LABORATORY MANUAL

I. C. ENGINES
&
GAS TURBINES
(ME-317-F)

LIST OF EXPERIMENTS

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Note:-

1) **At least ten experiments are to be performed in the semester**.

2) **At least seven experiments should be performed from the above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.**

EXPERIMENT NO.1

Aim: **-To Study the construction details & working principal of 2-Stroke / 4-Stroke Petrol Engine.**

Apparatus: **- Models of 2-Stroke / 4-Stroke Engines.**

Theory: - The working Principle of Engines.

- ## Four Stroke (S.I) Engine.

In a four stroke engine, the cycles of operations is completed in 4 strokes of piston or 2 revolution of crank shaft. Each stroke consists of 180° & hence the fuel cycle consists of 720° of crank rotation. The 4-Strokes are: -

- **Suction or Intake Stroke**: - In starts at, when the piston is at top dead centre & about to move downwards. The inlet valve is open at that time and exhaust valve is closed due to suction created by the motion of the piston towards the bottom dead centre, the charge containing air fuel mixture is drawn into the cylinder. When the piston reaches BDC the suction stroke ends and inlet valve is closed.
- **Compression Stroke**: - The charge taken into the cylinder during suction stroke is compressed by return stroke of piston. During this stroke both the valves are closed. The mixture which fills the entire cylinder volume is now compressed into the clearance volume. At the end, the mixture is ignited with the help of electrode of spark plug. During the burning process the chemical energy of fuel is converted to heat energy. The pressure is increased in the end due to heat release.
- **Expansion Stroke**: - The burnt gases escape out and the exhaust valve opens but inlet valve remaining closed the piston moves from BDC to TDC and sweeps the burnt gases out at almost atmospheric pressure. The exhaust valve gets closed at the end of this stroke. Thus, for one complete cycle of engine, there is only one power stroke while crank shaft makes 2 revolutions.
- **Exhaust Stroke**: - During the upward motion of the piston, the exhaust valve is open and inlet valve is closed. The piston moves up in cylinder pushing out the burnt gases through the exhaust valve. As the piston reaches the TDC, again the inlet valve opens and fresh charge is taken in during next downward movement of the piston and the cycle is repeated.

2-Stroke (S.I) Engines.

In a 2-Stroke engine, the filling process is accompanied by the change compressed in a crank case or by a blower. The induction of compressed charge moves out the product of combustion through exhaust ports. Therefore, no piston stroke is required. For these 2-strokes one for compression of fresh charge and second for power stroke.
The charge conducted into the crank case through the spring loaded valve when the pressure in the crank case is reduced due to upward motion of piston during the compression stroke. After the compression & ignition expansion takes place in usual way.
During the expansion stroke the charge in crankcase is compressed. Near the end of the expansion stroke, the piston uncovers the exhaust ports and the cylinder pressure drops to atmosphere pressure as combustion produced leave the cylinder.

Construction Details

- **Cylinder**: - It is a cylindrical vessel or space in which the piston makes a reciprocating produces.
- **Piston**: - It is a cylindrical component fitted into the cylinder forming the moving boundary of combustion system. It fits in cylinder perfectly.
- **Combustion Chamber**: - It is the space enclosed in the upper part of cylinder, by the cylinder head & the piston top during combustion process.
- **Inlet Manifold**: - The pipe which connects the intake system to the inlet valve of engine.
- **Exhaust Manifold**: - The pipe which connects the exhaust system to the exhaust valve of engine.
- **Inlet / Exhaust Valves**: - They are provided on the cylinder head to head to regulate the charge coming into or going out of the chamber.
- **Spark Plug**: - It is used to initiate the combustion process in S.I engines.
- **Connected Rod**: - It connects piston & the crank shaft.
- **Crank shaft**: - It converts the reciprocating motion of the piston into useful rotary motion of output shaft.
- **Gudgeon pins**: - It forms a link between connection rod and the piston.
- **Cam shaft**: - It controls the opening & closing of the valves.
- **Cam:** - They open the valves at the correct tunes.
- **Carburetor**: - Used in S.I engine for atomizing & vaporizing and mixture it with air in varying proportion.

Viva Questions

1. Describe the working principle of 2-Stroke petrol Engine?
2. Describe the working principle of 4-Stroke petrol Engine?
3. What is Suction Stroke?
4. What is compression Stroke?
5. Describe Expansion / Power Stroke?

6. Describe Exhaust Stroke?
7. What are the construction details of a four stroke petrol Engine?
8. What is the main deference in 2-Stroke Petrol Engine and 4-Stroke Petrol Engine?

EXPERIMENT NO.2

Aim: - **To study the constructional details & working principles involved in a 2-Stroke & 4-Stroke Diesel Engines.**

Apparatus: - **Model of 2-Stroke / 4-Stroke Diesel Engine.**

Theory: -

- ### Four Stroke (C.I.) Engine.

