in bar
15 disp(pN,"Delivery pressure in bar:")
16 N=log(pN/p1)/log(p2byp1);.....//No of stages

```

```
17 disp(round(N),"No of stages:")
18 tN1=t1*((pN/p1)^((ga-1)/ga));
19 etao=(tN1-t1)/(tN-t1);.....// Overall
    efficiency
20 disp(etao*100,"Overall efficiency in %:")
```

---

# Chapter 21

## Gas Turbines and Jet Propulsion

**Scilab code Exa 21.1** Open cycle gas turbine

```
1 clc;funcprot(0); //EXAMPLE 21.1
2 // Initialisation of Variables
3 p1=1;.....//Pressure of air while entering the
             turbine in bar
4 t1=293;.....//Temperature of air entering the
               turbine in K
5 p2=4;.....//Pressure of air after compression in
               bar
6 etac=0.8;....//Efficiency of compressor
7 etat=0.85;....//Efficiency of turbine
8 afr=90;.....//Air fuel ratio
9 ma=3;.....//Mass of air in kg/s
10 ga=1.4;.....//Ratio of specific heats
11 cp=1;.....//Specific heat at constant
               pressure in kJ/kgK
12 C=41800;.....//Calorific value of fuel in kJ
               /kg
```

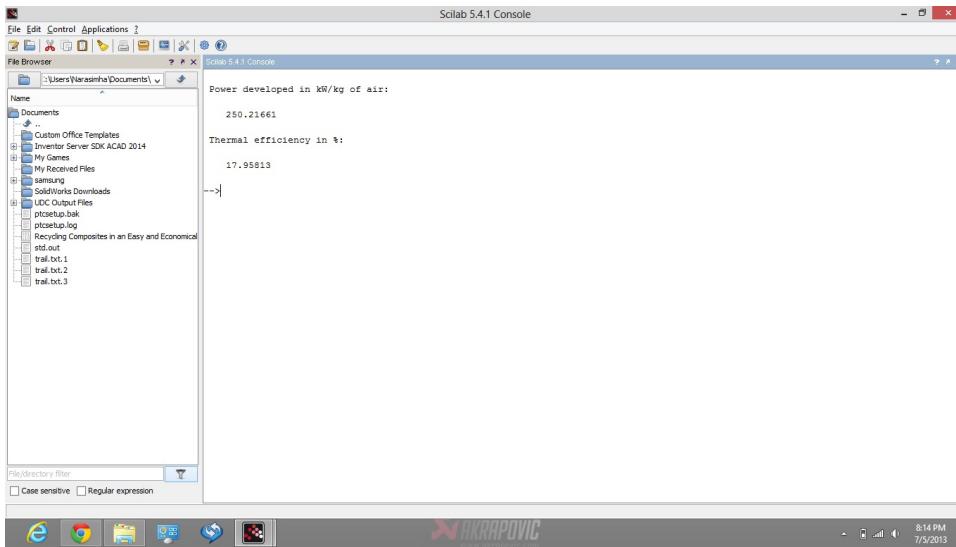


Figure 21.1: Open cycle gas turbine

```

13 // Calculations
14 t2=t1*((p2/p1)^((ga-1)/ga));.....// Ideal
   temperature of air after compression in K
15 t21=((t2-t1)/etac)+t1;.....// Actual
   temperature of air after compression in K
16 t3=round((C/((afr+1)*cp))+t21);.....//
   Temperature before expansion in turbine in K
17 p4=p1;p3=p2;t4=t3*((p4/p3)^((ga-1)/ga));.....
   // Ideal temperature after expansion in turbine in
   K
18 t41=t3-(etat*(t3-t4));.....// Actual
   temperature after expansion in turbine in K
19 wt=((afr+1)/afr)*cp*(t3-t41);.....// Work done by
   turbine in kJ/kg of air
20 wc=round(1*cp*(t21-t1));.....// Work done
   by compression in kJ/kg of air
21 wnet=wt-wc;.....// Net work done in kJ/kg
22 P=wnet*ma;.....// Power developed in kW/
   kg of air
23 disp(P,"Power developed in kW/kg of air:")

```

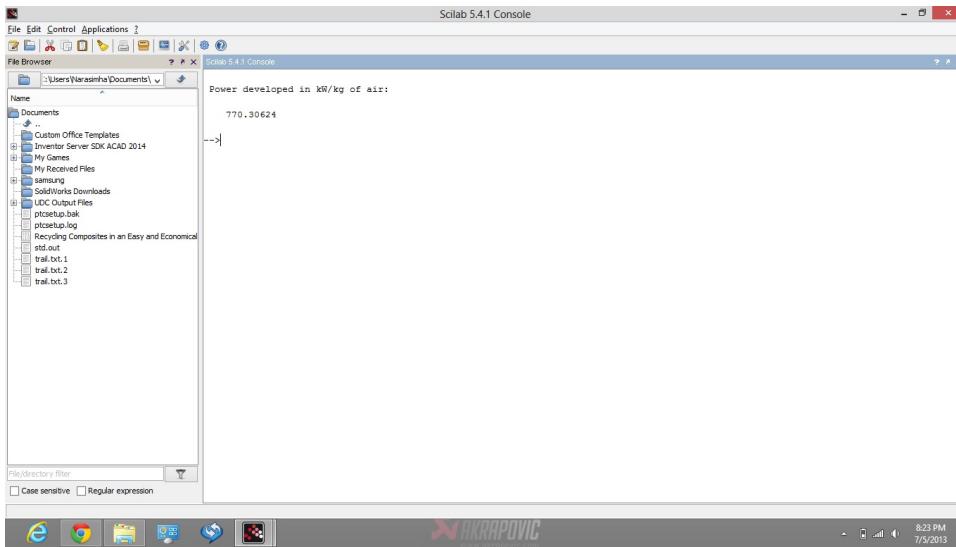


Figure 21.2: Open cycle gas turbine

```

24 qs=(1/afr)*C;..... //Heat supplied in kJ/
    kg of air
25 etath=wnet/qs;..... //Thermal efficiency
26 disp(etath*100,"Thermal efficiency in %:")

```

---

### Scilab code Exa 21.2 Open cycle gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.2
2 // Initialisation of Variables
3 t1=288;..... //Temperature of air entering the
    turbine in K
4 t3=883;..... //Temperature before expansion
    in turbine in K
5 etac=0.8;..... //Efficiency of compressor
6 etat=0.82;..... //Efficiency of turbine
7 rp=6;..... //Pressure ratio

```

```

8 ma=16;.....//Mass of air in kg/s
9 gac=1.4;.....//Ratio of specific heats for
    compression process
10 gae=1.333;.....//Ratio of specific heats for
    expansion process
11 cpc=1.005;.....//Specific heat at constant
    pressure in kJ/kgK during compression process
12 cpe=1.11;.....//Specific heat at constant
    pressure in kJ/kgK during expansion process
13 C=41800;.....//Calorific value of fuel in kJ
    /kg
14 //Calculations
15 t2=t1*((rp)^(gac-1)/gac));.....//Ideal
    temperature of air after compression in K
16 t21=((t2-t1)/etac)+t1;.....//Actual
    temperature of air after compression in K
17 t4=t3/((rp)^(gae-1)/gae));.....//Ideal
    temperature after expansion in turbine in K
18 t41=t3-(etat*(t3-t4));.....//Actual
    temperature after expansion in turbine in K
19 wt=cpe*(t3-t41);.....//Work done by turbine in
    kJ/kg of air
20 wc=(1*cpc*(t21-t1));.....//Work done by
    compression in kJ/kg of air
21 wnet=wt-wc;.....//Net work done in kJ/kg
22 P=wnet*ma;.....//Power developed in kW/
    kg of air
23 disp(P,"Power developed in kW/kg of air:")

```

---

### Scilab code Exa 21.3 Thermal efficiency of Gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.3
2 // Initialisation of Variables

```

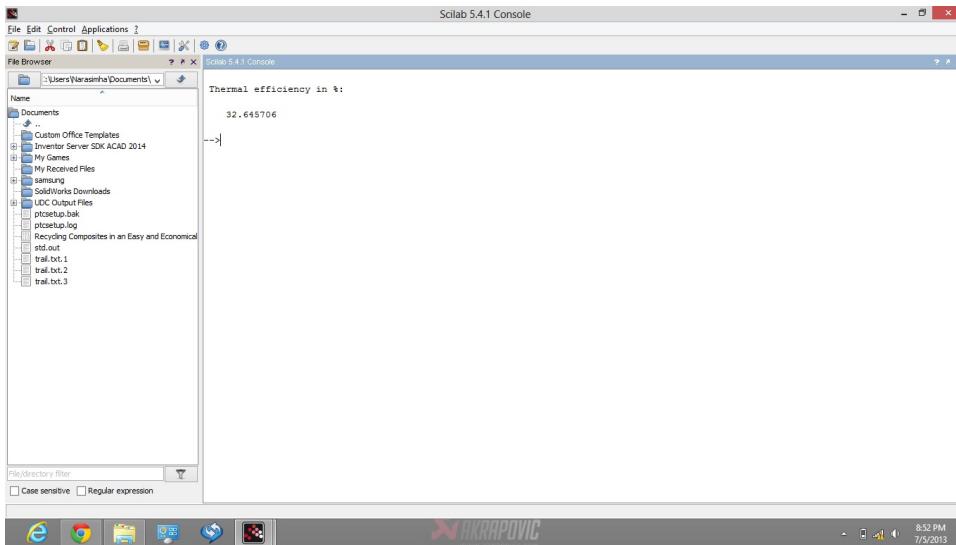


Figure 21.3: Thermal efficiency of Gas turbine

```

3 p1=1;.....//Pressure of air while entering the
   turbine in bar
4 t1=300;.....//Temperature of air entering the
   turbine in K
5 p2=6.2;.....//Pressure of air after compression
   in bar
6 etac=0.88;....//Efficiency of compressor
7 etat=0.9;....//Efficiency of turbine
8 far=0.017;.....//Fuel air ratio
9 ga=1.4;.....//Ratio of specific heats for
   compression
10 gae=1.333;.....//Ratio of specific heats for
   expansion
11 cp=1.147;.....//Specific heat at constant
   pressure in kJ/kgK during expansion
12 cpc=1.005;.....//Specific heat at constant
   pressure in kJ/kgK during compression
13 C=44186;.....//Calorific value of fuel in kJ
   /kg
14 // Calculations

```

