# Course EN 310 (IC Engine and Combustion Lab)

# Experiment No. 2A: SI Engine Performance Testing

1. **Objective:**

   To study the performance of multi cylinder four stroke petrol engine.

2. **Aim:**

   To determine

   - Brake power
   - Fuel consumption
   - Specific fuel consumption
   - Brake Thermal efficiency
   - Swept volume
   - Air consumption
   - Volumetric efficiency

3. **Introduction:**

   The most commonly used source of power for motor vehicles, introduced by the German engineers Gottlieb Daimler and Karl Benz in 1885. The petrol engine is a complex piece of machinery made up of about 150 moving parts. It is a reciprocating piston engine, in which a number of pistons move up and down in cylinders. A mixture of petrol and air is introduced to the space above the pistons and ignited. The gases produced force the pistons down, generating power. The engine-operating cycle is repeated every four strokes (upward or downward movement) of the piston, this being known as the four-stroke cycle. The motion of the pistons rotates a crankshaft, at the end of which is a heavy flywheel. From the flywheel, the power is transferred to the car’s driving wheels via the transmission system of clutch, gearbox, and final drive.

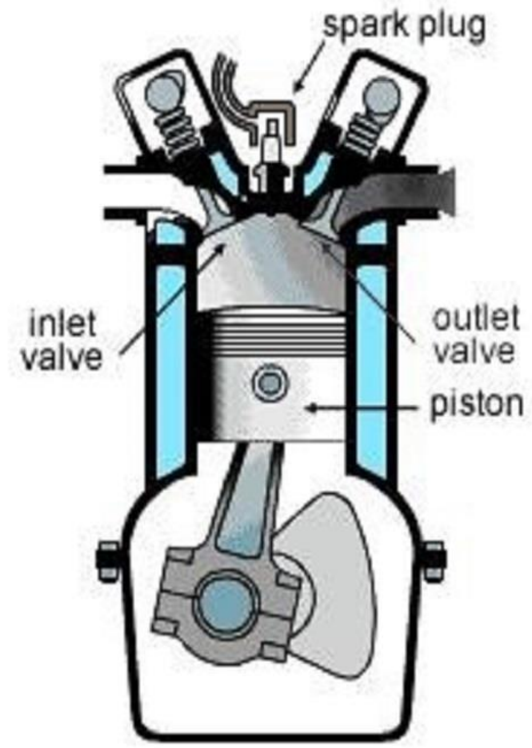


*Figure 1 Components of a 4-stroke IC engine*

## 4. Theory:

### The Four Stroke Cycle

The 'stroke' means simply, when the piston moves either all the way up or all the way down inside the cylinder. As you might guess, in the four-stroke engine each of the four strokes accomplishes something different. Therefore, let's have a look at the four strokes and see what happens:

**Induction:**

The first stroke is called Induction. This is when the fuel and air mixture is drawn into the cylinder by the piston going down and producing suction. As the piston travels down the cylinder it creates a vacuum above it and the fuel mixture is drawn into the cylinder in the empty space left by the piston The piston starts at the top, the camshaft turns and pushes on the tappets which causes the intake valve to open (on the left), and the piston moves down to let the engine take in a cylinder full of air and fuel. This is also sometimes called the intake stroke.

**Compression:**

Compression is the second of the four strokes. This is the stage when the fuel and air mixture is compressed and forced into the top of the cylinder ready for ignition. The camshaft has turned, pushed the tappets, which have in turn allowed the inlet valve to return to the closed position. The piston moves back up and compresses this fuel/air mixture. Compressing the mixture makes the explosion more powerful. As the valves are both closed, the cylinder is sealed and the mixture can't escape.

**Ignition:**

As the piston reaches the top of the compression stroke, the spark plug 'fires' and ignites the highly compressed fuel and air mixture. The piston is then forced back down the cylinder by the resulting explosion, turning the crankshaft and generating the propulsion for the engine which makes the car go along the road. The diagram shows the piston on way down the cylinder just after the mixture has ignited.