  In four strokes C.I. Engine compression ratio is from 16 to 20. During suction stroke air is inducted. In C.I. engines high pressure. Fuel pump and injectors are provided to inject the fuel into combustion chamber and ignition chamber system is not necessary.

Construction Details

1. **Suction**: - During suction stroke, air is inducted through inlet valve.
2. **Compression**: - The air inducted is compressed into the clearance volume.
3. **Expansion**: - Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that the combustion maintains the pressure constant inspired of piston movement on its expansion stroke increasing the volume. After injection of fuel, the products of combustion chamber expand.
4. **Exhaust**: - The piston traveling from BQC to TDC pushes out the products of combustion out of cylinder.

- ### Two Stroke (C.I.) Engine.

In two stroke engines, the cycle is completed in one revolution of the crankshaft. In 2-stroke engine, the filling process is accomplished by the charge compressed in crankcase or by a blower. The induction of compressed charge moves out of the exhaust ports. Therefore, no piston strokes are required for these 2 operations. Two strokes are sufficient to complete the cycle one for compressing the fresh charge and other for expansion or power stroke.

1. **Compression:** - The air or charge is inducted into the crankcase through the spring loaded inlet valve when the pressure in crankcase is reduced due to upward motion of piston.

2. **Expansion**: - During this, the charge in the crankcase is compressed. At the end the piston uncovers the exhaust ports and cylinder pressure drops to the atmospheric pressure. Further movement of piston opens the transfer ports, permitting the slightest compressed charge in the crankcase to enter the engine cylinder.

Construction Details

1. **Cylinder**: - In it the piston makes a reciprocating process motion.
2. **Piston:** - It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits into cylinder.
3. **Combustion Chamber**: - The space enclosed in the upper part of the cylinder, by the head and the piston top during the combustion process.
4. **Inlet/ Outlet ports**: - They are provided on the side of cylinder to regulate the charge coming in and out of cylinder.
5. **Fuel Injector**: - It injects the fuel in combustion chamber to initiate combustion process for power stroke.
6. **Connecting Rod**: - It interconnects crank shaft and the piston.
7. **Fly Wheel**: - The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates cow sing change in angular velocity of shaft. In order to achiever uniform torque an internal mass is attached to the output shaft & this is called as fly wheel.

Viva Questions

1. Describe the working principle of 2-Stroke Diesel Engine?
2. Describe the working principle of 4-Stroke Diesel Engine?
3. What is compression Stroke?
4. Describe Expansion / Power Stroke?
5. What are the construction details of a four stroke Diesel Engine?
6. What is the main deference in 2-Stroke Diesel Engine and 4-Stroke Diesel Engine?
7. Describe the deference in 2-stroke Diesel Engine & 2-Stroke Petrol Engine?

EXPERIMENT No. 3

AIM:- Analysis of exhaust gases from Two-Stroke single-cylinder petrol engine by Orsat Apparatus.

APPARATUS USED:- Orsat apparatus, caustic potash solution, alkaline solution of pyrogallic acid, cuprous chloride solution, brine and dry flue gas sample.

THEORY:-

To check the combustion efficiency of I. C. engines, it is essential to know the constituents of the flue gases being exhausted. The various constituents the flue gases are CO_2, excess O_2, CO, SO_2, and N_2.The volumetric analysis of mainly CO_2, O_2, and CO is required, because the heat released is sufficiently large when carbon of the fuel burns to rather than when it burns to CO, secondly to determine the requisite amount of oxygen for proper burning of fuel. Such an analysis can be carried out conveniently with the help of Orsat apparatus.

An Orsat apparatus is shown in figure. It consists of three flasks to absorb different gases. Flask no. 1 contains caustic potash solution and this absorbs CO_2 present in the flue gas. Similarly flask no. 2 and 3 contains alkaline solution of pyrogallic acid, and cuprous chloride solution to absorb O_2, and CO respectively.

100 ml of a dry flue gas sample is sucked in the eudiometer tube of the apparatus and is allowed to react with the three solutions turn by turn. The amount of CO_2, O_2, and CO absorbed in the respective solution is estimated from the eudiometer scale.