```

15 t2=t1*((p2/p1)^((ga-1)/ga));.....// Ideal
    temperature of air after compression in K
16 t21=((t2-t1)/etac)+t1;.....// Actual
    temperature of air after compression in K
17 t3=(((C*far)/((far+1)*cpc))+t21);.....//
    Temperature before expansion in turbine in K
18 p4=p1;p3=p2;t4=t3*((p4/p3)^((gae-1)/gae))
    ;.....// Ideal temperature after expansion
    in turbine in K
19 t41=t3-(etat*(t3-t4));.....// Actual
    temperature after expansion in turbine in K
20 wt=(cp*(t3-t41));.....// Work done by turbine in
    kJ/kg of air
21 wc=round(1*cpc*(t21-t1));.....// Work
    done by compression in kJ/kg of air
22 wnet=wt-wc;.....// Net work done in kJ/kg
23 qs=(far)*C;.....// Heat supplied in kJ/kg
    of air
24 etath=wnet/qs;.....// Thermal efficiency
25 disp(etath*100,"Thermal efficiency in %:")

```

---

### Scilab code Exa 21.4 Air fuel ratio for gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.4
2 // Initialisation of Variables
3 t1=300;.....//Temperature of air entering the
    turbine in K
4 t3=1148;.....//Temperature before expansion
    in turbine in K
5 etac=0.8;....//Efficiency of compressor
6 etat=0.852;....//Efficiency of turbine
7 rp=4;.....//Pressure ratio
8 p1=1;.....//Pressure of air before

```

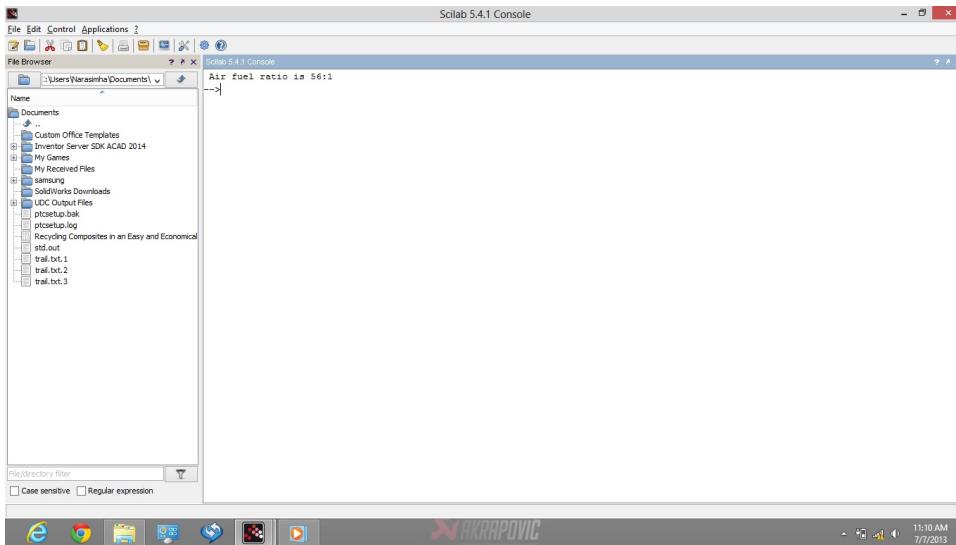


Figure 21.4: Air fuel ratio for gas turbine

```

        entering compressor
9 ga=1.4;.....//Ratio of specific heats
10 cp=1.0;.....//Specific heat at constant
    pressure in kJ/kgK
11 C=42000;.....//Calorific value of fuel in kJ
    /kg
12 perlcc=10;.....//Percent loss of calorific
    value of fuel in combustion chamber
13 //Calculations
14 p2=p1*rp;.....//Pressure of air after
    compression in bar
15 etacc=(100-perlcc)/100;.....//Efficiency of
    combustion chamber
16 t2=t1*((rp)^((ga-1)/ga));.....//Ideal
    temperature of air after compression in K
17 t21=((t2-t1)/etac)+t1;.....//Actual
    temperature of air after compression in K
18 afr=((C*etacc)/(cp*(t3-t21)))-1;.....//Air fuel
    ratio
19 printf("Air fuel ratio is %d:1",round(afr))

```

---

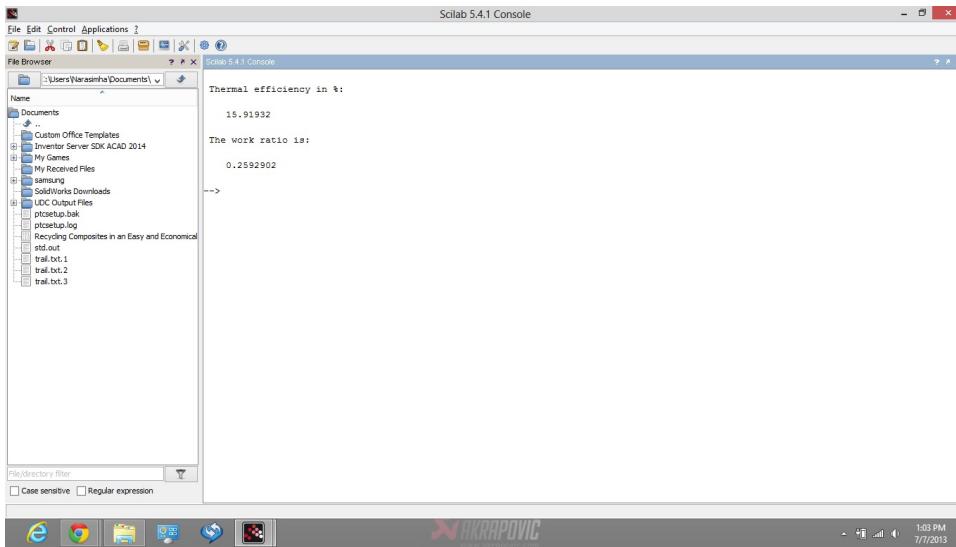


Figure 21.5: Thermal efficiency of gas turbine

### Scilab code Exa 21.5 Thermal efficiency of gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.5
2 // Initialisation of Variables
3 t1=300;.....//Temperature of air entering the
   turbine in K
4 t3=883;.....//Temperature before expansion
   in turbine in K
5 etac=0.8;....//Efficiency of compressor
6 etat=0.852;....//Efficiency of turbine
7 rp=4;.....//Pressure ratio
8 p1=1;.....//Pressure of air before
   entering compressor
9 ga=1.4;.....//Ratio of specific heats
10 cp=1.11;.....//Specific heat at constant

```

```

    pressure in kJ/kgK
11 C=42000;.....//Calorific value of fuel in kJ
   /kg
12 perlcc=10;.....//Percent loss of calorific
   value of fuel in combustion chamber
13 //Calculations
14 p2=p1*rp;.....//Pressure of air after
   compression in bar
15 etacc=(100-perlcc)/100;.....//Efficiency of
   combustion chamber
16 t2=t1*((rp)^((ga-1)/ga));.....//Ideal
   temperature of air after compression in K
17 t21=((t2-t1)/etac)+t1;.....//Actual
   temperature of air after compression in K
18 qs=cp*(t3-t21);.....//Heat supplied in
   kJ/kg
19 t4=t3/((rp)^((ga-1)/ga));.....//Ideal
   temperature after expansion in turbine in K
20 t41=t3-(etat*(t3-t4));.....//Actual
   temperature after expansion in turbine in K
21 wt=cp*(t3-t41);.....//Work done by turbine in kJ
   /kg of air
22 wc=(1*cp*(t21-t1));.....//Work done by
   compression in kJ/kg of air
23 wnet=wt-wc;.....//Net work done in kJ/kg
24 etath=wnet/qs;.....//Thermal efficiency
25 disp(etath*100,"Thermal efficiency in %:")
26 wrr=wnet/wt;.....//Work ratio
27 disp(wrr,"The work ratio is:")

```

---

### Scilab code Exa 21.6 Open cycle gas turbine

```
1 clc;funcprot(0); //EXAMPLE 21.6
```

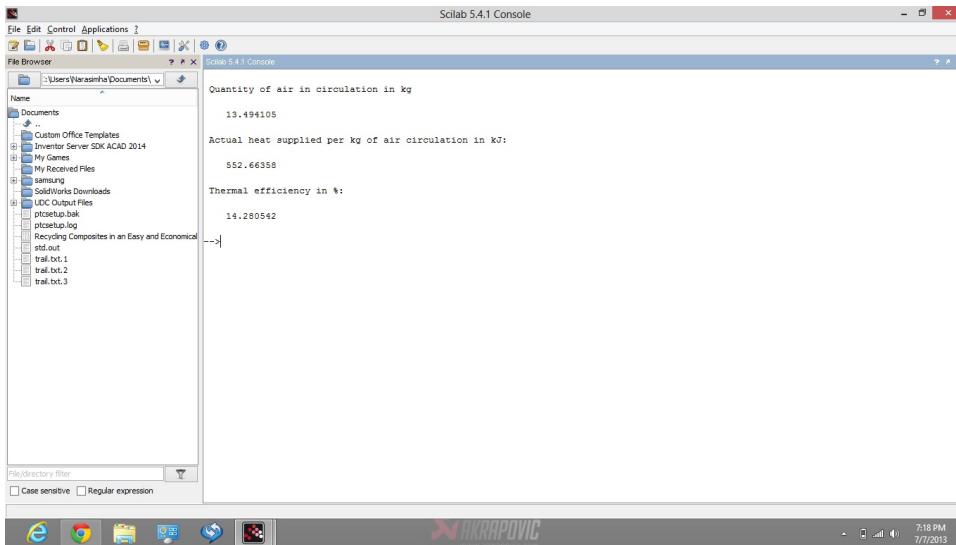


Figure 21.6: Open cycle gas turbine

```

2 // Initialisation of Variables
3 p1=1;.....//Pressure of air while entering the
    turbine in bar
4 t1=293;.....//Temperature of air entering the
    turbine in K
5 p2=5;.....//Pressure of air after compression in
    bar
6 plcc=0.1;.....//Pressure loss in combustion chamber
    in bar
7 t3=953;.....//Temperature before expansion in
    turbine in K
8 etac=0.85;....//Efficiency of compressor
9 etat=0.8;....//Efficiency of turbine
10 etacc=0.85;....//Efficiency of combustion chamber
11 ga=1.4;.....//Ratio of specific heats
12 cp=1.024;.....//Specific heat at constant
    pressure in kJ/kgK
13 P=1065;.....//Power developed by the plant
    in kW

```

14

