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Experiment Name : Performance test on 4 cylinder 4 stroke turbocharged diesel engine

Title of experiment: Performance test on 4 cylinder 4-stroke turbocharged diesel engine

Objective: To determine volumetric efficiency, brake thermal efficiency and brake mean pressure of engine with and without intercooler.

Apparatus: Engine cylinder, 4 stroke 4 cylinder diesel engine, panel board.

Theory:

The turbocharger is used to improve an engine's volumetric efficiency by increasing the intake density. The compressor draws ambient air and compresses it before it enters into the intake manifold. This results into greater mass of air entering the cylinder at high pressure on each intake stroke. Due to increased air mass (i.e more oxygen molecule) the engine can respond more powerful explosion when the fuel and oxygen are burned and thus more power coming out of the engine.

A turbocharger must have at least 4 openings

(i) for the engine exhaust gas to enter;
(ii) for the exhaust gas to exit;
(iii) for intake air to enter the turbocharger and
(iv) for intake air to exit the turbocharger on its way to engine intake

An intercooler is an air to air heat exchanger which cools the compressed air coming out from compressor of the turbocharger before it fed to the engine.

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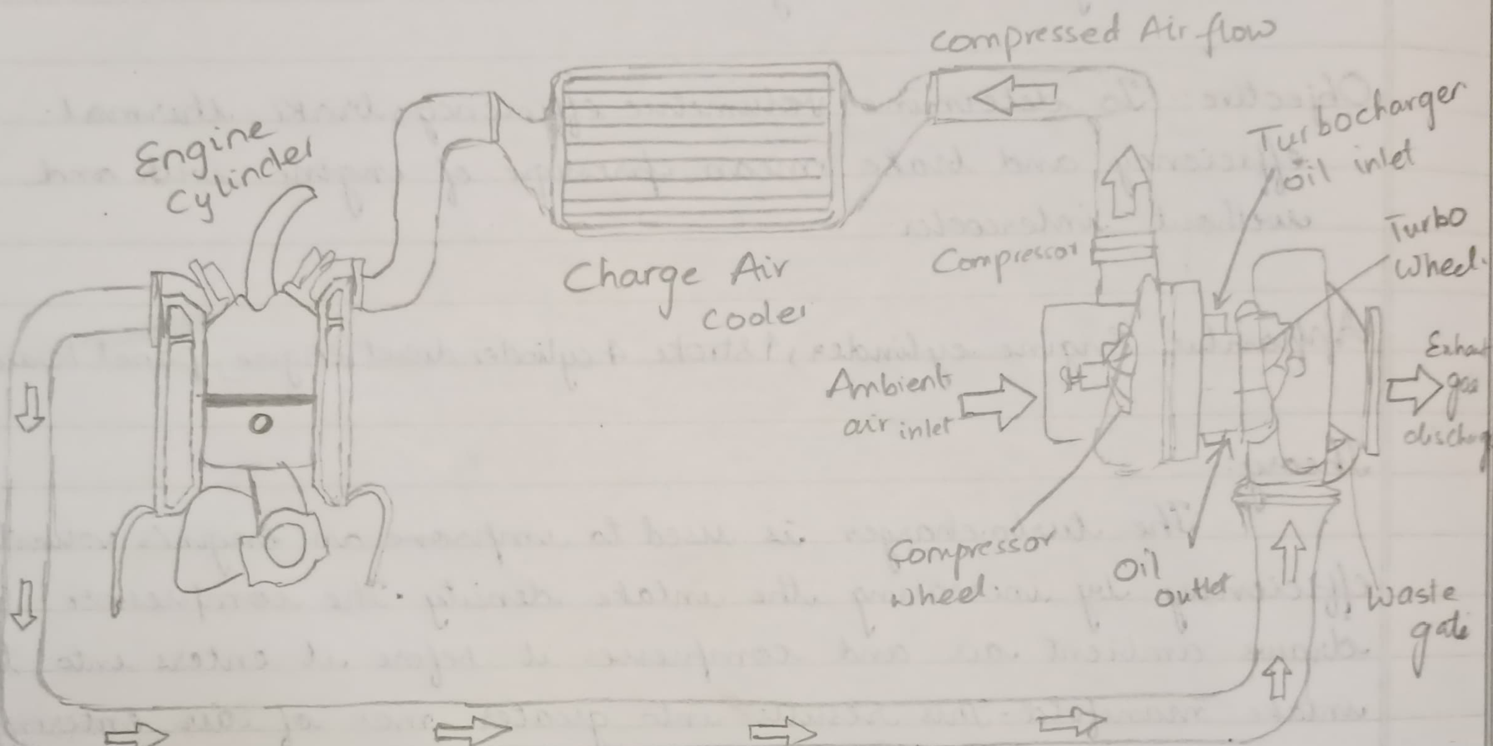