**Exhaust:**

This is when the exhaust gases (after the fuel is burnt) are forced out of the engine. Once the piston hits the bottom of its stroke, the exhaust valve opens (on the right). The piston travels back up inside the cylinder and this time it 'pushes' the exhaust gasses out through the now open exhaust vent. Now the engine is ready for the next cycle, so it intakes another charge of air and gas. Moreover, we are back to the intake stroke.

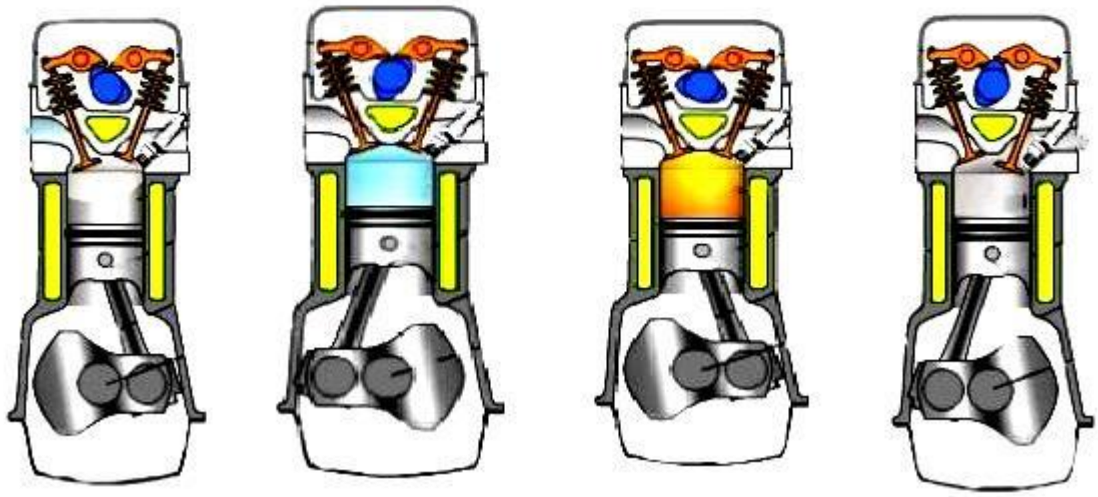

*Figure 2 Different strokes in a 4-stroke IC engine*

## 5. Description:

Test Rig consists of:

1. Three Cylinder, Four Stroke petrol engine,
2. Eddy Current Dynamometer,
3. Panel Board Arrangement,
4. Fuel Consumption measuring arrangement,
5. Air intake measuring arrangement,
6. Arrangement for measuring the heat carried away by cooling water from engine jacket,
7. Arrangement for measuring the heat carried away by exhaust gases.

**Multi-Cylinder Petrol Engine:**

A medium capacity Maruti Suzuki Alto petrol engine is selected for experimental purposes. The specification for the Engine is as follows:

| | | |
|---|---|---|
| Engine | : | 3 cylinder, 4 stroke, water cooled |
| Bore diameter | : | 66.5 mm |
| Stroke | : | 72 mm |

The engine setup is complete with self-starter, lubricating-oil filter, air cleaner, distributor, ignition coil, exhaust calorimeter etc.

**Loading Device (Eddy Current Dynamometer):**

It consists of a stator on which are fitted a number of electromagnets and a rotor disc made of copper or steel and coupled to the output shaft of the engine. When the rotor rotates, eddy currents are produced in the stator due the magnetic flux set up by the passes of field current in the electromagnets. These eddy currents oppose the rotor motion, thus loading the engine. The torque is measured exactly as in other types of absorption dynamometers, i.e. with the help of rope brake.

**Panel Board Arrangement:**

The units fitted on the Panel board are:

1. An ignition and starting switch to switch on the ignition circuit and to start the engine.

2. A Pilot lamp indicator for ignition.
3. Throttle valve control mechanism to control the position of the throttle in relation to the speed and load on the engine.