```

15 // Calculations
16 p3=p2-plcc;.....// Pressure before
   expansion in turbine in bar
17 p4=p1;
18 t2=t1*((p2/p1)^((ga-1)/ga));.....// Ideal
   temperature of air after compression in K
19 t21=((t2-t1)/etac)+t1;.....// Actual
   temperature of air after compression in K
20 t4=t3*((p4/p3)^((ga-1)/ga));.....// Ideal
   temperature after expansion in turbine in K
21 t41=t3-(etat*(t3-t4));.....// Actual
   temperature after expansion in turbine in K
22 wt=(cp*(t3-t41));.....//Work done by turbine in
   kJ/kg of air
23 wc=round(1*cp*(t21-t1));.....//Work done
   by compression in kJ/kg of air
24 wnet=wt-wc;.....//Net work done in kJ/kg
25 ma=P/wnet;.....//Quantity of air in
   circulation in kg
26 disp(ma,"Quantity of air in circulation in kg")
27 qs=cp*(t3-t21)/etac;.....//Actual heat
   supplied per kg of air circulation in kJ
28 disp(qs,"Actual heat supplied per kg of air
   circulation in kJ:")
29 etath=wnet/qs;.....//Thermal efficiency
30 disp(etath*100,"Thermal efficiency in %:")

```

---

### Scilab code Exa 21.7 Pressure ratio and temperature of the exhaust

```

1 clc;funcprot(0); //EXAMPLE 21.7
2 // Initialisation of Variables
3 ma=20;.....//Air flow rate in kg/s
4 t1=300;.....//Temperature of air entering the

```

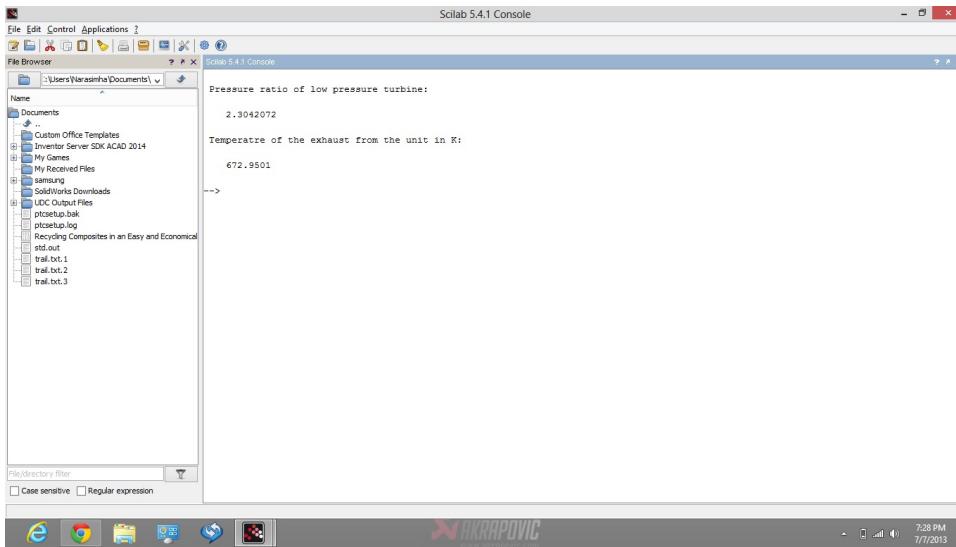


Figure 21.7: Pressure ratio and temperature of the exhaust

```

turbine in K
5 t3=1000;.....//Temperature before expansion
    in turbine in K
6 rp=4;.....//Pressure ratio
7 cp=1;.....//Specific heat at constant
    pressure in kJ/kgK
8 ga=1.4;.....//Ratio of specific heats
9 //Calculations
10 t2=t1*((rp)^((ga-1)/ga));.....//
    Temperature of air after compression in K
11 t4=t3-t2+t1;.....//Temperature after
    expansion in turbine in K
12 prlp=rp/((t3/t4)^(ga/(ga-1)));.....//
    Pressure ratio of low pressure turbine
13 disp(prlp,"Pressure ratio of low pressure turbine:")
14 t5=t4/((prlp)^((ga-1)/ga));.....//Temperature
    of the exhaust from the unit in K
15 disp(t5,"Temperature of the exhaust from the unit in
    K:")

```

---

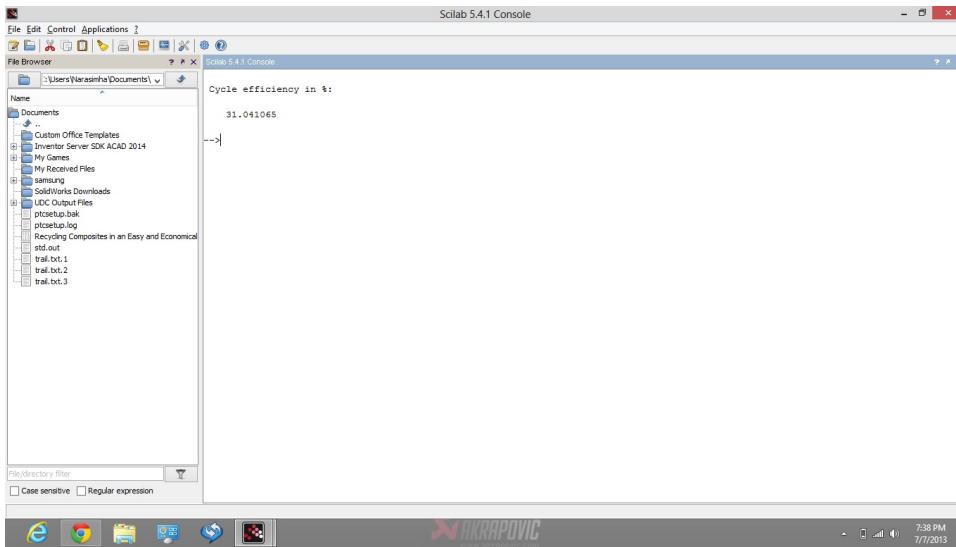


Figure 21.8: Efficiency of open cycle gas turbine

### Scilab code Exa 21.8 Efficiency of open cycle gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.8
2 // Initialisation of Variables
3 p1=1;.....//Pressure of air while entering the
   turbine in bar
4 t1=300;.....//Temperature of air entering the
   turbine in K
5 t21=490;.....//Actual temperature of air after
   compression in K
6 t3=1000;.....//Temperature before expansion
   in turbine in K
7 rp=5;.....//Pressure ratio
8 etac=0.8;....//Efficiency of compressor
9 etat=0.8;....//Efficiency of turbine

```

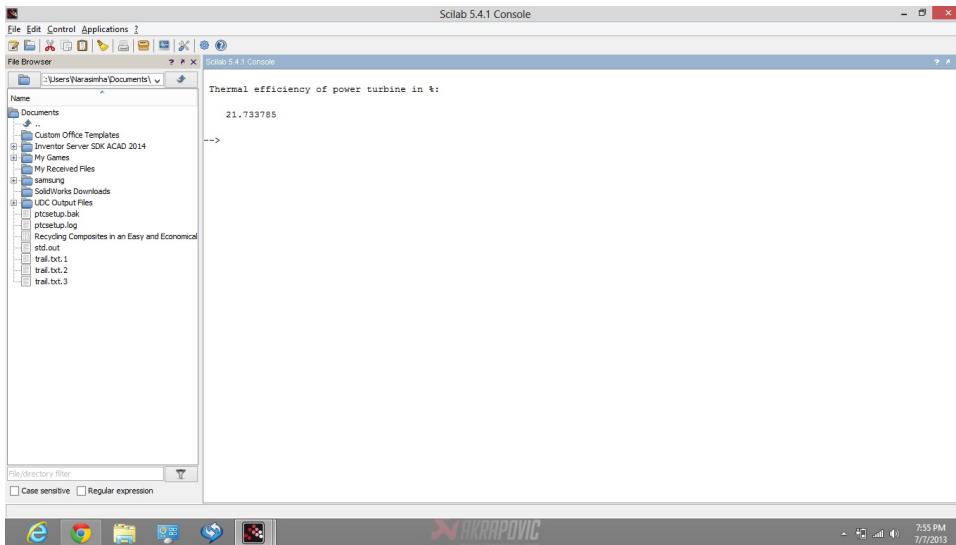


Figure 21.9: Multi stage gas turbine

```

10 ga=1.4;.....//Ratio of specific heats
11 cp=1.005;.....//Specific heat at constant
   pressure in kJ/kgK
12 //Calculations
13 t4=t3/((rp)^((ga-1)/ga));.....//Ideal
   temperature after expansion in turbine in K
14 t41=t3-(etat*(t3-t4));.....//Actual
   temperature after expansion in turbine in K
15 t5=((t41-t21)*etac)+t21;.....//Temperature of
   the exhaust from the unit in K
16 wc=cp*(t21-t1);.....//Work consumed by
   compressor in kJ/kg
17 wt=cp*(t3-t41);.....//Work done by turbine in kJ/
   kg
18 qs=cp*(t3-t5);.....//Heat supplied in kJ/kg
19 etac=(wt-wc)/qs;.....//Cycle efficiency
20 disp(etac*100,"Cycle efficiency in %:")

```

---

### Scilab code Exa 21.9 Multi stage gas turbine

```
1 clc;funcprot(0); //EXAMPLE 21.9
2 // Initialisation of Variables
3 p1=1;.....//Pressure of air while entering the
    turbine in bar
4 t1=288;.....//Temperature of air entering the
    turbine in K
5 p2=8;.....//Pressure of air after compression in
    bar
6 t3=1173;.....//Temperature before expansion
    in turbine in K
7 etac=0.76;....//Efficiency of compressor
8 etat=0.86;....//Efficiency of turbine
9 ma=23;.....//Quantity of air circulation in kg/s
10 ga=1.4;.....//Ratio of specific heats for
    compression
11 gag=1.34;.....//Ratio of specific heats for
    expansion
12 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
13 cpg=1.128;.....//Specific heat at constant
    pressure in kJ/kgK
14 C=4200;.....//Calorific value of fuel in kJ/
    kg
15 etamech=0.95;.....//Mechanical efficiency
16 etagen=0.96;.....//Generator efficiency
17 //Calculations
18 t2=t1*((p2/p1)^((ga-1)/ga));.....//Ideal
    temperature of air after compression in K
19 t21=((t2-t1)/etac)+t1;.....//Actual
    temperature of air after compression in K
20 p4=p1;p3=p2;.....//Isobaric processes
21 t4=t3*((p4/p3)^((gag-1)/gag));.....//Ideal
```

```

        temperature after expansion in turbine in K
22 t41=t3-(etat*(t3-t4));.....//Actual
        temperature after expansion in turbine in K
23 wc=cp*(t21-t1);.....//Work done by
        compressor
24 m1=(wc)/(cpg*(t3-t41));.....//Flow through
        compressor turbine in kg
25 m2=1-m1;.....//Flow through power turbine
        in kg
26 wpt=m2*(cpg*(t3-t41));.....//turbine work in kJ/
        kg
27 P=ma*wpt*etamech*etagen;.....//Power output in
        kW
28 qi=cpg*t3-cp*t21;.....//Input heat in kJ/kg
        of air
29 etath=wpt/qi;.....//Thermal efficiency of
        power turbine
30 disp(etath*100,"Thermal efficiency of power turbine
        in %:")