Schematic set-up

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System constraints:

Orifice diameter (m) = 0.043

Engi Dynamo arm length (m) = 0.2

Coeff of discharge for orifice, cd = 0.6

Ambient temperature (Deg C) = 30

Fuel density (Kg/m³) = 830

Fuel calorific value (KJ/Kg) = 42000

Cylinder diameter (m), D = 0.075

Stroke (m), L = 0.0785

No of cylinders = 4

No. of rev/cycle = 2

Sp-heat limit min (KJ/Kg·Deg K) = 1.4

Sp-heat limit max (KJ/Kg·Deg K) = 1.5

Observations

Engine Speed (rpm)	Load (Kg)	Mano deflec (mm)	Fuel flow (secs/100ml)	Engine Cooling (LPh)	Calo water (LPh)	T1 (Engine Water in) (Deg C)	T2 (Engine water out) (Deg C)	T3 (Cal water out) (Deg C)	T4 (Exhaust in) (Deg C)	T5 (Exhaust out) (Deg C)
2562	46	76	31.72	1000	250	30	58	52	396	306
3013	45.3	96	27.09	1000	250	30	57	57	441	343
3013	45.3	96	27.09	1000	250	30	57	57	441	343
3444	43.8	126	23.07	1000	250	30	67	60	478	378
3444	43.8	126	23.07	1000	250	30	67	60	478	378
4006	40.8	156	20.78	1000	250	30	66	65	512	411
4006	40.8	156	20.78	1000	250	30	66	65	512	411

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Calculations

1) Brake power (BP) in kW

$$BP = \frac{2\pi \times N \times T}{60 \times 1000} = \frac{2\pi \times N \times Wg \times R}{60 \times 1000}$$

$g = 9.81 m/s^2$

$R = 0.2 m$

Given:-

$N = 2562$ rpm, $W = 46$ kg, $\Delta H = 76$ mm, $t = 31.72$ sec / 100 ml.

$m_{w1} = 1000$ Lph, $m_{w2} = 250$ Lph, $T_1(°C) = 30°C$, $T_2 = 58°C$, $T_3 = 52°C$.

$T_4 = 396°C$, $T_5 = 306°C$.

$$\Rightarrow BP = \frac{2\pi \times 2562 \times 46 \times 9.81 \times 0.2}{60 \times 1000} = 24.21 \text{ kW}$$

2) Total fuel consumption (TFC, $\dot{m}_f$) in kg/hr

$$(TFC), \dot{m}_f = \frac{100 \times \rho_{oil} \times 3600}{t \times 10^6}$$

$\rho_{oil} = 830 kg/m^3$

$$= \frac{100 \times 830 \times 3600}{31.72 \times 10^6} = 9.42 \text{ kg/hr}$$

3) Brake thermal efficiency (η_{bth}) in %

$$\eta_{bth} = \frac{\text{Brake power in kW}}{\text{Rate of heat input}} = \frac{\text{Brake power} \times 3600 \times 100\%}{\dot{m}_f \times HV}$$

HV = 42000 kJ/kg for diesel.

$$= \frac{24.21 \times 3600 \times 100}{9.42 \times 42000} = 22.029\%$$

MVR

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4) Air consumption ($\dot{m}_a$) and Air fuel ratio (A_f)

$$\dot{m}_a = 3600 \times C_d \times \frac{\pi}{4} d^2 \times \rho_{air} \times \sqrt{2g \times \frac{\Delta H}{1000} \times \frac{\rho_w}{\rho_{air}}} \quad kg/hr$$

$$A/F = \frac{\dot{m}_a}{\dot{m}_f} = \frac{\text{Air consumption (kg/hr)}}{\text{Total fuel consumption (kg/hr)}}$$

C_d = discharge co-efficient of orifice = 0.6

d = diameter of orifice = 0.048 m.

ρ_w = density of water = 1000 kg/m³

ρ_{air} = density of air = 1.22 kg/m³

for N = 2562 rpm

$$\dot{m}_a = 3600 \times 0.6 \times \frac{\pi}{4} \times 0.048^2 \times 1.22 \times \sqrt{2 \times 9.81 \times \frac{76}{1000} \times \frac{1000}{1.22}}$$

$$= 166.7 \text{ kg/hr}$$

$$A/F = \frac{166.7}{9.42} = 17.69$$

5) Volumetric efficiency η_{vol} in %

$$\eta_{vol} = \frac{\dot{m}_a}{\dot{m}_{ath}} \times 100 = \frac{\dot{m}_a}{\frac{V_s \times N \times 60 \times \rho_{air}}{K}} \times 100$$

V_s = swept volume = $n \times \frac{\pi}{4} \times D^2 \times L$ in m²

$n \rightarrow$ no. of cylinder.