**Fuel Input Measuring Arrangement:**

Consists of self-mounting type fuel tank of about 15 litres capacity suitably mounted on a stand. The stand fixed on the air tank, fuel goes from the reservoir to fuel filter through a burette. The burette facilitates the measurement of the fuel consumption for a definite period of time with the help of a stopwatch.

**Air Intake Measuring Arrangement:**

Test rig consists of an air tank fitted with an orifice plate with orifice diameter 35mm and a manometer to measure the flow rate of air sucked by the engine. The co-efficient of discharge of orifice is about 0.64.

## 6. Experimental Procedure:

1. Fill oil in the oil sump of engine. It should be in between the marks provided on the oil dipstick.
2. Fill the petrol in petrol tank.
3. Fill the manometer fluid i.e. water, up to half of the height of manometer.
4. Fill the burette with petrol and supply the petrol to the engine by opening the valve provided at the left side of burette.
5. Switch on Mains Power Supply to the panel.
6. Open cold water supply to the engine jacket and exhaust calorimeter.
7. Insert the ignition key and turn it in the clockwise direction to ignition on position, which is indicated by an indicator lamp. Turn the ignition switch key further clockwise against the spring pressure to start the engine. As soon as the engine starts, leave the ignition key and let it run for 2 minutes under no load condition.
8. After two minutes, when engine start running smoothly, firstly load on engine with the help of dimmer-stat provided for eddy current dynamometer.
9. Wait till steady state temperature achieved.
10. Note down the reading of load and RPM.
11. For measuring fuel consumption close the petrol supply valve provided on left side of burette so that fuel flows from burette. Note down the time to consume 20ml of petrol.
12. Now open the fuel supply valve which refill the burette and continue the petrol supply.
13. Note down the reading of manometer to calculate the air intake by the engine.
14. Note the temperature of inlet and outlet of the water circulating through the engine jacket from Digital Temperature Indicator.

15. Note the flow rate of water to engine jacket from Rotameter provided.
16. Note down the temperature of inlet and outlet of exhaust gases & water circulating through the calorimeter.
17. Note the flow rate of water to calorimeter from the rotameter provided.
18. Repeat the experiment for different load.
19. When the experiment is over reduce the load on engine by removing the load on the dynamometer and reducing the throttle gradually.
20. Turn off the ignition key and remove it from the switch.
21. Then close the fuel and cooling water supply to the engine.

## 7. Specification:

| | | |
|---|---|---|
| Engine | : | 3 cylinder, 4-stroke, water cooled |
| Type | : | Stationary, Vertical 4-stroke, MPFI. |
| Bore diameter (D) | : | 66.5mm |
| Stroke (L) | : | 72mm |
| Dynamometer Arm Length (Re) | : | 210mm |
| Orifice diameter ($d_o$) | : | 35mm |
| Compression Ratio | : | 9.2:1 |
| Rated power | : | 27.6kW @ 5000 rpm |

## 8. Formula:

Brake Power (BP):

$$BP = \frac{2\pi N \times (W \times 9.81 \times r)}{60000} \text{ kW}$$

Fuel Consumption ($W_f$):

$$W_f = \frac{X_f \times \rho_f}{t \times 10^6} \quad kg/sec$$

Specific Fuel Consumption (SFC):

$$SFC = \frac{W_f}{BP} kg/kW \sec$$

Heat Supplied By Fuel ($H_f$):

$$H_f = W_f \times CV \quad kW$$

Brake Thermal Efficiency ($\eta_{bt}$):

$$\eta_{bt} = \frac{BP}{H_f} \times 100 \ \%$$

Actual Air Consumption ($Q_a$):

$$Q_a = C_d \times a_o \times \sqrt{(2 \times g \times H)} \quad m^3/\sec$$

$$where\ldots\ldots \quad H = \frac{h \times \sin\theta}{100} \times \frac{\rho_m}{\rho_a} \quad m$$