```

---

### Scilab code Exa 21.10 Multi stage gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.10
2 // Initialisation of Variables
3 t1=288;.....//Temperature of air entering the
        turbine in K
4 t3=883;.....//Temperature before expansion
        in turbine in K
5 etac=0.82;....//Efficiency of compressor
6 etathp=0.85;....//Efficiency of high pressure
        turbine
7 etatlp=0.85;....//Efficiency of low pressure
        turbine

```

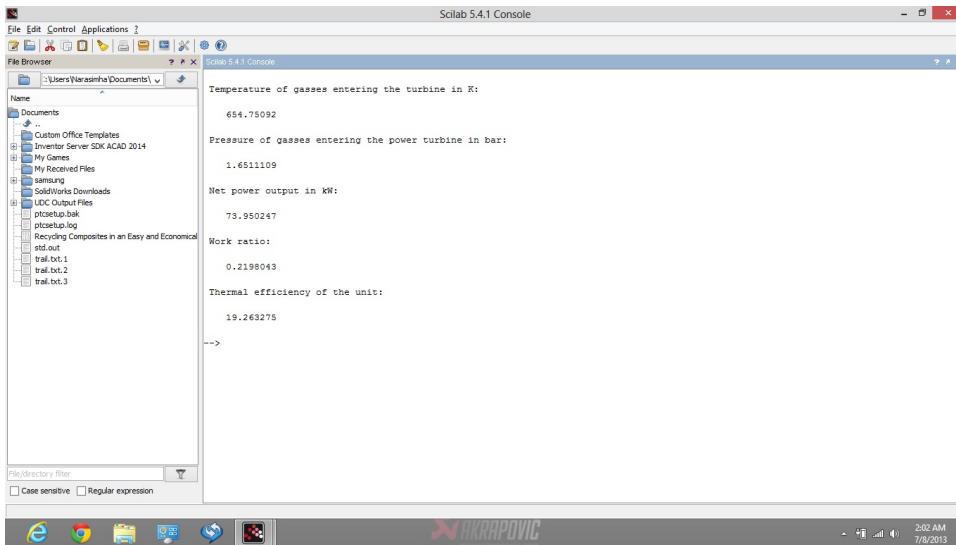


Figure 21.10: Multi stage gas turbine

```

8 rp=7;.....// Pressure ratio
9 p1=1.01;.....// Pressure of air before
    entering compressor
10 ga=1.4;.....// Ratio of specific heats for
    compression
11 gag=1.333;.....// Ratio of specific heats for
    expansion
12 cp=1.005;.....// Specific heat at constant
    pressure in kJ/kgK
13 cpg=1.15;.....// Specific heat at constant
    pressure in kJ/kgK in generator
14 // Calculations
15 p2=p1*rp;
16 t2=t1*((p2/p1)^((ga-1)/ga));.....// Ideal
    temperature of air after compression in K
17 t21=((t2-t1)/etac)+t1;.....// Actual
    temperature of air after compression in K
18 wc=cp*(t21-t1);.....// Compressor work in kJ/
    kg
19 t41=t3-(wc/cpg);.....// Temperature of gasses

```

```

        entering the turbine in K
20 disp(t41,"Temperature of gasses entering the turbine
      in K:")
21 t4=round(t3-((t3-t41)/etathp));.....//Ideal
      temperature of gases entering the turbine in K
22 p3=p2;.....//Isobaric processes
23 p4=p3/((t3/t4)^(1/((gag-1)/gag)));....//Pressure of
      gasses entering the power turbine in bar
24 disp(p4,"Pressure of gasses entering the power
      turbine in bar:")
25 t5=t41*(((t3/t4)^(1/((gag-1)/gag)))/(rp))^(gag-1)/
      gag);
26 t51=t41-(etatlp*(t41-t5));
27 wlp=cpg*(t41-t51);.....//Net power output in
      kW
28 disp(wlp,"Net power output in kW:")
29 wr=wlp/(wlp+wc);.....//Work ratio
30 disp(wr,"Work ratio:")
31 qs=cpg*(t3-t21);.....//Heat supplied in kJ/kg
32 etath=wlp/qs;.....//Thermal efficiency
33 disp(etath*100,"Thermal efficiency of the unit:")

```

---

### Scilab code Exa 21.11 Power developed and efficiency of power plant

```

1 clc;funcprot(0); //EXAMPLE 21.11
2 // Initialisation of Variables
3 rp=5.6;.....//Pressure ratio
4 t1=303;.....//Temperature of intake air in K
5 p1=1;.....//Pressure of intake air in bar
6 t5=973;.....//Highest temperature of the
      cycle in K
7 etac=0.85;.....//Effeciency of compressor
8 etat=0.9;.....//Efficiency of turbine

```

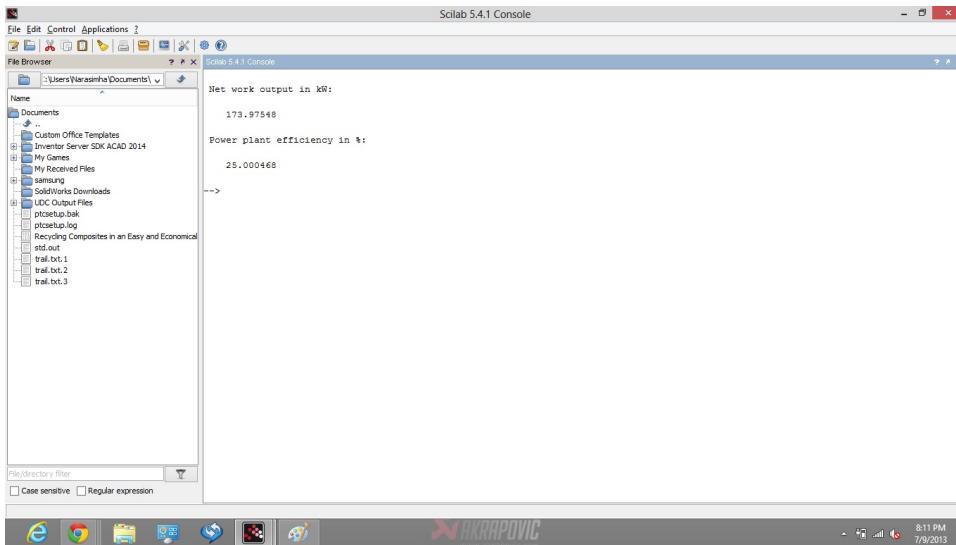


Figure 21.11: Power developed and efficiency of power plant

```

9 ma=1.2;.....//Rate of air flow in kg/s
10 cp=1.02;.....// Specific heat at constant
    volume in kJ/kgK
11 ga=1.41;.....//Ratio of specific heats
12 //Calculations
13 t2=t1*((sqrt(rp))^(ga-1)/ga));
14 t21=((t2-t1)/etac)+t1;
15 wc=2*ma*cp*(t21-t1);.....//Work input for the
    two stage compressor in kJ/s
16 t6=t5/(rp^((ga-1)/ga));
17 t61=t5-etat*(t5-t6);
18 wt=ma*cp*(t5-t61);.....//Work output from
    turbine in kJ/s
19 wnet=wt-wc;.....//Net work available
    in kJ/s
20 disp(wnet,"Net work output in kW:")
21 qs=ma*cp*(t5-t21);.....//Heat supplied
    in kJ/s
22 etath=wnet/qs;
23 disp(etath*100,"Power plant efficiency in %:")

```

---

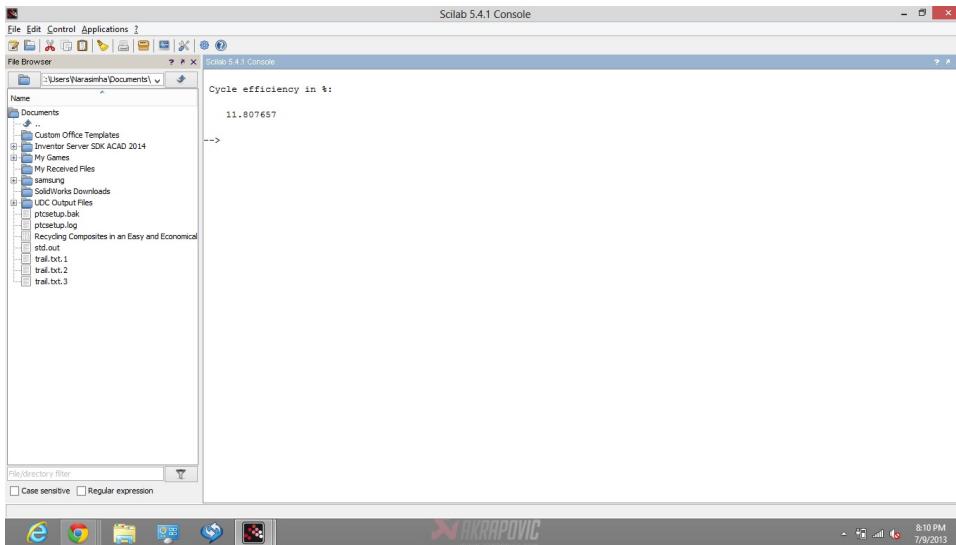


Figure 21.12: Efficiency of gas turbine cycle

### Scilab code Exa 21.13 Efficiency of gas turbine cycle

```

1 clc;funcprot(0); //EXAMPLE 21.13
2 // Initialisation of Variables
3 t1=288;.....//Temperature of intake air in K
4 rp=4;.....//Pressure ratio
5 etac=0.82;.....//Compressor efficiency
6 etahe=0.78;.....//Efficiency of heat exchanger
7 etat=0.7;.....//Turbine efficiency
8 t3=873;.....//Temperature before expansion in
     turbine in K
9 R=0.287;.....//Gas constant for air in kJ/kgK
10 ga=1.4;.....//Ratio of specific heats
11 //Calculations
12 t2=t1*((rp)^((ga-1)/ga));.....//Ideal

```

