COURSE: EN-310 (I.C. ENGINE & COMBUSTION LAB)

Expt. No.- 1: CI Engine testing with Diesel

AIM:

1) To perform load test on Diesel engine fueled with diesel and determine the friction power by Willan's line method.

2) To evaluate various losses and heat balance in engine at different load condition.

Apparatus:

DXP 15-5 series engine, Inclined tube manometer, Fuel tank measurements, Instrumentation with data logger

Engine Specifications:

Make	: Cummins
Type	: 4-stroke, single cylinder, in-line, water cooled, compression ignition
Model	: X 1.7 G1
Bore	: 102 mm
Stroke	: 116 mm
Compression ratio	: 17.5:1
Rated power	: 7.4 kW, 1500 rpm @ 50 hz
Starting system	: 12 V electric
Arm length	: 185 mm

Observations:

Calorific value of diesel	: 43.7 MJ/kg
Diameter of orifice meter	: 22 mm
Constant of orifice meter	: 0.012
Speed of engine (constant)	: 1550 rpm (use the observed values)
Density of air	: 1.013 kg/m^3
Specific heat of exhaust gas	: 1.1 kJ/kg.K
Fuel	: H.S diesel
Ambient temperature	:
Ambient pressure	:
Specific heat of water	: 4.18 kJ/kg.K

Introduction:

I.C. (Internal combustion) engine is an energy conversion device. It transforms chemical energy of fuel into mechanical energy. The input to an I.C. Engine is fuel and air, and the output is power and combustion products (pollutants). As any other machine, the performance of engine is evaluated based on the outputs it delivers in comparison with the inputs it consumes. It is expected that the engine produces very high power and very less pollutants for a particular amount of fuel it consumes.

1. **Brake torque and power :-** Brake power is the power delivered at the end use. Brake torque is normally measured with a dynamometer. The engine is clamped on a test bed and the shaft is connected to the dynamometer rotor.

$$\boldsymbol{Torque(T) = Force(F) * Arm\ length}$$
$$Power(P) = T * \omega$$

2. **Mechanical efficiency (η_m): -** The ratio of the brake power (B.P) delivered by the engine to the indicated power (I.P, the power developed by combustion of fuel inside the engine cylinder) is called the mechanical efficiency.
$$\eta_m = \frac{B.P}{I.P}$$

3. **Brake thermal efficiency (η_{bth}):-** The ratio of the brake power delivered by the engine to the fuel energy supplied.
$$\eta_{bth} = \frac{B.P}{m_f * C.V}$$

4. **Air/ Fuel (A/F) ratio: -**The ratio of air flow rate(m_a) to the fuel flow rate(m_f) to engine.

$$\left({}^{A}/_{F}\right) Ratio = \frac{m_a}{m_f}$$

5. **Volumetric efficiency(η_v):-**It is defined as the volume flow rate of air into the intake system divided by the rate at which volume is displaced by the piston.
$$\eta_v = \frac{2m_a}{\rho_{a,i} . V_d . N}$$

Where, V_d = displaced volume or swept volume
$$V_d = \frac{\pi}{4} d^2 . L$$

6. **Air flow rate (m_a) :-**

$$m_a = C_d . A . \rho_a \sqrt{2gh_w \frac{\rho_w}{\rho_a}}$$

Where, A- Area of orifice, C_d-Coefficient of discharge of orifice meter.

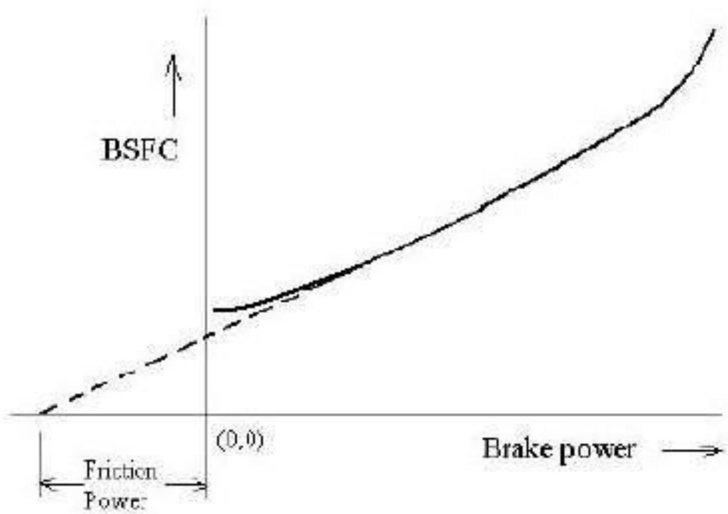
7. **Brake specific fuel consumption (B.S.F.C): -**

$$BSFC = \frac{m_f}{B.P}$$

Willan's line method: (To be completed by the group)

