ACS COLLEGE OF ENGINEERING

Kambipura, Mysore Road, Bangalore – 560074

DEPARTMENT OF AERONAUTICAL ENGINEERING

ENERGY CONVERSION LAB MANUAL

(BAEL504)

(Prescribed for V– Semester Aeronautical Engineering)

ACADEMIC YEAR 2022 – 2023

NAME OF THE FACULTY : ....

BRANCH : ....

SEMESTER &YEAR : ____

ACADEMIC YEAR : ....

INDEX

EXPERIMENT NO. 1

ABELS'S PENSKY APPARATUS

AIM: To determine the flash and fire point of the given oil using Abel's Pensky apparatus

APPARATUS: Abel's flash and fire point apparatus, thermometers and Broom sticks and given oil

THEORY:

Flash point of the oil is the lowest temperature at which the oil gives sufficient amount of vapors resulting in flash when the flame is brought near it. Fire point of the oil is the lowest temperature at which the oil gives sufficient amount of vapors resulting continual burning of oil at least for 5 seconds when the flame is brought near to it. Abel's apparatus is used for flash points between 2.2^0 to $49^{0.}$ It consists of oil cup provided with a cover with level indicator up to, which the cup must be filled with oil.

PROCEDURE:

1. Clean the oil cup and pour a sample of oil up to the level indicated by the filling mark.
2. Before starting the room temperature is noted. The oil is heated for every 2^0rise in temperature is observed for the momentary flash.
3. The temperature at which flash appears is the flash point and is noted.
4. The oil is further heated till the oil catches the fire and burns continuously at least for 5sec and it is the fire point and is noted.
5. The flame is then put off

OBSERVATION:

1. Type of oil

TABULAR COLUMN:

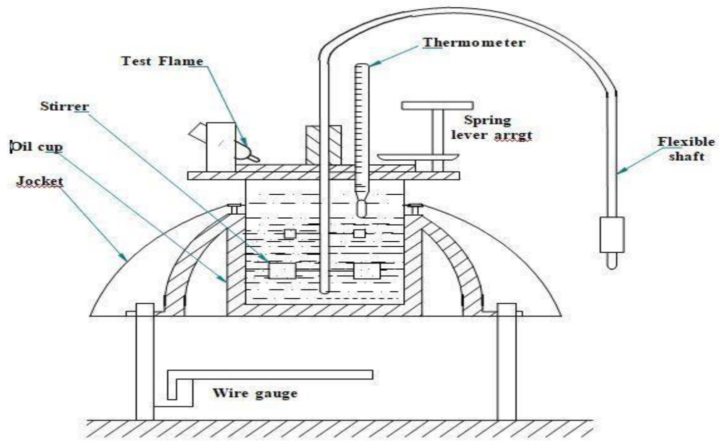
Sl. No	Heating		Cooling	
	Temperature	Observation	Temperature	Observation

RESULT:

Flash point of the given oil is__________

Fire point of the given oil is__________

SCHEMATIC SKETCH:



TABULAR COLUMN:

Sl. No	Heating		Cooling	
	Temperature	Observation	Temperature	Observation

RESULT:

Flash point of the given oil is__________

Fire point of the given oil is__________

EXPERIMENT NO. 2

BOYS GAS CALORIMETER

AIM: To Determine the Calorific Value of solid gaseous fuel (LPG)

APPARATUS: Experiment setup, stop watch, balancing unit.

THEORY: Experimental method is based on **heat transfer from burning known quantity of gaseous fuel** for heating known quantity of water that circulates through copper coil heat exchanger. The counter flow heat exchange takes place between the burning gas and circulating water. So, with the assumption that heat absorbed by circulating water equal to the heat released by gaseous fuel we can calculate the calorific value of burnt fuel.