```

    temperature of air after compression in K
13 t21=((t2-t1)/etac)+t1;.....//Actual
    temperature of air after compression in K
14 t4=t3/(rp^((ga-1)/ga));.....//Ideal
    temperature after expansion in turbine in K
15 t41=t3-etag*(t3-t4);.....//Actual temperature
    after expansion in turbine in K
16 cp=R*(ga/(ga-1));.....// Specific heat at
    constant pressure in kJ/kgK
17 wc=cp*(t21-t1);.....//Compressor work in kJ/
    kg
18 wt=cp*(t3-t41);.....//Turbine work in
    kJ/kg
19 wnet=wt-wc;.....//Net work available
    in kJ/s
20 t5=(etahe*(t41-t21))+t21;
21 qs=cp*(t3-t5);.....//Heat supplied in kJ
    /kg
22 etac=wnet/qs;.....//Cycle efficiency
23 disp(etac*100,"Cycle efficiency in %:")

```

---

### Scilab code Exa 21.14 Heat exchanger in gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.14
2 // Initialisation of Variables
3 etahe=0.72;.....//Efficiency of heat
    exchanger
4 p1=1.01;.....//Pressure of air while entering
    the turbine in bar
5 t1=293;.....//Temperature of air entering the
    turbine in K
6 p2=4.04;.....//Pressure of air after compression
    in bar

```

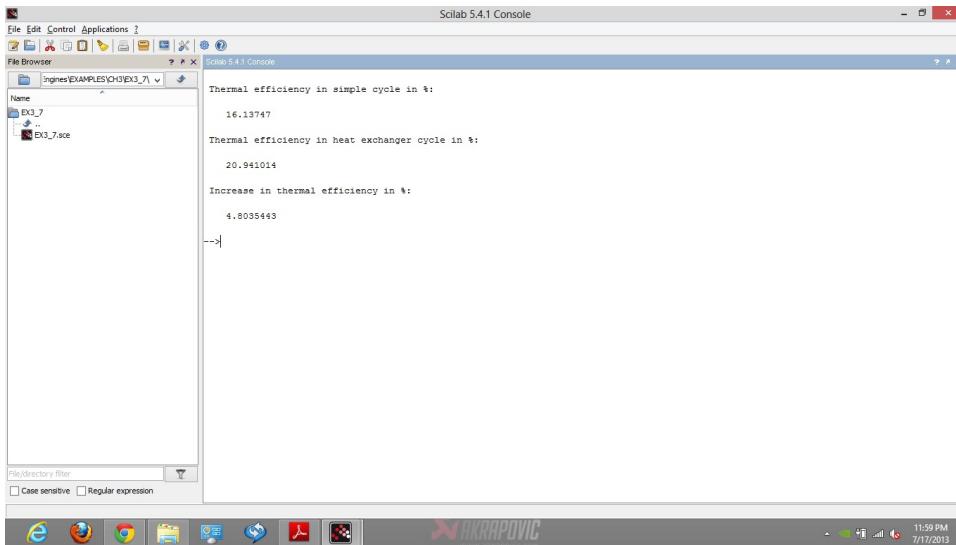


Figure 21.13: Heat exchanger in gas turbine

```

7 etat=0.85;.....//Turbine efficiency
8 pdhe=0.05;.....//Pressure drop on each side
      of heat exchanger in bar
9 pdcc=0.14;.....//Pressure drop in combustion
      chamber in bar
10 etac=0.8;.....//Compressor efficiency
11 ga=1.4;.....//Ratio of specific heats
12 C=41800;.....//Calorific value of fuel in kJ
      /kg
13 cp=1.024;.....//Specific heat at constant
      pressure in kJ/kgK
14 afrc=90;.....//Air fuel ratio for simple
      cycle
15 //Calculations
16 t2=(t1*((p2/p1)^((ga-1)/ga)));.....//Ideal
      temperature of air after compression in K
17 t21=round(((t2-t1)/etac)+t1);.....//Actual
      temperature of air after compression in K
18 t3=((1*C)/(cp*(afrc+1)))+t21;.....//
      Temperature before expansion in turbine in K

```

```

19 p4=p1;p3=p2-pdcc;t4=round(t3*((p4/p3)^((ga-1)/ga)))
    .....//Ideal temperature after expansion
    in turbine in K
20 t41=t3-(etat*(t3-t4));.....//Actual
    temperature after expansion in turbine in K
21 etath=(t3-t41-t21+t1)/(t3-t21);.....//Thermal
    efficiency in simple cycle
22 disp(etath*100,"Thermal efficiency in simple cycle
    in %:")
23 p3he=p2-pdhe-pdcc;.....//Pressure before
    expansion in turbine in bar in heat exchanger
    cycle
24 p4he=p1+pdhe;.....//Pressure after
    expansion in turbine in bar in heat exchanger
    cycle
25 t4he=t3*((p4he/p3he)^((ga-1)/ga));.....//
    Ideal temperature after expansion in turbine in K
    in heat exchanger cycle
26 t41he=round(t3-(etat*(t3-t4he)));.....//
    Actual temperature after expansion in turbine in
    K in heat exchanger cycle
27 t5=(etahe*(t41he-t21))+t21;
28 etathhe=(t3-t41he-t21+t1)/(t3-t5);.....//
    Thermal efficiency for heat exchanger cycle
29 disp(etathhe*100,"Thermal efficiency in heat
    exchanger cycle in %:")
30 inc=etathhe-etath;
31 disp(inc*100,"Increase in thermal efficiency in %:")

```

---

**Scilab code Exa 21.15** Multi stage gas turbine with intercooler and heat exchanger

```
1 clc;funcprot(0); //EXAMPLE 21.15
```

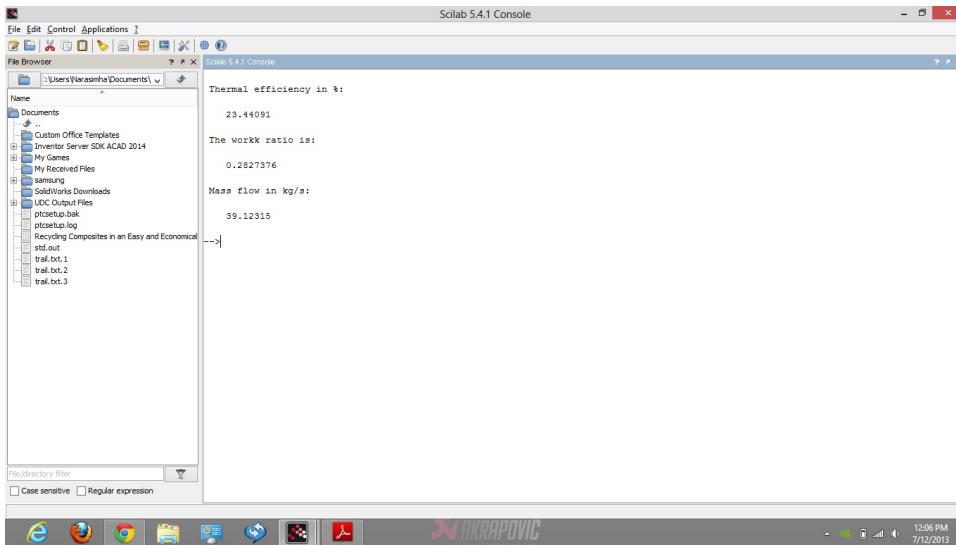


Figure 21.14: Multi stage gas turbine with intercooler and heat exchanger

```

2 // Initialisation of Variables
3 t1=293;.....//Temperature of air entering the
   turbine in K
4 rp=9;.....//Overall pressure ratio
5 etac=0.8;.....//Efficiency of compressor
6 t6=898;.....//Reheat remperature
7 t8=t6;etat=0.85;.....//Efficiency of turbine
8 etamech=0.95;.....//Mechanical efficiency
9 etahe=0.8;.....//Heat exchanger thermal
   efficiency
10 cpg=1.15;.....//Specific heat capacity for
    gases in heat exchanger in kJ/kgK
11 cpa=1.005;.....//Specific heat capacity for
    normal air in kJ/kgK
12 gag=1.333;.....//Ratio of specific heats for
    gases in heat exchanger
13 ga=1.4;.....//Ratio of specific heats for
    normal gases
14 P=4500;.....//Power output of turbine in
    kW

```

```

15 // Calculations
16 t2=t1*((sqrt(rp))^(ga-1)/ga));
17 t21=((t2-t1)/etac)+t1;
18 wc=cpa*(t21-t1);.....//Work input per
    compressor stage
19 whp=(2*wc)/etamech;.....//Work output of HP
    turbine in kJ/kg
20 t71=t6-(whp/cpg);t7=round(t6-((t6-t71)/etat));
21 k=(rp/((t6/t7)^(gag)/(gag-1)))^((gag-1)/gag);
22 k1=((round((k/2)*100))*2)/100;.....//
    Rounding off upto 2 decimals
23 t9=t8/(k1);
24 t91=t8-((t8-t9)*etat);
25 wout=cpg*(t8-t91)*etamech;.....//Net work
    output in kJ/kg
26 t5=etahe*(t91-t21)+t21;
27 qs=cpg*(t6-t5)+cpg*(t8-t71);.....//Heat
    supplied
28 etath=wout/qs;.....//Thermal efficiency
29 disp(etath*100,"Thermal efficiency in %:")
30 wgross=whp+(wout/etamech);.....//Gross work
    output in kJ/kg
31 wr=wout/wgross;.....//Work ratio
32 disp(wr,"The workk ratio is:")
33 m1=P/wout;.....//Mass flow in kg/s
34 disp(m1,"Mass flow in kg/s:")

```

---

### Scilab code Exa 21.16 Multi stage gas turbine

```

1 clc;funcprot(0); //EXAMPLE 21.16
2 // Initialisation of Variables
3 //Conditions of the closed gas turbine
4 t1=293;.....//Temperature at the inlet of