PROCEDURE:-

1. Fill 2/3 of the aspirator bottle with the brine solution.
2. Fill three flasks i.e. flask no. 1, 2,and 3 with the required quantity of the caustic potash solution, alkaline solution of pyrogallic acid, and cuprous chloride solution respectively and close their valves.
3. Open the valve of flask no. 1, now by operating the rubber bladder and opening the three way cock to the atmosphere, bring the level of caustic potash solution to the mark A. close the valve of flask no. 1.
4. Repeat as step 3, to bring the level of alkaline solution of pyrogallic acid, and cuprous chloride solution to their respective marks B and C. Close the valves of flask no. 2 and 3.
5. Open the three-way cock to the atmosphere and raise the aspirator bottle so that air present in the Eudiometer is expelled to atmosphere. Close the three way cock and lower the aspirator bottle to read zero on eudiometer scale. The eudiometer is ready to receive 100 ml of gas sample.
6. Open the three-way cock and allow the flue gas sample to enter the eudiometer. Close the three-way cock, now 100 ml of gas has entered the apparatus. Open the three-way cock to the atmosphere and raise the aspirator bottle so that whole gas present in the eudiometer is expelled to atmosphere. Repeat this step twice or thrice so that 100 ml of representative flue gas sample remain in the apparatus. Close the three way cock finally.
7. Now open the valve of flask no. 1. Raise and lower the aspirator bottle few times so that gas is passed-in and out of flask several times. Lower the aspirator bottle and bring the level of caustic potash solution again to mark A. Close the valve of flask. Bring the aspirator bottle near the eudiometer and position it so that, the liquid level in the both is same. Note the liquid level on the scale. This gives the %age of CO_2 present in the flue gas sample.
8. Repeat the procedure as step 7 to determine the %age of O_2, and CO respectively by passing the remaining sample through the two flasks.

OBSERVATIONS:-

Amount of flue gas after absorption by caustic potash solution = X ml

Amount of flue gas after absorption by alkaline solution of pyrogallic acid = Y ml

Amount of flue gas after absorption by cuprous chloride solution = Z ml

CALCULATIONS:-

(i) Amount of flue gas sample = 100 ml

(ii) Amount of CO_2 = (100 - X) ml

(iii) Amount of O_2 = (X –Y) ml

(iv) Amount of CO = (Y + Z) ml

(v) Amount of N_2 = (100 – Z) ml

PRECAUTIONS:-

1. The apparatus should be air tight.
2. The eudiometer tube of the apparatus should be well flushed with the flue gas sample before performing the experiment.
3. The brine solution in the aspirator bottle should be saturated, as it may absorb some constituents of the gas sample and thereby cause errors.

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Question

1. What is the working of orsat apparatus ?
2. What is the purpose of orsat apparatus ?
3. Which solution is mainly used in orsat Appratus?
4. Define the brine and dry flue gas?

EXPERIMENT No. 4

AIM:- To prepare heat balance sheet on Single-Cylinder Diesel Engine.

APPARATUS USED :- Single-Cylinder Diesel Engine (Constant Speed) Test Rig, Stop Watch and Digital Tachometer.

THEORY:-

The thermal energy produced by the combustion of fuel in an engine is not completely utilized for the production of the mechanical power. The thermal efficiency of I. C. Engines is about 33 %. Of the available heat energy in the fuel, about 1/3 is lost through the exhaust system, and 1/3 is absorbed and dissipated by the cooling system.

It is the purpose of heat balance sheet to know the heat energy distribution, that is, how and where the input energy from the fuel is is distributed.

The heat balance sheet of an I. C. Engine includes the following heat distributions:

a. Heat energy available from the fuel brunt.
b. Heat energy equivalent to output brake power.
c. Heat energy lost to engine cooling water.
d. Heat energy carried away by the exhaust gases.
e. Unaccounted heat energy loss.

FORMULE USED :-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and*

$W (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N\, T) / 60,000}$ KW

; Where $N =$ *rpm,* $T =$ *Torque* *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$

Kg/Sec

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So 1 ml = 10^{-6} m^3

(iv) Heat energy available from the fuel brunt, $\mathbf{Q_s = m_f \times C.V. \times 3600}$ KJ/hr

(v) Heat energy equivalent to output brake power, $\mathbf{Q_{BP} = BP \times 3600}$ KJ/hr

(vi) Heat energy lost to engine cooling water, $\mathbf{Q_{CW} = m_w \times C_w (t_{wo} - t_{wi}) \times 3600}$ KJ/hr

(vii) Heat energy carried away by the exhaust gases, $\mathbf{Q_{EG} = m_{fg} \times C_{fg} (t_{fg} - t_{air}) \times 3600}$ KJ/hr

; Where $m_{fg} = (m_f + m_{Air})$ *Kg/Sec, and* $m_{Air} = C_d\, A_o \sqrt{2\, g\, \Delta h\, \rho_{Air}\, \rho_{Water}}$ Kg/ Sec

; Where C_d *(Co-efficient of Discharge) = 0.6,* $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ *Kg/ m³,*

A_o *(Area of Orifice)* $= (\pi\, d_o^2)/ 4$ *m²,* $P_1 = 1.01325$ *Bar,* $R = 0.287$ *KJ/Kg . K,*

$T_a = (t_a + 273)$ *K,* t_a *= Ambient Temperature* ^oC

(viii) Unaccounted heat energy loss, $\mathbf{Q_{Unaccounted} = Q_s - \{ Q_{BP} + Q_{CW} + Q_{EG} \}}$ KJ/hr

PROCEDURE :-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load and run the engine till it attain the working temperature and steady state condition.

3. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
4. Set the dynamometer to 20 % of the full load, till it attains the steady state condition. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
5. Repeat the experiment at 40 %, 60 %, and 80 % of the full load at constant speed.
6. Disengage the dynamometer and stop the engine.
7. Do the necessary calculation and prepare the heat balance sheet.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Specific Heat of Water, C_w	= 4.187	KJ/Kg . K
Specific Heat of Exhaust Flue Gases, C_{fg}	= 2.1	KJ/Kg . K
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Density of fuel (Diesel), ρ_{Fuel}	= 810 to 910	Kg/m^3

Density of Water, ρ_{water} = 1,000 Kg/m^3

Brake Drum Diameter, D = 181.5×10^{-3} m

Rope Diameter, d = m

Or Belt thickness, t_{Belt} = 5.5×10^{-3} m

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Engine Cooling Water Flow Rate, m_w (Kg/hr)	Engine Cooling Water Temperatures, (^{o} C)		Exhaust Gas Temperature, t_{fg} (^{o} C)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)			t_{wi} (^{o} C)	t_{wo} (^{o} C)		
1.	1500								
2.	1500								
3.	1500								
4.	1500								

CALCULATIONS:-

RESULT TABLE :-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/hr)	Air Flow Rate, m_{air} (Kg/hr)	Exhaust Gas Flow Rate, m_{fg} (Kg/hr)
1.	1500				
2.	1500				
3.	1500				
4.	1500				

HEAT BALANCE SHEET :-

Heat Energy Supplied	KJ/hr	% age	Heat Energy Consumed (Distribution)	KJ/hr	% age
Heat energy available from the fuel brunt			(a) Heat energy equivalent to output brake power.		
			(b) Heat energy lost to engine cooling water.		
			(c) Heat energy carried away by the exhaust gases.		
			(d) Unaccounted heat Energy Loss.		
Total	____	100 %	Total	__________	100 %

RESULT:-

Viva Questions

1. Explain the air-fuel ratio?
2. What is Injection Timing?
3. What are the methods of available for improving the performance of an engine?
4. Distinguish between power and specific output?
5. What is the importance of specific fuel consumption?
6. What is the torque of an engine?

EXPERIMENT No. 5

AIM:-To find the indicated power (IP) on Multi-Cylinder Petrol Engine by Morse test.

APPARATUS USED: - Multi-Cylinder Petrol Engine Test Rig, Stop Watch, Hand Gloves, and Digital Tachometer.

THEORY :-

The purpose of Morse Test is to obtain the approximate Indicated Power of a Multi-cylinder Engine.It consists of running the engine against a dynamometer at a particular speed, cutting out the firing of each cylinder in turn and noting the fall in BP each time while **maintaining the speed constant**. When one cylinder is cut off, power developed is reduced and speed of engine falls. Accordingly the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered to be independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test.

FORMULE USED :-

(i) Brake Power, $\mathbf{BP = WN/C}$ KW

; Where W = Load on the Dynamometer Kg, N = rpm of the Engine, and C = Dynamometer Constant.

(ii) Indicated Power **(IP)** of each Cylinders:

$$\mathbf{IP_1 = (BP_T - BP_{2,3,4})} \quad \text{KW}$$

$$\mathbf{IP_2 = (BP_T - BP_{1,3,4})} \quad \text{KW}$$

$$\mathbf{IP_3 = (BP_T - BP_{1,2,4})} \quad \text{KW}$$

$$\mathbf{IP_4 = (BP_T - BP_{1,2,3})} \quad \text{KW}$$

(iii) Total IP of the Engine, $\mathbf{IP_T = (IP_1 + IP_2 + IP_3 + IP_4)}$ KW

(iv) Mechanical Efficiency, $\boldsymbol{\eta_{mechanical} = BP_T / IP_T}$

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition. Adjust the dynamometer load to obtain the desired engine speed. Record this engine speed and dynamometer reading for the BP calculation.
4. Now cut off one cylinder. Short-circuiting its spark plug can do this.
5. Reduce the dynamometer load so as to restore the engine speed as at step 3 . Record the dynamometer reading for BP calculation.
6. Connect the cut off cylinder and run the engine on all cylinders for a short time. This is necessary for the steady state conditions.
7. Repeat steps 4, 5, and 6 for other remaining cylinders turn by turn and record the dynamometer readings for each cylinder.
8. Bring the dynamometer load to zero, disengage the dynamometer and stop the engine.
9. Do the necessary calculations.