The equipment consists of heat exchanger unit double walled stainless steel vessel insulted with either glass wool or ceramic wool in the annular space. Inside the inner vessel double pass copper coil and shell assemble through which the burnt fuel passes through

Based on energy balance consideration i.e., heat lost by one substance = heat gained by another substance (when the experiment stabilizes)

Heat released by the gas = heat gained by cooling water

Write the theory on following topics

- **a.** Definition of calorific value
- **b.** Types of calorific values and their definitions
- **c.** Types of calorimeters and their applications

PROCEDURE:

1. Keep the gas cylinder on the weighing balance and note down the initial weight of the cylinder.
2. Connect the water supply to the inlet of the Rotameter.
3. Allow gas through the calorimeter by slowly opening the control valve of the cylinder.
4. Note the gas pressure, which passes through colorimeter.
5. Allow the water to circulate through the calorimeter.
6. After getting ignition of fuel note down the mass of fuel for known time.
7. Note down the temperature readings after attaining steady state.
8. Repeat the experiment for different flow rates of water

TABULAR COLUMN

Sl no	Volumetric flow rate of water LPM	Mass flow rate of gas kg/min	Pressure of gas Pg kg/cm^2	Inlet temperature of water T1 ^{O}C	Outlet temperature of water T2 ^{O}C	Calorific value of gas Cvg kJ/kg	Calorific value of gas at NTP Cvg kJ/kg

M_g= (initial wt of cylinder- final wt of cylinder)/(time taken for reduction of weight)
$Cvg*m_g=Vw*\rho_w*Cpw(T2-T1)$
$CVg=(Vw*\rho_w*Cpw(T2-T1))/m_g$

RESULTS: Calorific value ofgiven fuel______________kJ/kg

EXPERIMENT NO. 3

VALVE TIMING DIAGRAM

AIM: To draw the value timing diagram of the given engine
APPARATUS: Given engine, measuring tape, scale.

THEORY:
Here in this type of engines opening and closing and fuel injection do not takes place exactly at the dead center positions. The valves open slightly earlier and close after that respective dead center position. The injection (ignition) also occurs prior to the compression and piston reaches to the dead center position. All the valves operated at some degree on either side in terms of crank angles from dead center position.

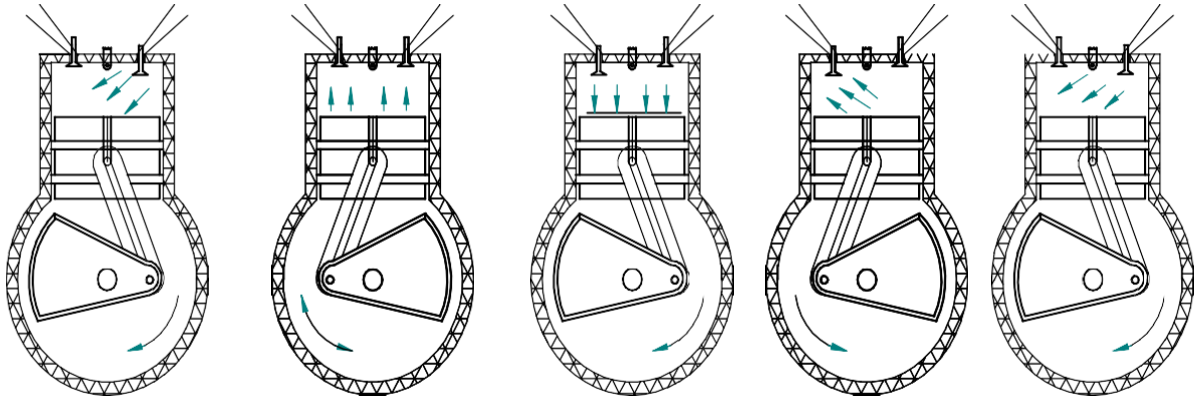
PROCEDURE:

1. Note the location of the inlet and exhaust valves of the given engine.
2. The flywheel is turned in clockwise direction and the positions of TDC and BDC are identified with respect to the crank position
3. The circumferential length of flywheel is measured with help of thread and ruler
4. The flywheel is turned in clock wise direction and the position and inlet valve begin to open is marker.
5. This point is measured from the initial reference mark (TDC) and this length is noted.
6. The flywheel turned in the same direction and the position of inlet valve closing and exhaust valve opening and exhaust valve closing are noted and corresponding length with respective to the reference marks.
7. The reading is recorded in the tabular column and corresponding angles turned (in degrees) are determined.