```

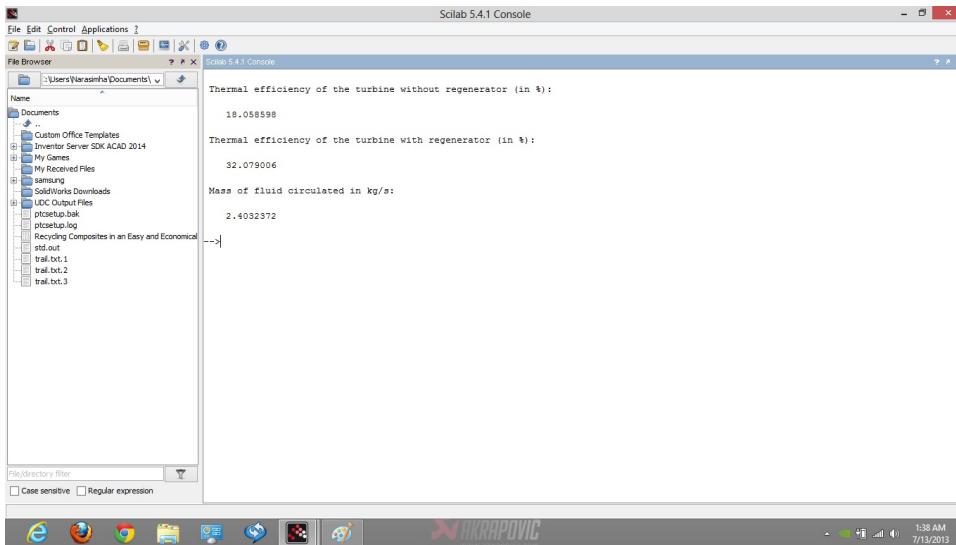


Figure 21.15: Multi stage gas turbine

```

first stage compressor in K
5 t5=1023;.....//Maximum temperature in K
6 p1=1.5;.....//Inlet pressure in bar
7 p2=6;.....//Pressure in bar
8 etac=0.82;.....//Compressor efficiency
9 etat=0.82;.....//Turbine efficiency
10 etare=0.70;.....//Regenerator efficiency
11 P=350;.....//Power developed by the
    plant in kW
12 ga=1.4;.....//Ratio of specific heats
13 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK
14 t3=t1;
15 //Calculations
16 t2=t1*((sqrt(p2/p1))^{(ga-1)/ga});
17 t21=((t2-t1)/etac)+t1;t41=t21;
18 t6=t5/((p2/sqrt(p1*p2))^{(ga-1)/ga});
19 t61=t5-(etat*(t5-t6));t81=t61;
20 t7=t5;
21 ta=(etare*(t81-t41))+t41;....//Temperature of air

```

```

        coming out of regenerator in K
22 wnet=2*cp*(t5-t61-t21+t1);.....//Net work done in
      kJ/kg of air
23 qs=cp*(t5-t41+t7-t61);.....//Heat supplied
      without regenerator in kJ/kg of air
24 qsr=cp*(t5-ta+t7-t61);.....//Heat supplied
      with regenerator in kJ/kg of air
25 etath=wnet/qs;.....//Thermal efficiency (
      without regenerator)
26 etathr=wnet/qsr;.....//Thermal efficiency (with
      regenerator)
27 mfl=P/wnet;.....//mass of fluid circulated in
      kg/s
28 disp(etath*100,"Thermal efficiency of the turbine
      without regenerator (in %):")
29 disp(etathr*100,"Thermal efficiency of the turbine
      with regenerator (in %):")
30 disp(mfl,"Mass of fluid circulated in kg/s:")

```

---

### Scilab code Exa 21.17 gas turbine power plant

```

1 clc;funcprot(0); //EXAMPLE 21.17
2 // Initialisation of Variables
3 t1=293;.....//Temperature of inlet air into
      low pressure compressor in K
4 p1=1.05;.....//Pressure of inlet air into low
      pressure compressor in bar
5 t3=300;.....//Temperature of air after passing
      it through intercooler in K
6 t6=1023;.....//temperature of air in combustion
      chamber in K
7 rp=2;.....//Pressure ratio of each compressor
8 etac=0.82;.....//Compressor efficiency

```

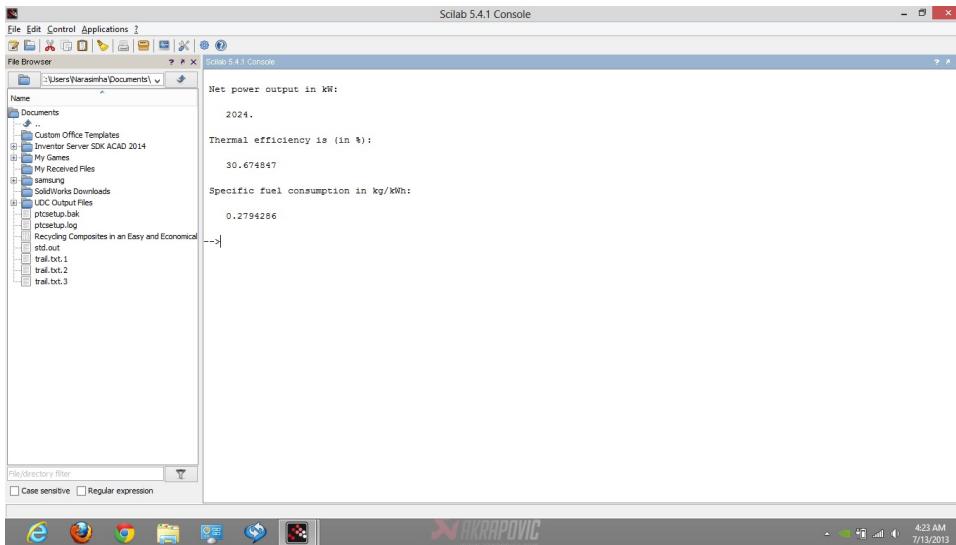


Figure 21.16: gas turbine power plant

```

9 etat=0.82;.....//Turbine efficiency
10 etaht=0.72;.....//Heat exchanger efficiency
11 ma=16;.....//Air flow in kg/s
12 ga=1.4;.....//Ratio of specific heats for air
13 gag=1.33;.....//Ratio of specific heats for
   gases
14 cpa=1.0;.....//Specific heat at constant
   pressure in kJ/kgK for air
15 cpg=1.15;.....//Specific heat at constant
   pressure in kJ/kgK for gases
16 C=42000;.....//Calorific value of fuel in kJ/kg
17 //Calculations
18 t2=round(t1*(rp^((ga-1)/ga)));
19 t21=round(((t2-t1)/etac)+t1);
20 t4=t3*(rp^((ga-1)/ga));
21 t41=round(((t4-t3)/etac)+t3);
22 t71=round(((cpg*t6)-cpa*(t21-t1+t41-t3))/cpg);
23 t7=t6-((t6-t71)/etat);
24 p6=p1*rp*rp;
25 p7=p6/((t6/t7)^((gag)/(gag-1)));

```

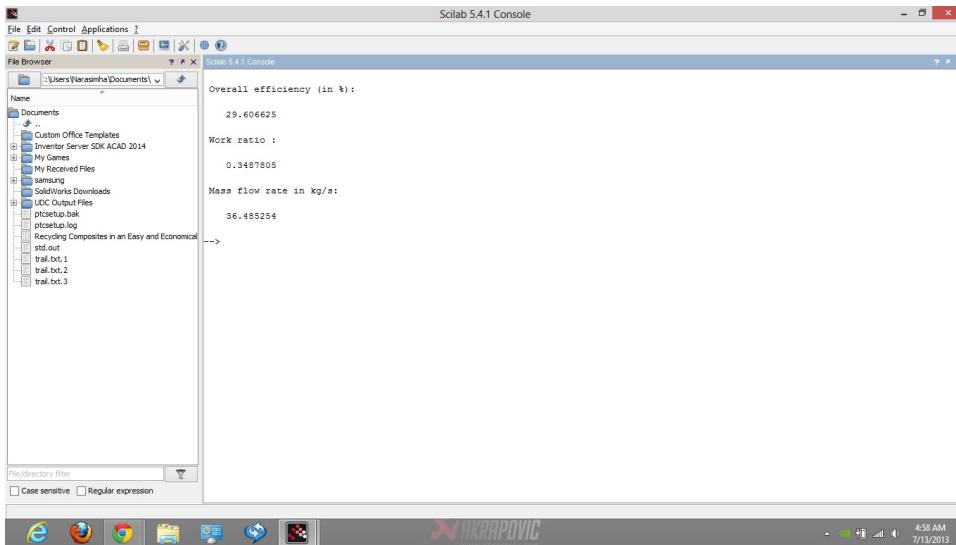


Figure 21.17: Multi stage gas turbine

```

26 t8=round(t71/((p7/p1)^((gag-1)/gag)));
27 t81=round(t71-(etat*(t71-t8)));
28 P=cpg*(t71-t81);.....//Net power output in kJ/
    kg
29 disp(P*ma,"Net power output in kW: ")
30 t5=etaht*(t81-t41)+t41;
31 qs=ma*cpg*(t6-t5);.....//Heat supplied in
    combustion chamber in kJ/s
32 etath=P*ma/qs;.....//Thermal efficiency
33 disp(etath*100,"Thermal efficiency is (in %):")
34 afr=C/(cpg*(t6-t5));.....//Air fuel ratio
35 mf=ma*3600/afr;.....//Fuel supplied per
    hour in kg
36 sfc=mf/(P*ma);.....//Specific fuel consumption
    in kg/kWh
37 disp(sfc," Specific fuel consumption in kg/kWh:")

```

---

### Scilab code Exa 21.18 Multi stage gas turbine

```
1 clc;funcprot(0); //EXAMPLE 21.18
2 // Initialisation of Variables
3 t1=293;.....//Temperature of inlet air into
   low pressure compressor in K
4 p1=1.1;.....//Pressure of inlet air into low
   pressure compressor in bar
5 p2=3.3;.....//Pressure of air in the low
   pressure compressor in bar
6 t3=300;.....//Intercooled temperature in K
7 pli=0.15;.....//Loss in pressure due to
   intercooling in bar
8 p3=p2-pli;.....//Pressure after intercooling
   in bar
9 p4=9.45;.....//Pressure of air after high
   pressure compressor in bar
10 p6=p4;t6=973;.....//Temperature of gases
    supplied to high pressure turbine in K
11 t8=943;.....//Reheat temperature in K
12 plr=0.12;.....//Loss of pressure after
   reheating in bar
13 p7=3.62;.....//Pressure of gases at the end
   of expansion in high pressure turbine in bar
14 p8=p7-plr;.....//Pressure of outlet gases in
   bar
15 ga=1.4;.....//Ratio of specific heats for air
16 gag=1.33;.....//Ratio of specific heats for
   gases
17 cpa=1.005;.....//Specific heat at constant
   pressure in kJ/kgK for air
18 cpq=1.15;.....//Specific heat at constant
   pressure in kJ/kgK for gases
19 etac=0.82;.....//Compressor efficiency
```

```

20 etat=0.85;.....//Turbine efficiency
21 etaht=0.65;.....//Efficiency of heat exchanger
22 P=6000;.....//Power generated in kW
23 p9=p1;
24 //Calculations
25 t2=round(t1*((p2/p1)^((ga-1)/ga)));
26 t21=round(((t2-t1)/etac)+t1);
27 t4=round(t3*((p4/p3)^((ga-1)/ga)));
28 t41=round(((t4-t3)/etac)+t3);
29 t7=round(t6/((p6/p7)^((gag-1)/gag)));
30 t71=round(t6-(etat*(t6-t7)));
31 t9=round(t8/((p8/p9)^((gag-1)/gag)));
32 t91=round(t8-(etat*(t8-t9)));
33 t5=round(etaht*(t91-t41)+t41);
34 wthp=cpg*(t6-t71);.....//Work done by high
    pressure turbine in kJ/kg of gas
35 wtlp=cpg*(t8-t9);.....//Work done by low pressure
    turbine in kJ/kg of gas
36 wchp=cpg*(t21-t1);.....//Work done by high
    pressure compressor in kJ/kg of gas
37 wcelp=cpg*(t41-t3);.....//Work done by low pressure
    compressor in kJ/kg of gas
38 qs=cpg*(t6-t5+t8-t71);.....//Heat supplied in kJ
    /kg of gas
39 etath=(wthp+wtlp-wchp-wcelp)/qs;..//Overall
    efficiency
40 disp(etath*100,"Overall efficiency (in %):")
41 wr=(wthp+wtlp-wchp-wcelp)/(wthp+wtlp);.....//Work
    ratio
42 disp(wr,"Work ratio :")
43 m=P/(wthp+wtlp-wchp-wcelp);.....//Mass flow rate
44 disp(m,"Mass flow rate in kg/s:")