OBSERVATIONS:-

Engine Speed, N = rpm

No. of Cylinders, n = Four

Calorific Value of Fuel, C.V. = 42,000 KJ/Kg

OBSERVATIONS TABLE :-

Sl. No.	Cylinders Working	Dynamometer Reading, (KW)	Brake Power, BP (KW)	IP of the cut off cylinder, (KW)
1.	1-2-3-4	-------------------	BP_T	
2.	2-3-4		$BP_{2,3,4}$ =	IP_1 =
3.	1-3-4		$BP_{1,3,4}$ =	IP_2 =
4.	1-2-4		$BP_{1,2,4}$ =	IP_3 =
5.	1-2-3		$BP_{1,2,3}$ =	IP_4 =

CALCULATIONS:-

RESULT:- Total IP of the Multi-Cylinder Petrol Engine by Morse Test, IP_T = KW

Viva Questions

1. Define the morse test?
2. What is transmission dynamometer?
3. What is need of measurement of speed of an I.C. Engine?
4. What is a smoke and classify the measurement of a smoke?
5. What is the break power of I.C. Engines?

EXPERIMENT No. 6

AIM:- To prepare variable speed performances test on a Two-Stroke, Single-Cylinder Petrol Engine and prepare the curves: (i) BP, BSFC, BMEP, Torque Vs Speed and (ii) Volumetric Efficiency & A/F Ratio Vs Speed.

APPARATUS USED :- Two-Stroke, Single-Cylinder Petrol Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY :-

S.I. Engines are often used for automotive purposes. It is important to know the torque, brake mean effective pressure, and specific fuel consumption over the engine working speed range. For this purpose variable speed test at full load and part load is conducted.To test the park ignition engine at full load the throttle valve is kept wide open and the brake load is adjusted to obtain the lowest desired speed. The ignition timing may be set to obtain maximum output at this speed. Rate of fuel consumption, dynamometer load reading and speed are recorded.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *m, and* $W\,(Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where $N =$ *rpm,* $T =$ *Torque N-m,*

(iii) Indicated Power, $\mathbf{IP = n\,(P_m \times L_{Stroke} \times A \times N') / 60,000}$ KW

; Where $P_m =$ *Mean Effective Pressure* N/m^2*,*

L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/4$ m^2,

N' (Number of Power Strokes/ min.) = N/ 2 per min. ; For Four-Stroke Engine.

= N per min ; For Two-Stroke Engine.,

N = rpm, and n = Number of Cylinders.

(iv) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So 1 ml = 10^{-6} m^3

(v) Brake Mean Effective Pressure, $\mathbf{BMEP = (BP \times 60{,}000)/ (L_{Stroke} \times A \times N')}$ N/ m^2

; Where L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/4$ m^2,

N' (Number of Power Strokes/ min.) = N/ 2 per min.;

For Four-Stroke Engine. = N per min;

For Two-Stroke Engine., and N = rpm.

(vi) Brake Specific Fuel Consumption, $\mathbf{BSFC = (m_f \times 3600) / BP}$ Kg/ KW . hr

(vii) Indicated Specific Fuel Consumption, $\mathbf{ISFC = (m_f \times 3600) / IP}$ Kg/ KW .hr

(viii) Indicated Thermal Efficiency, $\mathbf{\eta_{Indicated\ Thermal} = (IP \times 100) / (m_f \times C.V.)}$%

(ix) Brake Thermal Efficiency, $\mathbf{\eta_{Brake\ Thermal} = (BP \times 100) / (m_f \times C.V.)}$ %

(x) Mass of the Air, $\mathbf{m_{Air} = C_d A_o \sqrt{2 g \Delta h \rho_{Air} \rho_{Water}}}$ Kg/ Sec *;*

Where C_d (Co-efficient of Discharge) = 0.6, $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/ m^3

A_o (Area of Orifice) = $(\pi d_o^2)/4$ m^2, P_a = 1.01325 Bar, R = 0.287 KJ/ Kg . K, $T_a = (t_a + 273)$ K, t_a = Ambient Temperature ^OC

(xi) Air Fuel Ratio, $\mathbf{A/F = (m_{Air} / m_f)}$ Kg/ Kg of Fuel

(xii) Volumetric Efficiency, $\eta_{Volumetric} = (V_{Air} \times 100) / V_s$ %

; Where V_{Air} *(Volume of air inhaled/ Sec.) =* (m_{Air} / ρ_{Air}) m^3*/ Sec.*

V_s *(Swept Volume/ Sec.) = n . (* L_{Stroke} *. A.. N')/ 60* m^3*/ Sec.,*

And Volume of fuel is Neglected ***(Based on free air conditions)****,*

L_{Stroke} *= Stroke m, A (Cross Section of the Cylinder) =* $(\pi D^2_{Bore})/4$ m^2*,*

N' (Number of Power Strokes/ min.) = N/ 2 per min. ;

For Four-Stroke Engine.