OBSERVATION:

1. Type of engine

SCHEMATIC SKETCH:



SUCTION STROKE SUCTION VALVE OPEN	COMPRESSION STROKE BOTH VALVE ARE CLOSED	IGNITION OR POWER STROKE BOTH VALVE ARE CLOSED	EXHAUST STROKES EXHAUSTVALVE OPEN	SUCTION STROKE SUCTIONVALVE OPEN

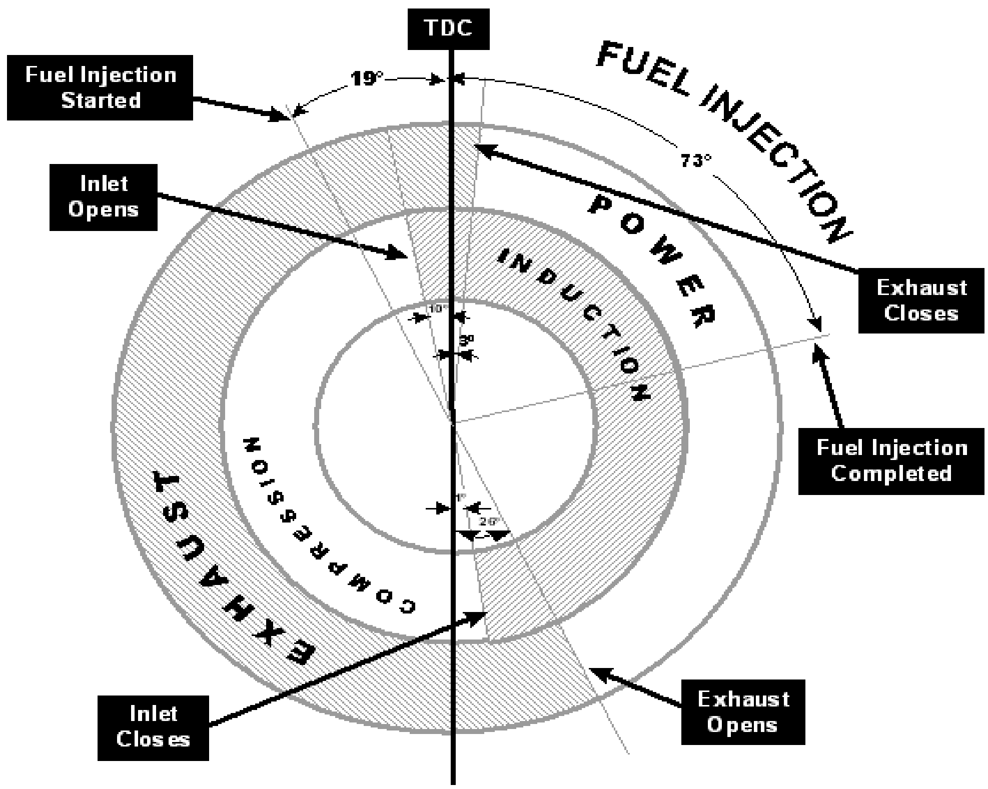


Fig. a typical Valve timing diagram

TABULAR COLUMN:

Sl. No.	Valve position	Piston position	o degree
1	IVO		
2	IVC		
3	EVO		
4	EVC		

IVO= Inlet valve open, IVC= inlet valve close

EVO= Exhaust valve open, EVC= Exhaust valve close

, Where, L = Arc length, cm

D=Flywheel diameter, m

Name of the stroke	Crank angle degree
Suction	
Compression	
Expansion	
Exhaust	

Draw the spiral diagram of the data obtained

RESULT: The opening and closing of inlet and exhaust valves are as shown in tabular column

EXPERIMENT NO. 4

PLANIMETER

AIM: To determine the area of irregular figure by using a planimeter.