```

---

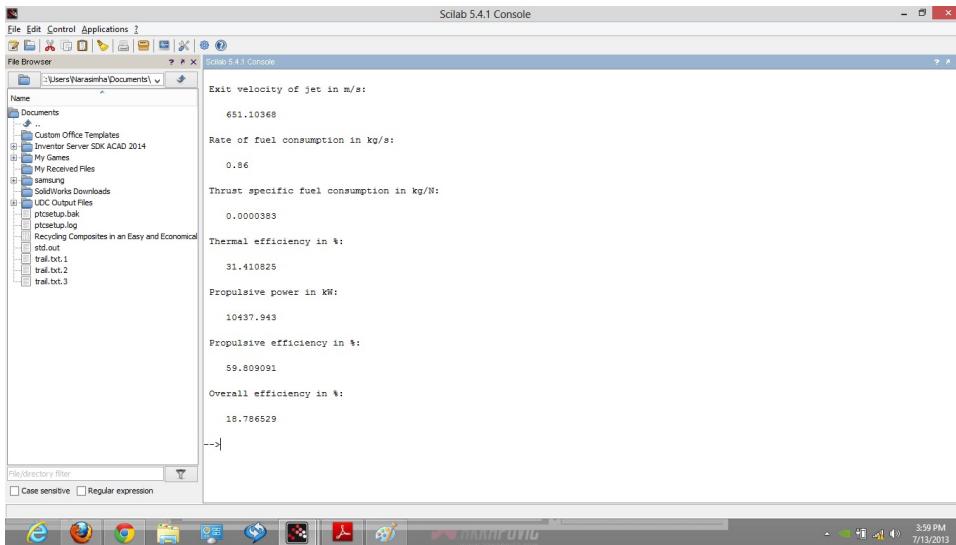


Figure 21.18: Turbo jet engine

### Scilab code Exa 21.19 Turbo jet engine

```

1 clc;funcprot(0); //EXAMPLE 21.19
2 // Initialisation of Variables
3 ma=60.2;.....//Rate of air consumption in kg/s
4 delh=230;.....//Enthalpy change for nozzle in kJ/
    kg
5 z=0.96;.....//Velocity co efficient
6 afr=70;.....//Air fuel ratio
7 etaco=0.92;.....//Combustion eficiency
8 CV=42000;.....//Calorific value of fuel in
    kJ/kg
9 v=1000;.....//Velocity of aircraft in km/h
10 Ca=v*(5/18);.....//Aircraft velocity in m/s
11 //Calculations
12 Cj=z*sqrt(2*delh*v);.....//Exit velocity of
    jet
13 disp(Cj,"Exit velocity of jet in m/s:")
14 mf=ma/afr;.....//Rate of fuel consumption
15 disp(mf,"Rate of fuel consumption in kg/s:")

```

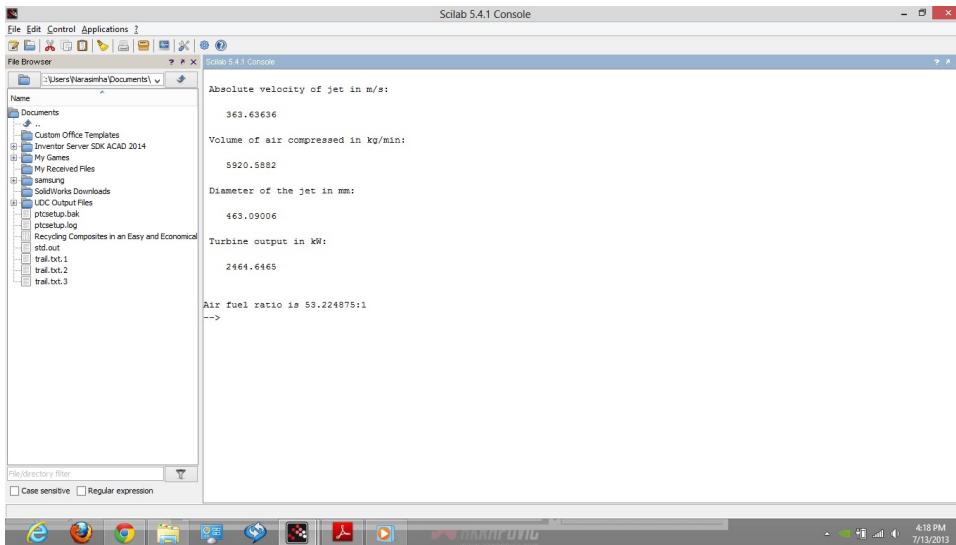


Figure 21.19: Turbo jet engine

```

16 tp=ma*(Cj-Ca);.....//Thrust produced in N
17 tsfc=mf/tp;.....//Thrust specific fuel
    consumption in kg/N
18 disp(tsfc,"Thrust specific fuel consumption in kg/N:
    ")
19 etath=((Cj^2)-(Ca^2))/(2*(1/afr)*CV*etaco*1000)
    ;.....//Thermal efficiency
20 disp(etath*100,"Thermal efficiency in %:")
21 pp=(ma/1000)*((Cj^2)-(Ca^2))/2;.....//Propulsive power in kW
22 disp(pp,"Propulsive power in kW:")
23 etapp=(2*Ca)/(Cj+Ca);.....//Propulsive efficiency
24 disp(etapp*100,"Propulsive efficiency in %:")
25 etaao=((Cj-Ca)*Ca)/((1/afr)*CV*etaco*1000)
    ;.....//Overall efficiency
26 disp(etaao*100,"Overall efficiency in %:")

```

---

### Scilab code Exa 21.20 Turbo jet engine

```
1 clc;funcprot(0); //EXAMPLE 21.20
2 // Initialisation of Variables
3 v=800;.....//Speed of the turbojet in km/h
4 etapp=0.55;.....//Propulsive efficiency
5 eta0=0.17;.....//Overall efficiency
6 al=9500;.....//Altitude in m
7 rhoa=0.17;.....//Density of air at the given
    altitude in kg/m^3
8 dr=6100;.....//Drag on the plane in N
9 CV=46000;.....//Calorific value of fuel in kJ/kg
10 //Calculations
11 Ca=v*(1000/3600);.....//Velocity of jet in m/s
12 Cj=((2*Ca)/etapp)-Ca;.....//Velocity of gases at
    nozzle exit relative to the aircraft in m/s
13 disp(Cj-Ca,"Absolute velocity of jet in m/s:")
14 ma=dr/(Cj-Ca);.....//Rate of air flow in kg/s
15 Va=(ma/rhoa)*60;.....//Volume of air
    compressed per min in kg
16 disp(Va,"Volume of air compressed in kg/min:")
17 d=sqrt((Va*4)/(60*pi*Cj));.....//Diameter of
    the jet in m
18 disp(d*1000,"Diameter of the jet in mm:")
19 tp=dr*(Ca/1000);.....//Thrust power in kW
20 wt=tp/etapp;.....//Turbine output in kW
21 disp(wt,"Turbine output in kW:")
22 mf=wt/(eta0*CV);.....//Rate of fuel
    consumption in kg/s
23 afr=ma/mf;.....//Air fuel ratio
24 printf("\n\nAir fuel ratio is %f:1",afr)
```

---

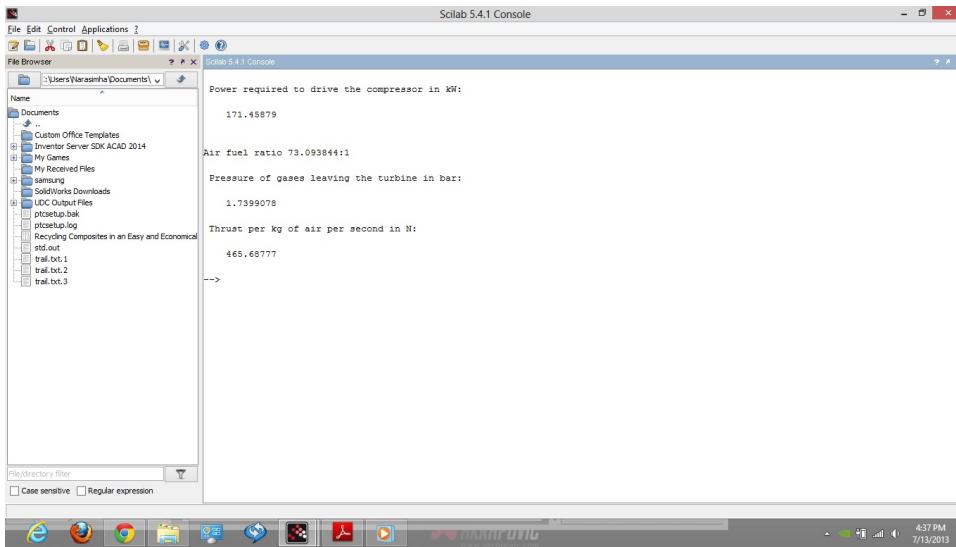


Figure 21.20: Jet propulsion

### Scilab code Exa 21.21 Jet propulsion

```

1 clc;funcprot(0); //EXAMPLE 21.21
2 // Initialisation of Variables
3 t1=288;.....//Temperature of the inlet air into
   compressor in K
4 p1=1.01;.....//Pressure of the inlet air into
   compressor in bar
5 t3=1023;.....//Maximum temperature in K
6 p2=4.04;.....//Pressure of air at the end of
   compression in bar
7 etac=0.82;.....//compressor efficiency
8 etat=0.78;.....//Turbine efficiency
9 etan=0.88;.....//Nozzle efficiency
10 R=0.287;.....//Gas constant for air in kJ/kgK
11 ga=1.4;.....//Ratio of specific heats
12 C=42000;.....//Calorific value of fuel in kJ/kg