= N per min ;

For Two-Stroke Engine.,

N = rpm., and n = Number of Cylinders.

(xiii) Mechanical Efficiency, $\eta_{mechanical}$ **= BP / IP**

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Adjust the dynamometer to the new value of the desired speed. Note and record the data as in step 4.
6. Repeat the experiment for various speeds upto the rated speed of the engine.
7. Do the necessary calculations.

OBSERVATIONS:-

No. of Cylinders, n	= Single	
Brake Drum Diameter, D	= 156×10^{-3}	m
Rope Diameter, d	= 18×10^{-3}	m
Bore, D_{Bore}	= 56.5×10^{-3}	m
Stroke, L_{Stroke}	= 58.04×10^{-3}	m
Engine Displacement, V_{Swept}	= 145.45×10^{-6}	m^3
Engine Horse Power, BHP	= 7.48	BHP at 5500 rpm.
Density of fuel (Petrol), ρ_{Fuel}	= 720 to 790	Kg/ m^3
Density of Manometer fluid, ρ_{Water}	= 1,000	Kg/ m^3
Calorific value of fuel (Petrol), C.V.	= 42000	KJ/ Kg
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Ambient Temperature, t_a	=	K
Atmospheric Pressure, P_a	= 1.01325	Bar

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Torque (N-m)	Brake Power, BP (KW)	Air Consumption Rate, m_{air} (Kg/hr)	Fuel Consumption Rate, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	BMEP (N/m^2)	A/F Ratio	η_{mech} % age
1.									
2.									
3.									
4.									

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. What is volumetric efficiency?
2. What is air fuel ratio in two stroke single cylinder petrol engine?
3. What is air delivery ratio in two stroke single cylinder petrol engine?
4. What is tapping efficiency?
5. Define pressure lose co-efficient?
6. Define excess Air factor?

EXPERIMENT No. 7

AIM:- To determine Frictional Power of Four-Stroke , Single Cylinder Diesel (Constant Speed) Engine by Willian's Line Method.

APPARATUS USED :- Four-Stroke , Single Cylinder Diesel (Constant Speed) Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

A curve between the fuel consumption rate and the Brake Power is called the Willain's Line. This method is used for determining the FP of the Diesel Engine, which is assumed to be independent of the load at constant speed. In this method, fuel consumption rate is measured for various loads at constant speed. The load on the engine is varies with the help of dynamometer and corresponding to each setting BP is calculated. Then a graph is drawn of fuel consumption rate against the BP, and is extended back to cut the BP axis. The negative BP then corresponds to the FP at a particular speed. This method is also enables to determine IP without the use of an indicator.

FORMULE USED :-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and* $W\ (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where N = *rpm,* T = *Torque N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Specific Fuel Consumption, **BSFC = (m_f x 3600) / B P** Kg/ KW . hr

(v) Friction Power, **F P = From BSFC vs BP Curve.** KW

(vi) Indicated Power, **IP = BP + FP** KW

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Change the dynamometer load so that the engine speed Change, to maintain the engine speed constant fuel consumption increases.
6. Note down the fuel consumption rate at this load setting.
7. Repeat steps 5 and 6 for various loads.
8. Disengage the dynamometer and stop the engine.
9. Do the necessary calculation.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Density of fuel (Diesel), ρ_{fuel}	= 810 to 910	Kg/m^3
Brake Drum Diameter, D	= 181.5×10^{-3}	m
Rope Diameter, d	=	m
or		
Belt thickness, t_{Belt}	= 5.5×10^{-3}	m

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)
		S_1 (Kg)	S_2 (Kg)	
1.	1500			
2.	1500			
3.	1500			
4.	1500			

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/Sec)	Brake Specific Fuel Consumption, BSFC (Kg/ KW . hr)
1.	1500			
2.	1500			
3.	1500			
4.	1500			

RESULT:- Performance curves are plotted and they are similar to the standard performance Curves and FP is calculated By **Willian's line Method**.

Viva Questions

1. What is fan dynamometer?
2. Explain an automatic fuel flow meter?
3. Explain the method of measurement of smoke by comparison method?
4. Define the friction power?
5. Define Willian's lines methods?

EXPERIMENT No. 8

AIM:- To perform constant speed performance test on a Four-Stroke Single-Cylinder Diesel Engine & Draw curves of (i) BP vs Fuel Rate, Air Rate and A/F ratio and (ii) BP vs BMEP, Mechanical Efficiency & BSFC.