The knowledge of the engineering community related to the I.C. engine friction is somewhat limited. Yet there is no single law (equation) arrived at, which can be useful to find out the exact power lost in friction (friction power) in an engine over its operational range. Hence in general

practice, the friction power of a given engine is arrived at experimentally. Many methods are established for the same purpose. Willan's line is one of them.
This method includes plotting the fuel consumption (on Y-axis) v/s brake power output (on X-axis), both obtained by experimentally testing the engine. The plot is extrapolated to cut X-axis (i.e. zero fuel consumption). The value of X-intercept is equivalent to the friction power of the engine.
It has been observed that at a particular engine speed, the power lost in overcoming friction remains constant, irrespective of the load on the engine (over a particular range of 30 to 80 % of full load). This is because; the amount of air taken in during the suction stroke is constant at a particular speed of engine. Due to this reason the method of Willan's line is useful to determine friction power in case of compression ignition engines.



Limitation of Willan's method:
The plot has a slight curve, and generally approximated to a straight line. Due to this approximation, accurate extrapolation (to get friction power) is difficult.

Procedure: (To be completed by the group)

1. Check the coolant and lubricating oil level in the engine.
2. Start the engine and run it at no load condition till the exhaust temperature and coolant temperature stabilizes.
3. Take the readings from the control panel for variables included in the observation table.
4. Measure the air flow rate using the manometer/panel connected to the orifice meter at the suction of engine.
5. Measure the fuel flow rate.
7. Repeat the above procedure for various loads at an interval of 3 kW.
8. From the above measured data, obtain the plot of fuel flow rate v/s brake power to obtain Willan's line. Get the value of friction power from X-intercept.
9. Also obtain the plot of mechanical efficiency, brake thermal efficiency, volumetric efficiency B.S.F.C, A/F Ratio v/s brake power.

Observation table: (To be completed by the group)

RPM	Load (kg)	T_{Ewi} (Engine Water Inlet) ^oC	T_{Ewo} (Engine Water outlet) ^oC	$T_{ex\text{-}gas}$ (Exhaust gas) ^oC	Air Flow (mm H_2O)	Air Flow (kg/h)	Fuel Rate (cc/min)	Fuel Rate (kg/h)	Engine Water Flow rate (l/h)	Brake Torque (Nm)	Brake Power (kW)	η_{b_th} (%)

Sample calculation: (To be completed by the group)

Result table: (To be completed by the group)

SR. NO.	BRAKE LOAD (kg)	B.S.F.C. (Kg/kWhr)	B. THERMAL EFFICIENCY (%)	AIR CONSUMPTION (kg/hr)	A/F RATIO	VOLUMETRIC EFFICIENCY (%)
1						
2						
3						
4						
5						

Precautions:

1. Run the engine at least for 15 minutes at no load condition.
2. Take the readings with proper attention until the exhaust and the coolant temperature stabilize.
3. Never change the load until stabilize.
4. Unload the engine by 1 kW then only switch it off.

Graphs:

1. Willan's line
2. B. P. Vs. B.S.F.C.
3. B. P. Vs. Brake Thermal efficiency
4. B. P. Vs. A/F ratio
5. B. P. Vs. volumetric efficiency

Plot abovementioned graphs.

Engine Heat LossBalance:

Overall energy in fuel= $m_f * C.V\ of\ Fuel$ ….. (1)

Where, m_f is mass flow rate of fuel

Power produced by engine $= B.P = T.\omega$ ….. (2)

Friction loss= $from\ willan\ line$ ….. (3)

Heat loss in Exhaust= $m_{ex} C_{p_{ex}} \Delta T_{ex}$ ….. (4)

Heat rejected in engine$= m_w C_{p_w} \Delta T_w$ ….. (5)

Where, T is Torque and $\omega = \frac{2\pi N}{60}$ is rotational speed of engine.

For overall energy balance,

$$Eq.(1) = Eq.(2) + Eq.(3) + Eq.(4) + Eq.(5)$$

Heat balance table:

SR.NO.	FUEL ENERGY	ENGINE HEAT LOSS	EX. HEAT LOSS	POWER OUTPUT	FRICTION LOSS	ERROR
1						
2						
3						

Error Analysis: (To be completed by the group)

Conclusion: (To be written separately)