$D \rightarrow$ diameter of engine cylinder = 0.075 m

$L \rightarrow$ length of stroke = 0.0795 m

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K = Stroke factor = 2 (4 stroke engine)

for $N = 2562$.

$$V_s = \frac{4 \times \pi}{4} \times 0.75^2 \times 0.0795 = 1.404 \times 10^{-3} m^2.$$

$$\eta_{vol} = \frac{\dot{m}_a}{\dot{m}_{ath}} \times 100 = \frac{166.7}{1.404 \times 10^{-3} \times \frac{2562 \times 60}{2} \times 11.22} \times 100$$

$$= 1.26$$

6) Mean effective pressure (BMEP) in bar.

$$BMEP = \frac{BP}{V_s \times \text{no. of cylinders per sec.}} \times 10^{-2} \text{ bar}$$

number of cycles per sec $\frac{2562}{2 \times 60} = \frac{N}{K \times 60}$

for $N = 2562$ rpm

$$BMEP = \frac{24.21}{1.404 \times 10^{-3} \times \frac{2562}{2 \times 60}} \times 10^{-2} = 8.07 \text{ bar}.$$

Similarly, we can find other values for various engine speed.

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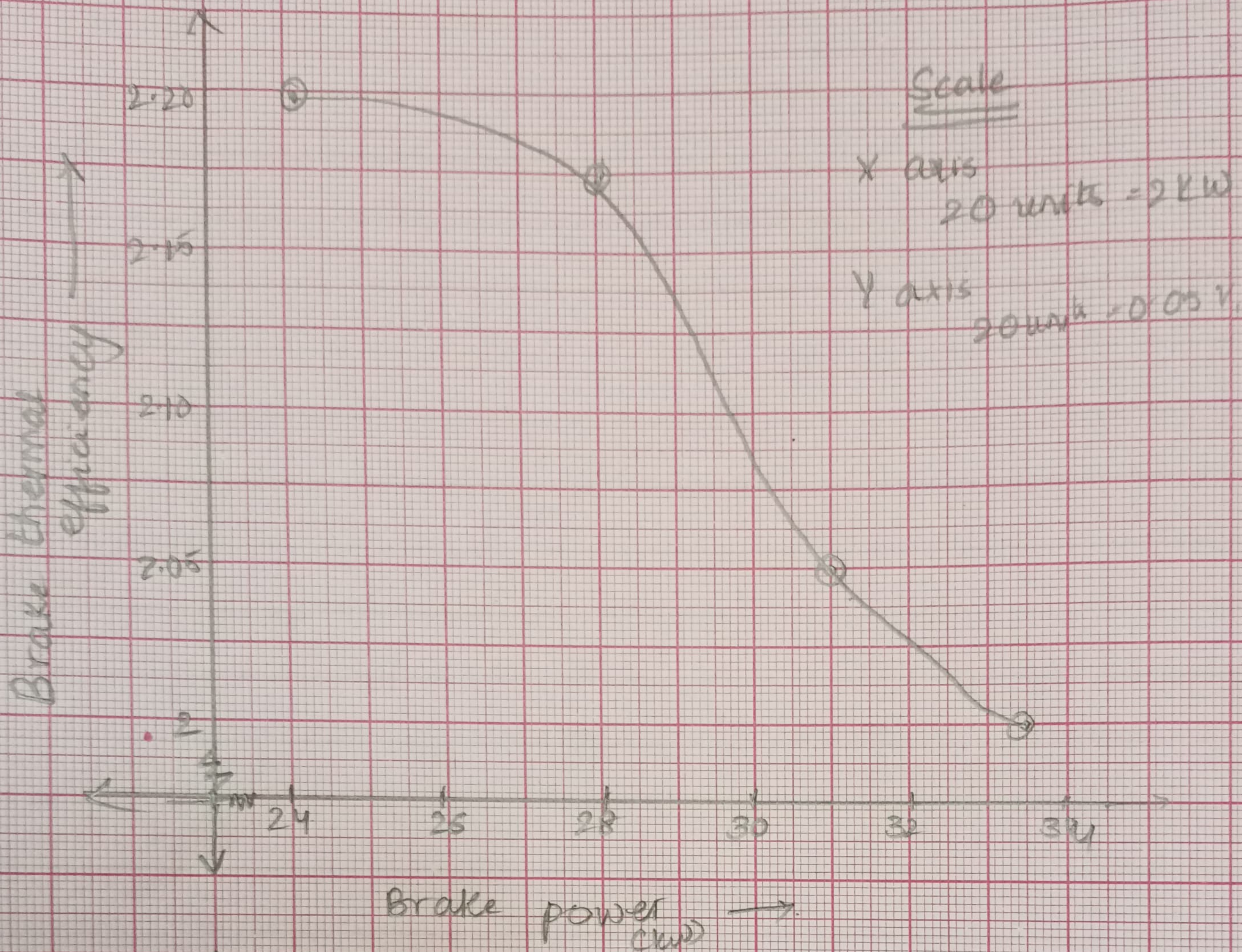
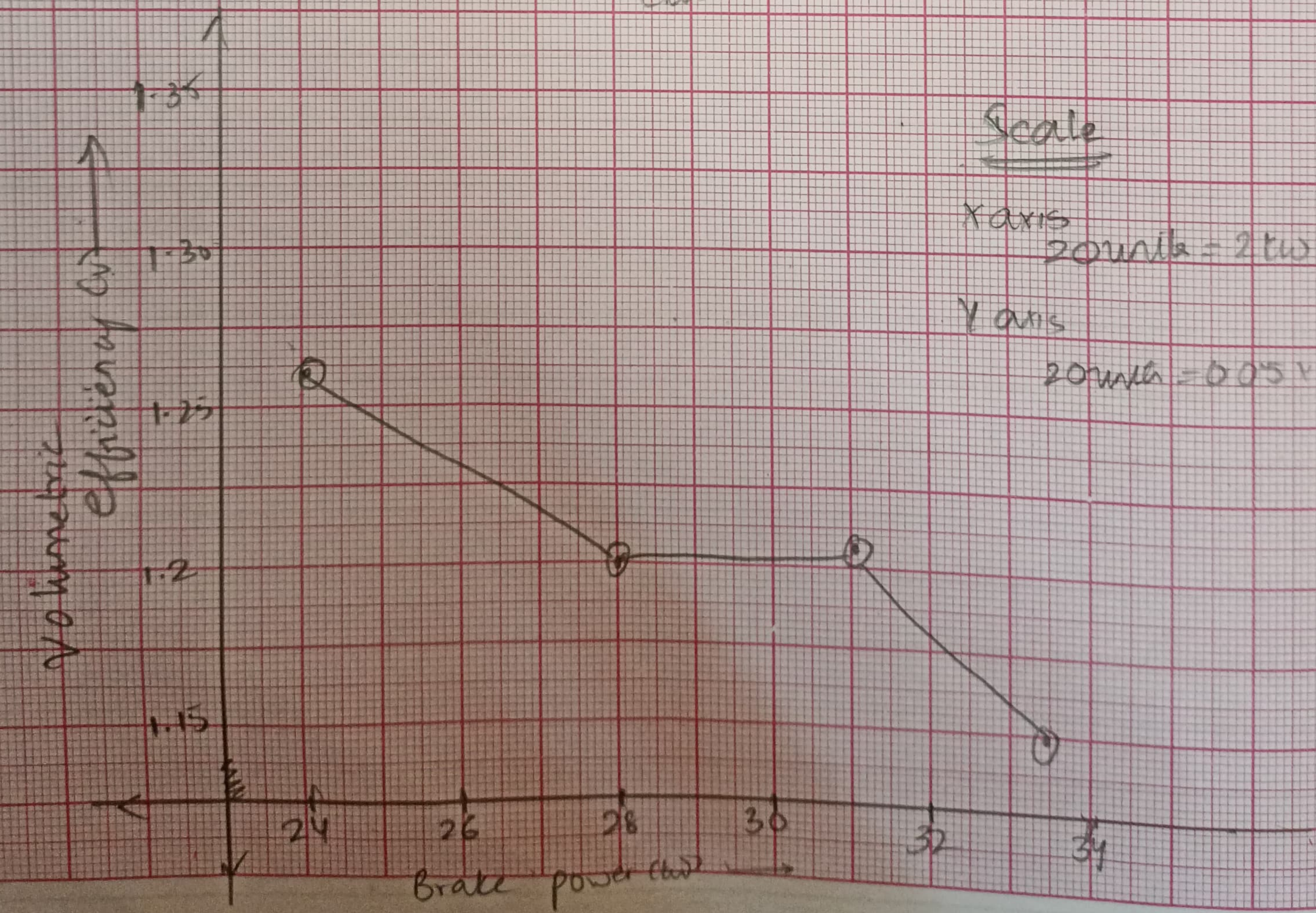