```

```

13 // Calculations
14 t2=t1*((p2/p1)^((ga-1)/ga));.....//Ideal
    temperature at the end of compression in K
15 t21=((t2-t1)/etac)+t1;.....//Actual
    temperature at the end of compression in K
16 cp=R*(ga/(ga-1));.....// Specific heat at
    constant pressure in kJ/kgK
17 Pc=cp*(t21-t1);.....//Power required to
    drive the compressor in kW
18 disp(Pc,"Power required to drive the compressor in
    kW:")
19 afr=((C)/(cp*(t3-t21)))-1;....//Air fuel ratio
20 printf("\n\nAir fuel ratio %f:1\n",afr)
21 t41=t1+t3-t21;.....//Actual temperatur of gases
    leaving the turbine in K
22 t4=t3-((t3-t41)/etat);.....//Ideal temperature of
    gases leaving the turbine in K
23 p3=p2;p4=p3*((t4/t3)^(ga/(ga-1)));.....//Pressure
    of gases leaving the turbine in bar
24 disp(p4,"Pressure of gases leaving the turbine in
    bar:")
25 p5=p1;t5=t41/((p4/p5)^((ga-1)/ga));
26 t51=t41-(etan*(t41-t5));
27 Cj=sqrt(2*cp*(t41-t51)*1000);.....//Jet
    velocity in m/s
28 th=Cj*1;.....//Thrust per kg per second
    in N
29 disp(th,"Thrust per kg of air per second in N:")

```

---

### Scilab code Exa 21.22 Turbo jet with diffuser and nozzle

```

1 clc;funcprot(0); //EXAMPLE 21.22
2 // Initialisation of Variables

```

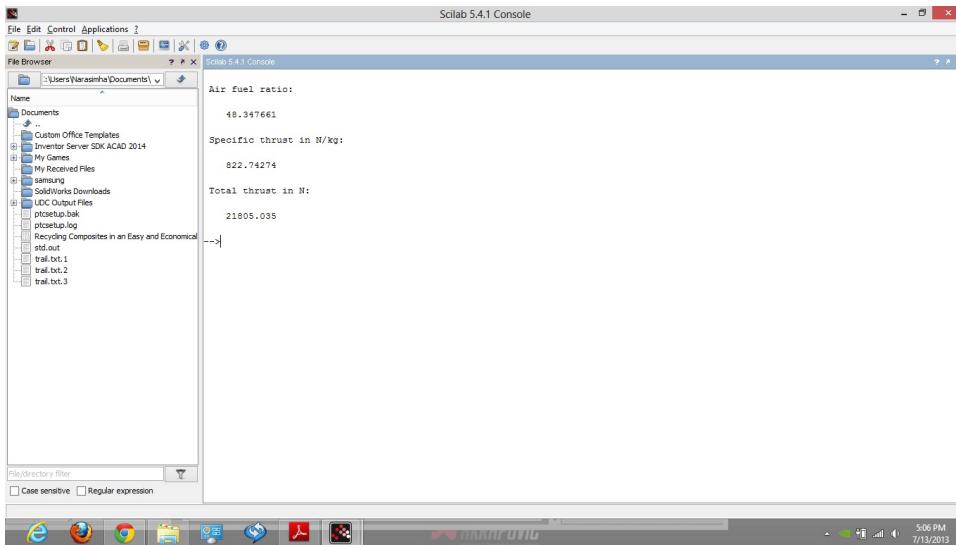


Figure 21.21: Turbo jet with diffuser and nozzle

```

3 Ca=216;.....//Speed of aircraft in m/s
4 t1=265.8;.....//Intake air temperature in
K
5 p1=0.78;.....//Intake air pressure in bar
6 rp=5.8;.....//Pressure ratio in
compressor
7 t4=1383;.....//Temperature of gases
entering the gas turbine in K
8 pd=0.168;.....//Pressure drop in
combustion chamber in bar
9 etad=0.9;.....//Diffuser efficiency
10 etan=0.9;.....//Nozzle efficiency
11 etac=0.9;.....//Compressor efficiency
12 etat=0.8;.....//Turbine efficiency
13 C=44150;.....//Calorific value of fuel in kJ/
kg
14 cp=1.005;.....//Specific heat at constant
pressure in kJ/kgK
15 ga=1.4;.....//Ratio of specific heats
16 cin=0.12;.....//Inlet cross sectio of the

```

```

        diffuser in m^3
17 R=0.287;.....//Gas constant in kJ/kgK
18 //Calculations
19 t2=t1+((Ca*Ca)/(2*cp*1000));.....//For ideal
    diffuser
20 t21=t1+((Ca*Ca)/(2*cp*etad*1000));.....//For actual
    diffuser
21 p2=p1*((t2/t1)^(ga/(ga-1)));
22 t3=t21*(rp^((ga-1)/ga));t31=t21+((t3-t21)/etac);
23 afr=(C-(cp*t4))/(cp*(t4-t31));.....//Air fuel
    ratio
24 disp(afr," Air fuel ratio:")
25 p3=p2*rp;p4=p3-pd;.....//Pressure of gases
    entering the turbine in bar
26 t51=t4-(t31-t21);t5=round(t4-((t4-t51)/etat));
27 p5=p4/((t4/t5)^(ga/(ga-1)));p6=p1;
28 t6=t51/((p5/p6)^((ga-1)/ga));t61=t51-(etac*(t51-t6))
    ;
29 Cj=44.72*sqrt(cp*(t51-t61));.....//Velocity at
    the exit of the nozzle in m/s
30 st=(1+(1/afr))*Cj;.....//Specific thrust in N
    /kg
31 disp(st," Specific thrust in N/kg:")
32 v1=Ca*cin;.....//Volume of flowing air in m^3/
    s
33 ma=(p1*v1*10^5)/(R*t1*1000);.....//Mass flow of
    air
34 tt=ma*st;.....//Total thrust in N
35 disp(tt," Total thrust in N:")

```

---

### Scilab code Exa 21.23 Jet engine

```
1 clc;funcprot(0); //EXAMPLE 21.23
```

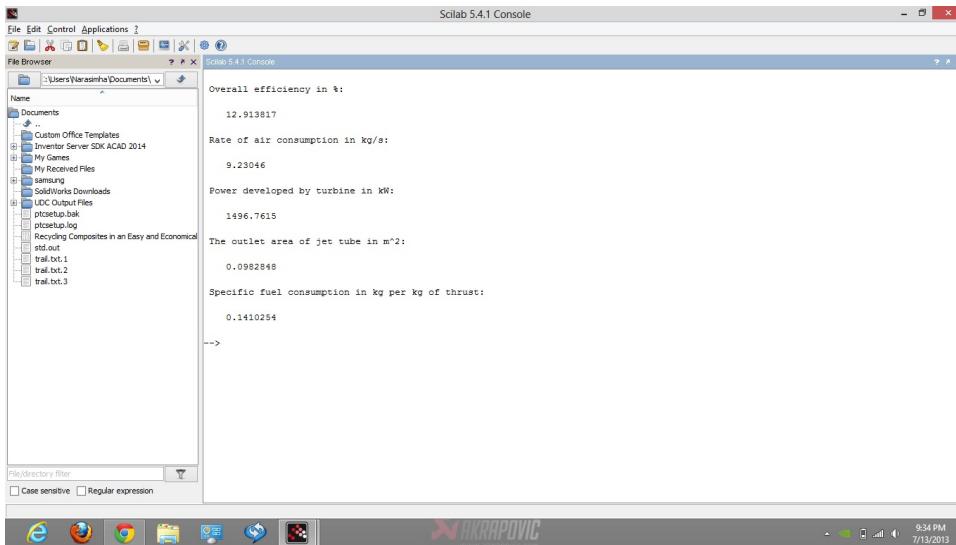


Figure 21.22: Jet engine

```

2 // Initialisation of Variables
3 al=9000;.....//Altitude in m
4 Ca=215;.....//Speed of aircraft in m/s
5 TP=750;.....//Thrust power developed in kW
6 p1=0.32;.....//Inlet pressure of air in bar
7 t1=231;.....//Inlet temperature of air in K
8 t3=963;.....//Temperature of gases leaving
    the combustion chamber in K
9 rpc=5.2;.....//Pressure ratio
10 C=42500;.....//Calorific value of fuel in kJ/kg
11 C41=195;.....//Velocity in ducts
12 etac=0.86;.....//Compressor efficiency
13 ga=1.4;.....//Ratio of specific heats for air
14 gag=1.33;.....//Ratio of specific heats for
    gases
15 etat=0.86;.....//Turbine efficiency
16 eta jt=0.9;.....//Jet tube efficiency
17 cp=1.005;.....//Specific heat at constant
    pressure in kJ/kgK for air
18 cpg=1.087;.....//Specific heat at constant

```

```

    pressure in kJ/kgK for gases
19 R=0.29;.....//Gas constant for exhaust
    gases in kJ/kgK
20 //Calculations
21 t2=t1*(rpc^((ga-1)/ga));
22 t21=t1+((t2-t1)/etac);
23 mf=(cpg*(t3-t21))/(C-(cpg*(t3-t21)));
24 afr=1/mf;.....//Air fuel ratio
25 t41=round(t3-((cp*(t21-t1))/(cpg*(1+mf))));
26 t4=t3-((t3-t41)/etat);p4=rpc;
27 rpt=(t3/t4)^(gag/(gag-1));.....//Expansion
    pressure ratio in turbine
28 rpj=p4/rpt;.....//Expansion pressure
    ratio in jet tube
29 t5=t41/(rpj^((gag-1)/gag));
30 Cj=sqrt(etajt*2*((cpg*1000*(t41-t5))+((C41*C41)/2)))
    ;
31 etao=((((1+mf)*Cj)-Ca)*Ca)/(1000*mf*C);....//Overall efficiency
32 disp(etao*100,"Overall efficiency in %:")
33 ma=(TP*1000)/(((1+mf)*Cj)-Ca)*Ca;.....//Rate of
    air consumption in kg/s
34 disp(ma,"Rate of air consumption in kg/s:")
35 P=ma*(1+mf)*cpg*(t3-t41);.....//Power
    developed by the turbine in kW
36 disp(P,"Power developed by turbine in kW:")
37 t51=t41-(((Cj^2)-(C41^2))/(2*1000*cpg));
38 rhoe=(p1*10^5)/(R*1000*t51);.....//Density of
    exhaust gases
39 Ajt=(ma*(1+mf))/(Cj*rhoe);.....//Discharge of jet
    area in m^2
40 disp(Ajt,"The outlet area of jet tube in m^2:")
41 sfc=(mf*ma*3600)/(1000*(TP/Ca));.....//Specific
    fuel consumption in kg/thrust-hour
42 disp(sfc,"Specific fuel consumption in kg per kg of
    thrust:")

```

---