Theoretical Air Consumption ($Q_t$):

$$Q_t = V_s \times \frac{N \times N_c}{60 \times n} \quad m^3/s$$

*where.....*

Swept Volume ($V_s$) :

$$V_s = \frac{\pi}{4} D^2 L \quad m^3$$

Volumetric Efficiency ($\eta_{vol}$):

$$\eta_{vol} = \frac{Q_a}{Q_t} \times 100$$

**8. Observation & Calculation:**

**Data:**

$N_c$ = 3 (number of cylinders)

$n$ = 2 (for 4 stroke)

$d_o$ = 0.035 m

$a_o$ = ____________$m^2$

$C_d$ = 0.64

$\rho_a$ = 1.21 kg / $m^3$

$\rho_m$ = 1000 kg / $m^3$

g = 9.81 m / $s^2$

$CV$ = 44650 kJ / kg

$\rho_f$ = 690 kg / $m^3$

N =_______________ rpm (crankshaft).

Volume of Diesel consumed = ___________ ml

**Observation Table:**

| Sr. No. | 1. | 2. | 3. | 4. |
|---|---|---|---|---|
| Load $W$ (kg) | | | | |
| Time to consume $X_f$ fuel (sec) | | | | |
| $h$ (cm) | | | | |

**Calculation:**

| Sr. No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $BP$ (kW) | | | | |
| Fuel consumption $W_f$ (kg / sec) | | | | |
| Specific fuel consumption (kg / kW sec) | | | | |
| Heat supplied by fuel $H_f$ (kW) | | | | |
| Brake thermal efficiency $\eta_{bt}$ (%) | | | | |
| Air consumption $Q_a$ (m$^3$ / sec) | | | | |
| Swept volume $V_s$ (m$^3$ / sec) | | | | |
| Volumetric efficiency $\eta_{vol}$ (%) | | | | |

Plot following graphs:

1) Load Vs BSFC
2) Load Vs BTE
3) Load Vs Volumetric efficiency

**10. Conclusions:**

# Experiment No. 2B: To perform the Morse Test on 4-stroke multi cylinder Petrol Engine

**Objective:**

Determine the indicated power developed in the each cylinder of the engine and mechanical efficiency of the engine.

**Theory:**

Morse test is applicable to multi-cylinder engines. The engine is run at desired speed and output (Brake power) is noted. Then combustion in one of the cylinders is stopped by short circuiting spark plug or by cutting off the fuel supply. Under this condition other cylinders "motor" this cylinder. The output is measured after adjusting load on the engine to keep speed constant at original value. The difference in output gives the indicated power of cut-out cylinder. Thus for each cylinder indicated power is obtained to find out total indicated power.

**Assumptions:**

1) At constant engine rpm, frictional power is assumed to be constant in all the cases.
2) Charge throttled is same in all the

**Equations:**

Brake power of engine can be calculated by using:

$$BP = \frac{2\pi N \times (W \times 9.81 \times r)}{60000} \text{ kW}$$

where…. N=engine speed (rpm); W=load (kg); r = Dynamometer Arm length = 0.21m.

**Indicated power of the cylinder is calculated by using:**

$IP_{(1\,2\,3)} = BP_{(1\,2\,3)} + FP_{(1\,2\,3)}$ ……….. (i)

$IP_{(2\,3)} = BP_{(2\,3)} + FP_{(1\,2\,3)}$ ……….. (ii)

Substracting (ii) from (i) we get,

$IP_{(1)} = BP_{(1\,2\,3)} - BP_{(2\,3)}$

Indicated power of the cylinder is calculated by using:

$IP_{(engine)} = IP_{(1)} + IP_{(2)} + IP_{(3)}$

Mechanical efficiency of the engine is given as,

$$\eta_{mech} = \frac{BP_{all}}{IP_{all}} \times 100 \ \%$$

**Observation Table:**

| Sr. No. | Operating condition | Speed (rpm) | Load (kg) |
|---|---|---|---|
| 1 | All cylinders are working | | |
| 2 | First cylinder is cut-off and remaining are working | | |
| *3* | Second cylinder is cut-off and remaining are working | | |
| *4* | Third cylinder is cut-off and remaining are working | | |

**Sample Calculation:**

**Conclusions:**