Scale
X axis
20 units = 2 kW
Y axis
20 units = 0.05 V
Brake thermal efficiency
Brake power (kW)
2.20
2.15
2.10
2.05
2
24
26
28
30
32
34


Scale
X axis
20 units = 2 kW
Y axis
20 units = 0.05 V
Volumetric efficiency (V)
Brake power (kW)
1.35
1.30
1.25
1.2
1.15
24
26
28
30
32
34

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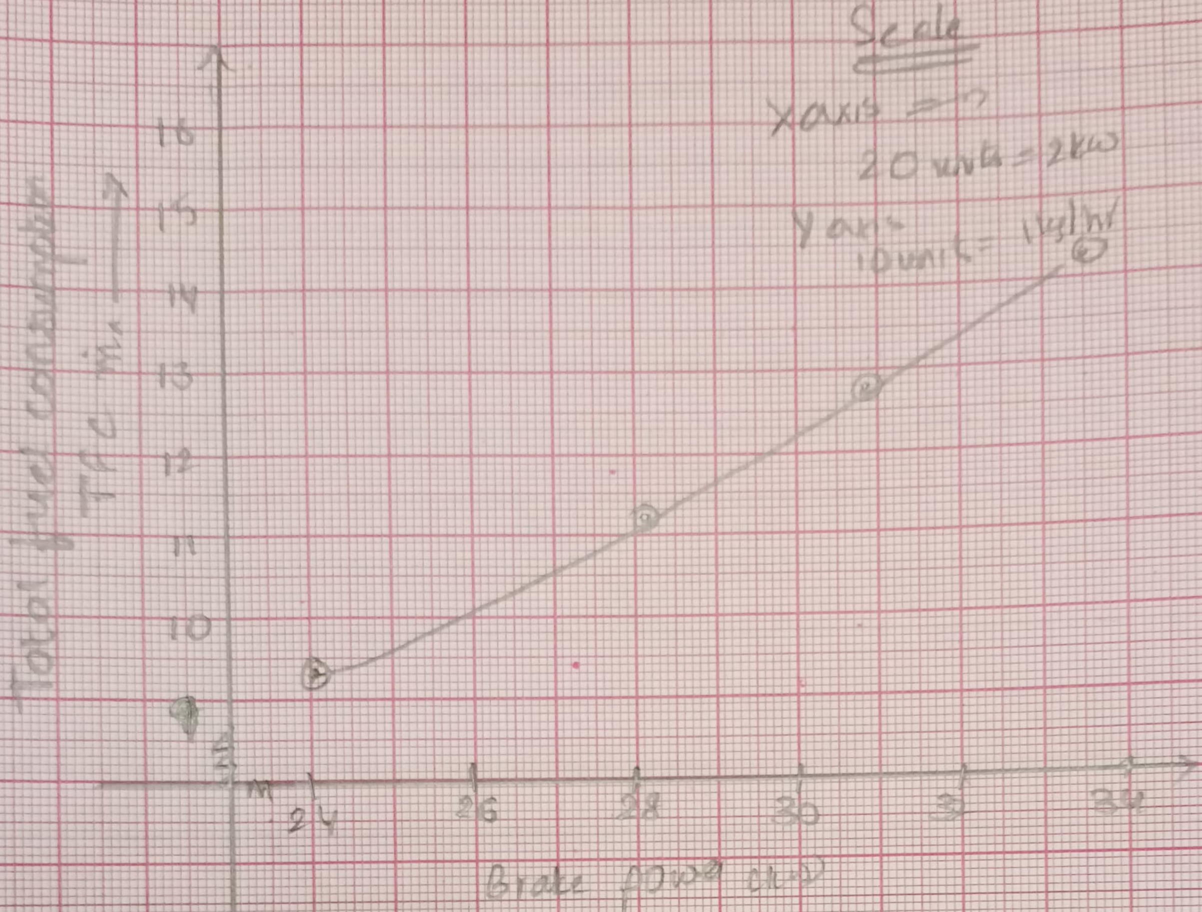
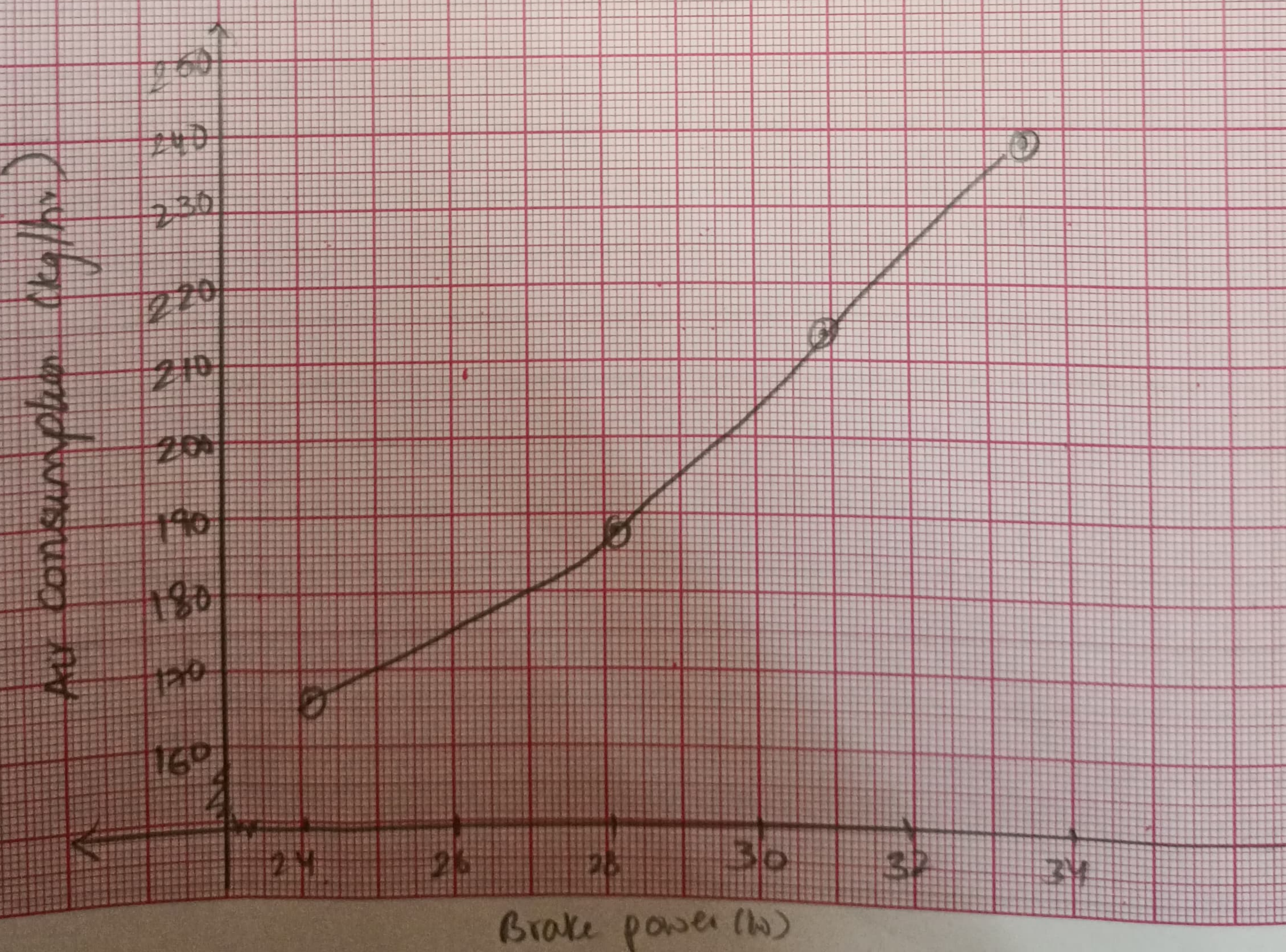