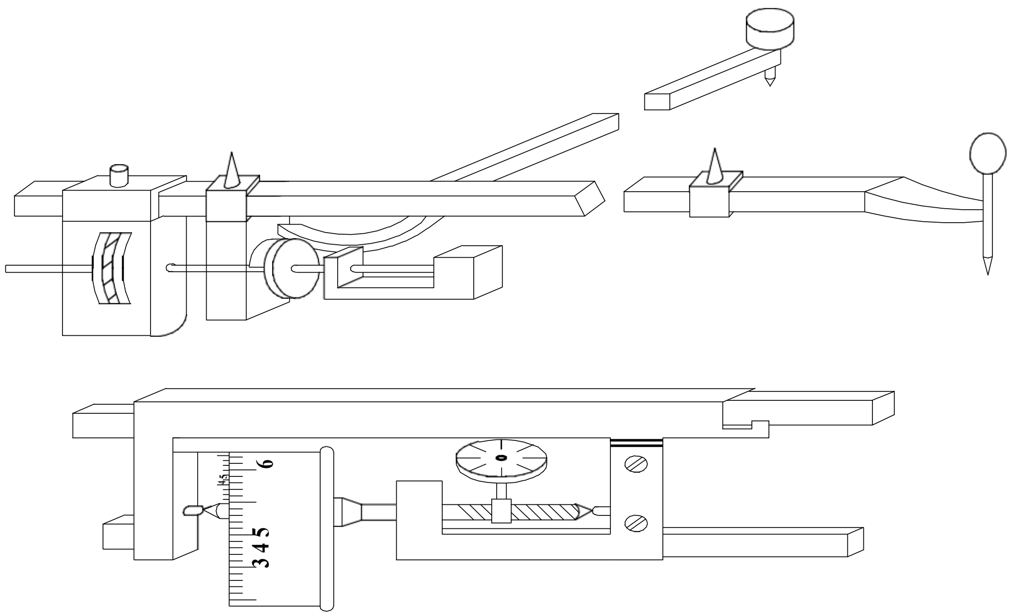
APPARATUS: Planimeter, drawing board and sheet. Drawing instruments

THEORY: They consist of a linkage with a pointer on one end, used to trace around the boundary of the shape. The other end of the linkage is fixed for a polar planimeter and restricted to a line for a linear planimeter. Tracing around the perimeter of a surface induces a movement in another part of the instrument and a reading of this is used to establish the area of the shape. The planimeter contains a measuring wheel that rolls along the drawing as the operator traces the contour. When the planimeter measuring wheel moves perpendicular to its axis, it rolls, and this movement is recorded. When the measuring wheel moves parallel to its axis, the wheel skids without rolling, so this movement is ignored. That means the planimeter measures the distance that its measuring wheel travels, projected perpendicularly to the measuring wheel's axis of rotation. The area of the shape is proportional to the number of turns through which the measuring wheel rotates when the planimeter is traced along the complete perimeter of the shape.

PROCEDURE:

1. Fix the figure whose area is to be determined on a smooth surface, preferably on a horizontal drawing board.
2. Set the index to read 100Sq cm on the tracing arm if the area is required in square cm.
3. Fix the anchor point inside or outside the figure such that the tracer is able to trace the whole boundary of the area.
4. Mark a starting point on the boundary of the figure & place the tracer on the starting point. Note the initial reading.
5. Move the tracer slowly along the boundary of the area in clock wise direction, until it comes back to the starting point
6. The No. of times the zero of the dials passes the fixed index mark neither in a clockwise or anticlockwise direction during the above process should be carefully noted. Record the final reading F & compute the area by using the above equation.

SCHEMATIC SKETCH:



TABULAR COLUMN:

SL. NO.	Shape of the plane	A_{th} cm^2	PLANIMETER READING			A_m cm^2	% Error
			I	F	M		
1	Square						
2	Circle						
3	Triangle						
4	Rectangle						

Where

A_{th}= The theoretical area of the given shape,cm^2

I = Initial reading

F = Final reading

M = Multiplier of planimeter, 100cm^2

A_m = Measured area of the given shapecm^2.

A_m = ()

N= No. of rotations of the disc (+ve for clockwise direction, -ve foe anticlockwise direction)

C= constant of planimeter, considered only when the anchor point is kept inside the plane

% Error= ———

RESULT:

EXPERIMENT NO. 5

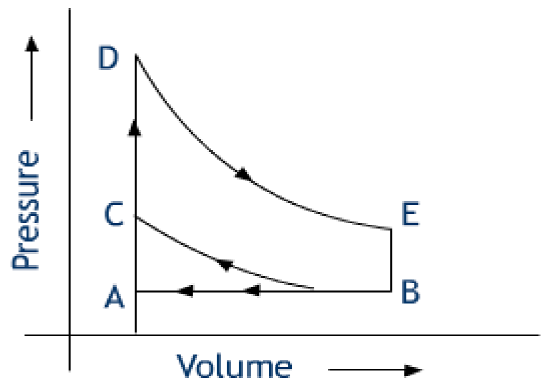
FOUR STROKE PETROL ENGINE

AIM: To determine the performance Characteristic of a 4-stroke petrol engine

APPARATUS: Four Stroke petrol engine test rig, stop watch, fuel etc.