APPARATUS USED: - Four-Stroke , Single-Cylinder (Constant Speed) Diesel Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

Under some circumstances (i.e Electric Generator) C. I. Engines are required to run at constant speed. For this purpose the test is to be performed at constant speed and the load is varied from zero to maximum. When load on the engine increases its speed decreases. Accordingly the fuel supply is adjusted to keep the engine speed constant. Corresponding to each load setting, dynamometer readings and fuel consumption rate are measured. The BP, BSFC, BMEP, A/F, and Mechanical Efficiency are calculated from measured data and plotted against the load.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and* $W\ (Load) = (S_1 - S_2)Kg$,

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where $N =$ *rpm,* $T =$ *Torque* *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Mean Effective Pressure, **BMEP = (BP x 60,000)/ (L_{Stroke} x A x N')** N/ m^2

; Where L_{Stroke} *= Stroke m, A (Cross Section of the Cylinder) =* $(\pi D^2_{Bore})/4$ *m^2,*

N' (Number of Power Strokes/ min.) = N/ 2 per min. ; For Four-Stroke Engine.= N per min; For Two-Stroke Engine., andN = rpm.

(v) Brake Specific Fuel Consumption, **BSFC = (m_f x 3600) / B P** Kg/ KW . hr

(vi) Mass of the Air, $\mathbf{m_{Air} = C_d A_o \sqrt{2 g \Delta h \rho_{Air} \rho_{Water}}}$ Kg/ Sec

; Where C_d *(Co-efficient of Discharge) = 0.6,* $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/ m^3 A_o *(Area of Orifice) =* $(\pi d_o^2)/ 4$ m^2, $P_a = 1.01325$ *Bar,* $R = 0.287$ *KJ/Kg . K,* $T_a = (t_a + 273)$ *K,* t_a *= Ambient Temperature* ^OC

(vii) Air Fuel Ratio, **A/F = (m_{Air} / m_f)** Kg/ Kg of Fuel

(viii) Mechanical Efficiency, $\eta_{mechanical}$ **= BP / IP**

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Change the dynamometer load so that the engine speed Change, to maintain the engine speed constant fuel consumption increases.
6. Note down the fuel consumption rate, speed, air inlet temperature, at this load setting.
7. Repeat steps 5 and 6 for various loads.
8. Disengage the dynamometer and stop the engine.
9. Do the necessary calculation.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Bore Diameter, D_{bore}	=	m
Stroke Length, L_{stroke}	=	m
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Specific Gravity of fuel, ρ_{fuel}	= 810 to 910	Kg/m^3
Density of Water, ρ_{water}	= 1,000	Kg/m^3
Brake Drum Diameter, D	= 181.5×10^{-3}	m
Rope Diameter, d	=	m
or		
Belt thickness, t_{Belt}	= 5.5×10^{-3}	m

OBSERVATIONS TABLE :-

S. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		
1.	1500				
2.	1500				
3.	1500				
4.	1500				

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	BMEP (N/ m^2)	A/F Ratio	Air Consumption Rate (Kg/ hr)	η_{mech} % age
1.	1500							
2.	1500							
3.	1500							
4.	1500							

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. What is break power ?
2. Define speed performance test on a four-stroke single – Cylinder diesel engine?
3. What is Air rate and A/F ratio in a four-stroke single – Cylinder diesel engine?
4. What is combustion phenomenon?
5. What is indicated power ?

EXPERIMENT No. 9

AIM:- To Study and Determine the effect of A/F Ratio on the performance of the Two-Stroke, Single-Cylinder Petrol Engine.

APPARATUS USED :- Two-Stroke, Single-Cylinder Petrol Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

Air fuel ratio has a major effect on the performance of the I. C. Engine. The Air fuel ratio of a S. I. Engine lies in the range of 10: 1, to 22: 1 depends upon the power requirements and the economic running of the engine. Richer mixtures are required for idle and full throttle running of the engine. Whereas for the mid-range , weaker mixtures are required. The mixture corresponding to the minimum fuel consumption is known as the Best Economy Mixture. It is nearly 15:1.Accurate measurement of air flow into the engine is difficult to achieve in practice, due not only to the nature of the air itself, but also the conditions under which the measurement has to be made.The common method of measuring the air flow rate is the tank and orifice method. During suction stroke the pressure inside the tank is less than the atmospheric pressure. The air enters the tank through the orifice plate , and by applying the Bernaulli's equation the air flow rate can be measured. The fuel consumption can be measured by noting down the fuel consumed during specified time. Thus the air fuel ratio can be set to desired value. The accuracy of the air flow measurement depends on the steady state conditions of air flow through the orifice and the damping of the pulsating effect.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; *Where* $R_{Effective} = (D + d)/2$ *m, and* $W\ (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; *Where* $N =$ *rpm,* $T =$ *Torque* *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$

Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Specific Fuel Consumption, $\mathbf{BSFC = (m_f \times 3600) / BP}$ Kg/ KW . hr

(v) Mass of the Air, $\mathbf{m_{Air} = C_d A_o \sqrt{2 g \Delta h \rho_{Air} \rho_{Water}}}$ Kg/ Sec

; *Where* C_d *(Co-efficient of Discharge) = 0.6,*

$\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/m^3

A_o *(Area of Orifice)* $= (\pi d_o^2)/4$ m^2,

$P_a = 1.01325$ *Bar,* $R = 0.287$ *KJ/Kg . K,*

$T_a = (t_a + 273)$ *K,* $t_a =$ *Ambient Temperature* ^{O}C

(vi) Air Fuel Ratio, $\mathbf{A/F = (m_{Air} / m_f)}$ Kg/ Kg of Fuel

PROCEDURE:-

1. Before starting the engine check the fuel supply, and lubrication oil.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed.
5. Note down the dynamometer load reading and fuel consumption rate.
6. Repeat the experiments for various air fuel ratios and different loads, and same speed.
7. Disengage the dynamometer, and stop the engine.
8. Do the necessary calculation, and plot the graphs.

OBSERVATIONS:-

No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 42,000	KJ/Kg
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Density of fuel (Petrol), ρ_{fuel}	= 720 to 790	Kg/m^3
Density of Water, ρ_{water}	= 1,000	Kg/m^3
Brake Drum Diameter, D	= 156×10^{-3}	m
Rope Diameter, d	= 18×10^{-3}	m
Bore, D_{Bore}	= $56.5 X 10^{-3}$	m
Stroke, L_{Stroke}	= 58.04×10^{-3}	m
Engine Displacement, V_{Swept}	= 145.45×10^{-6}	m^3
Engine Horse Power, BHP	= 7.48	BHP at 5500 rpm.

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		
1.					
2.					
3.					
4.					

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Torque (N-m)	Brake Power, BP (KW)	Air Consumption Rate m_{air} (Kg/hr)	Fuel Consumption, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	A/F Ratio, (Kg/ Kg of Fuel)
1.							
2.							
3.							
4.							

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. Mention the simplified various assumptions used in fuel Air-cycle Analysis
2. Explain the significance of the fuel-Air cycle ?
3. What is the difference between Air – Standard cycle & Fuel – Air cycle analysis?
4. Define carburetion?
5. What are the different Air – Fuel Mixture on which an Engine can be operated?
6. Explain the rich mixture, Lean Mixture & Stoichionetric Mixture ?

EXPERIMENT No. 10

AIM:- To study and draw the valve timings diagram Four-Stroke, Single-Cylinder Diesel Engine.

APPARATUS USED :- Four-Stroke, Single-Cylinder Diesel Engine Test Rig, Sprit Level,Marking Pencil, and Device for measuring crank angle.

THEORY :-

In four- stroke S. I. Engine the opening and closing of the valves, and the ignition of the air fuel mixture do not take place exactly at the dead centre positions. The valve open slightly earlier and close after their respective dead centre positions. The ignition also occurs prior, to the mixture is fully compressed, and the piston reaches the top dead centre position.Similarly in a C. I. Engine both the valves do not open and close exactly at dead centre positions, rather operate at some degree on either side in terms of the crank angles from the dead centre positions. The injection of the fuel is also timed to occur earlier.

PROCEDURE:-

1) Fix a plate on the body of the Engine touching the flywheel.
2) Mark the positions of the both the dead centers on the flywheel with the reference to the fixed plate. TDC and BDC in case of vertical Engines, IDC and ODC in case of horizontal Engines.
3) Mark on the flywheel when the inlet and exhaust valves open and close as the flywheel is rotated slowly.
4) Measure the valves (Tappet) Clearance.
5) Mark the spark ignition timing in case of petrol Engine and fuel injection timing in case of Diesel Engine.
6) Measure the angles of the various events and plot the valve timing diagram.

OBSERVATIONS TABLE :-

Sl. No.	Engine Types	Tappet Clearance		Valve Timings				
		Inlet Valve (mm)	Exhaust Valve (mm)	Inlet Valve		Exhaust Valve		Injection Timing (^{O})
				Open (^{O})	Close (^{O})	Open (^{O})	Close (^{O})	
1.	Four-Stroke, Single-Cylinder (Vertical) Diesel Engine.							

CALCULATIONS:-

RESULT:-Based on final calculation valve timing diagram is drawn and compare with the standard valve timing diagram.

Viva Questions

1. Define valve timing in four stroke petrol engine?
2. What is overlapping?
3. What is inlet valve?
4. What is exhaust valve?
5. What do you mean by ignition?
6. What are the various types of ignition systems that are commonly used?