Scale
X axis →
20 units = 2kW
Y axis
10 unit = 1kg/hr
Total fuel consumption
TFC
16
15
14
13
12
11
10
9
24
26
28
30
32
34
Brake power (kW)


Air consumption (kg/hr)
250
240
230
220
210
200
190
180
170
160
24
26
28
30
32
34
Brake power (kW)

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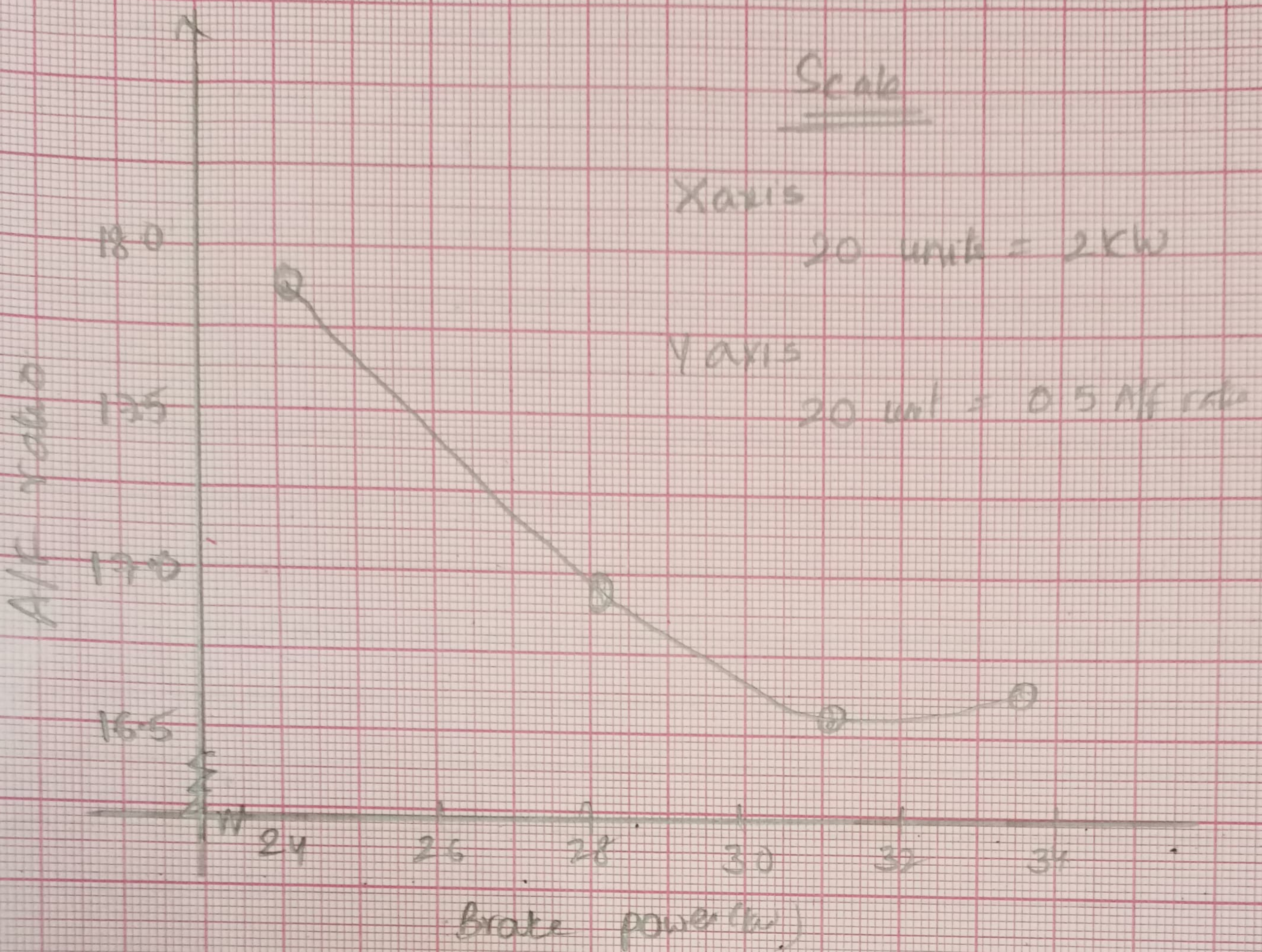
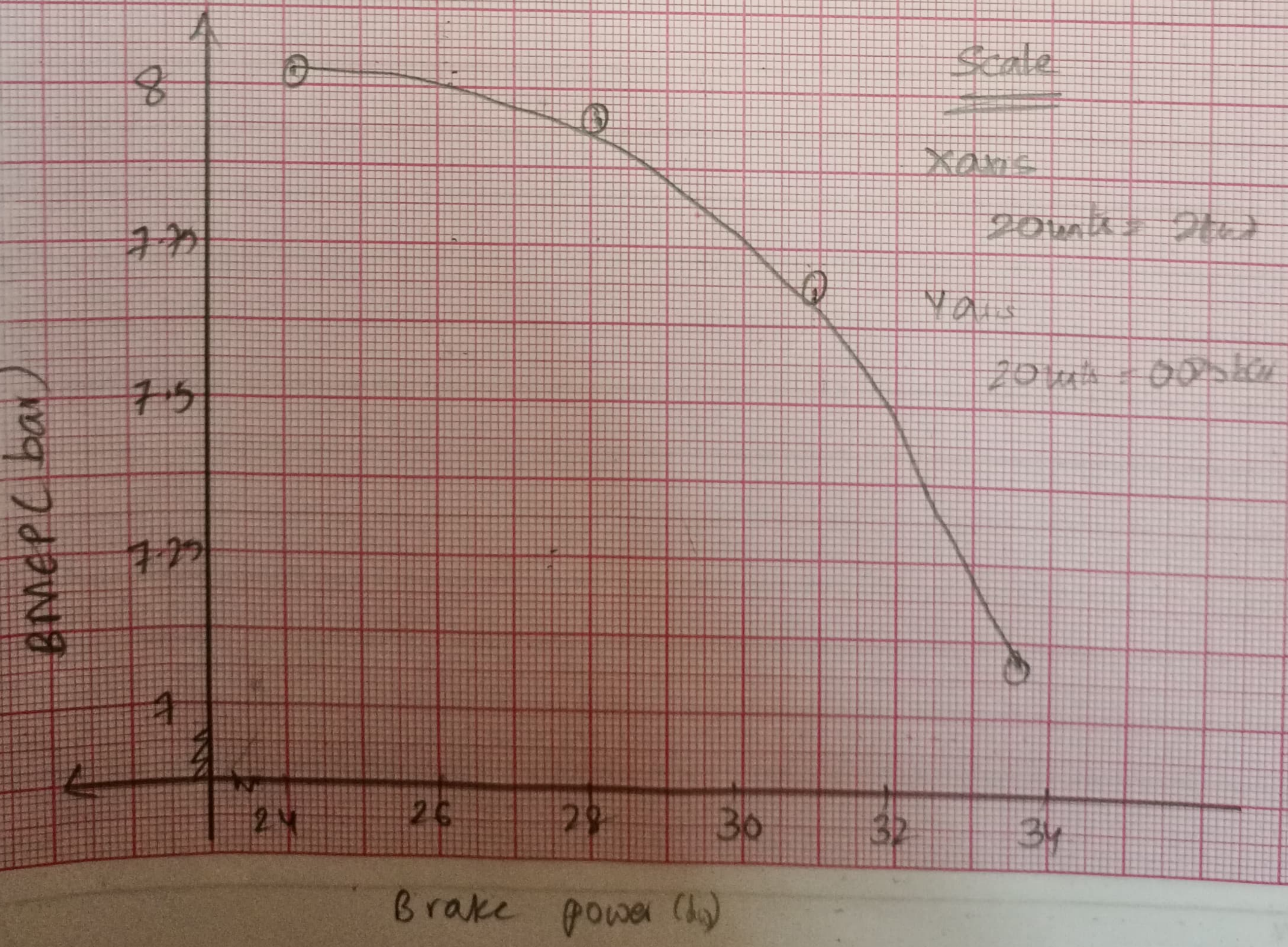