THEORY:

The four-stroke petrol engine works on the principle of Otto (constant volume) cycle. The parts of four-stroke petrol engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, spark plug, and inlet and exhaust valve. The four-stroke petrol engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle.



PROCEDURE:

1. Check the fuel in the tank.
2. Switch ON the power supply & console on the panel board and Ensure ignition switch in ON.
3. But keep the loadings witches in off position initially. Allow the petrol and start the engine by using rope.
4. Apply the load AC generator by switching on loading switches. Allow sometime until the speed stabilizes.
5. Repeat the procedure 4 to 5 different loads at constant speed i.e., 0.5KW load each
6. Tabulate the corresponding readings.
7. Once the experiment is over keep the petrol control valve in closed position. And switch of the console & power supply

OBSERVATION:

Rated speed = 3000rpm

Bore = 68.5mm

Stoke = 72 mm

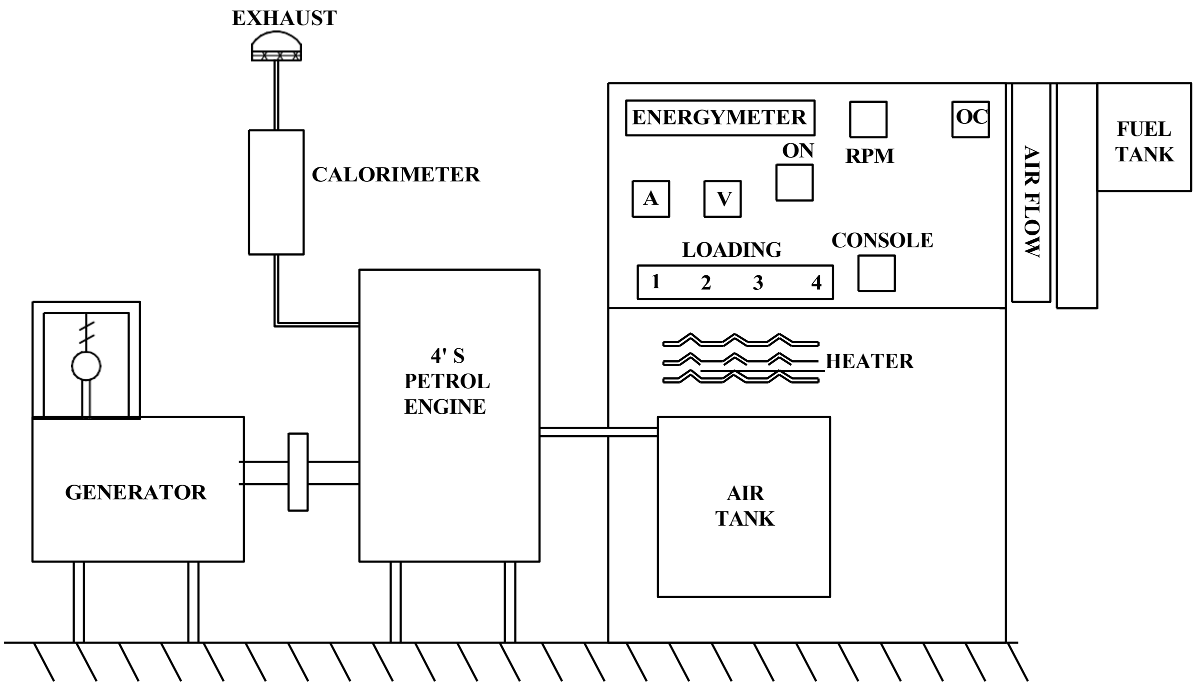
Compression ration = 8.7:1

Cooling – air cooling for the cylinder

Diameter of the orifice of the air tank intake = 0.01m

C_d of orifice = 0.62

SCHEMATIC SKETCH:



OBSERVED TABULAR COLUMN:

Sl. No	E_l kW	Speed RPM	F_N	t_f Sec	Air temperature T_1	h_w m H_2O

CALCULATED TABULAR COLUMN:

V_{th} m^3/S	V_a m^3/S	η_v	m_f kg/s	m_a kg/ S	A:F	BP kW	TFC Kg/hr	BSFC kg /kWh	Q_s kW	bt

Where

E_l= Electrical Load applied, Kw = V*I=…….