Scale
X axis
20 units = 2 kW
Y axis
20 unit = 0.5 A/f ratio
A/F ratio
18.0
17.5
17.0
16.5
24
26
28
30
32
34
Brake power (kW)


Scale
X axis
20 units = 2 kW
Y axis
20 units = 0.05 bar
BMEP (bar)
8
7.75
7.5
7.25
7
24
26
28
30
32
34
Brake power (kW)

Result

Brake Power (kW)	BMEP (bar)	Torque (N.m)	Bth eff. (%)	Air flow ($\dot{m}_a$) (kg/hr)	A/F	Volumetric efficiency (η_v)	TFC ($\dot{m}_f$) kg/hr
24.20	8.074.	90.252	2.202	166.62	17.69	1.265	9.42
28.028	7.951	88.878	2.178	187.27	16.98	1.209	11.03
28.028	7.951	88.878	2.178	187.27	16.98	1.209	11.03
30.977	7.688	85.935	2.050	214.54	16.56	1.212	12.95
30.977	7.688	85.935	2.050	214.54	16.56	1.212	12.95
33.564	7.161	80.049	2.000	238.72	16.60	1.159	14.32
33.564	7.161	80.049	2.000	238.72	16.60	1.159	14.3[illegible]

Conclusion

- From graph, we can find that brake thermal efficiency, volumetric efficiency decreases with increase in brake power.
- Air consumption, total fuel consumption increases with brake power but after a certain time there is no increment.
- Brake power decrease with A/F ratio increase.
- Brake power decrease with brake ~~power~~ mean effective pressure increase.
- 'volumetric efficiency' is greater than 100% (due to use of turbocharge)
- volumetric efficiency decreases with increase in brake power.
- Increase in air combustion, brake power increases but after certain limit there is not any increment in brake power with air consumption.