$t_{f=}$Time taken for 10cc of fuel consumption, S

h_w= Difference in monometer head, meter of water, m of H_2O

m_f = Mass of fuel kg/s=

v_f= Volume of fuel consumed = 10cc

s = specific gravity of fuel

V_a= Actual volume of air consumed, m^3/S √*60

C_d = Coefficient of discharge = 0.62

A_o = Area of orifice,____…… m

d_o = Diameter of Orifice, m

h_a = Head of the air, m,

H_w= difference in monometer reading

ρ_w= Density of water = 1000 kg /m^3, ρ_a= Density of air, kg/ m^3

P_a= Atmospheric pressure = 101.3 kPa, R= Gas Constant for air = 0.287 kJ/kgK

Ta = Ambient temperature, K

V_{th} = Swept volume of cylinder m^3/s

V_s= ———

D = Diameter of cylinder in meters, L = Stroke length in meters

N = Number of revolutions of crank shaft per min

m_a = Mass of air kg/s,..............................kg/s

CV = Calorific value kJ/kg

BP = Brake power kW

T= torque applied

=F_N*R N-m, R = radius of brake drum

Qs= Heat Supplied to engine

Qs=mf*CV ……kW,

CV is calorific value of fuel BSFC = h

TFC= total Fuel consumption in kg/ hr

bt=

A: F =

$\eta_{v} =$

GRAPH:

SFC	Vs	BP
η_{bth}	Vs	BP
m_f	Vs	BP

RESULTS:

EXPERIMENT NO. 6

FOUR STROKE DIELSEL ENGINE

Aim: 1) Draw the engine performance curves at constant speed under different load conditions.

2) Draw the heat balance sheet at constant speed and at constant load.

Procedure:

1. Using engine specifications calculate the full load that can be applied on the engine.
2. Check up the fuel supply system, lubrication system and water-cooling system.
3. Start the engine by cranking.
4. Once the engine reaches the steady speed, it can be loaded through hydraulic dynamometer for any specified load.
5. Note down the following readings.

a.	Load applied on the engine,	W, Kgf
b.	Speed of the engine,	N, rpm
c.	Manometer reading,	h, cm of water
d.	Time for 10 cc of fuel consumption,	t, secs
e.	Room temperature,	T_∞ °c
f.	Time for 1000-cc collection of water in 'T' secs of engine jacket and calorimeter (m_w and m_{cw}),	T, secs
g.	The water inlet and outlet temperatures of engine jacket	(T_{wi} & T_{wo})
h.	Water inlet and outlet temperatures of calorimeter	(T_{ci} & T_{co})
i.	Exhaust gas inlet and outlet temperatures,	(T_{gi} & T_{go})

6. Repeat the same procedure for different loads and tabulate the values

Engine Specifications:

Engine Type:	Four Stroke, Single-cylinder, Vertical, Water-cooled diesel engine with hydraulic dynamometer
Bore:	$D \rightarrow 102$ mm $\rightarrow 102 \times 10^{-3}$ m
Stroke:	$L \rightarrow 116$ mm $\rightarrow 116 \times 10^{-3}$ m
Power:	$P \rightarrow 7.36$ kW $\rightarrow 7.36 \times 10^{3}$ W
Speed:	$N \rightarrow 1500$ rpm
Dia. of Orifice:	$d \rightarrow 20$ mm $\rightarrow 20 \times 10^{-3}$ m
Co-eff. of Discharge of Orifice:	$C_d \rightarrow 0.62$

Observations:

Sl. No.	W Kgf.	N rpm.	Manometer Reading h, cm. Of water	Time for 10 cc of fuel consumption t, Sec	Room temp T_∞, °C.
1					
2					

<table>
<tr><td colspan="2" rowspan="2">Time for 1000 cc of water collection T, Sec.</td><td colspan="6">Water</td></tr>
<tr><td colspan="2">Engine jacket °C</td><td colspan="2">Calorimeter °C</td><td colspan="2">Exhaust gas °C</td></tr>
<tr><td rowspan="2">Engine jacket (m_w, Kg/min)</td><td rowspan="2">Calorimeter (m_{cw}, Kg/min)</td><td>3</td><td>2</td><td>1</td><td>3</td><td>4</td><td>6</td></tr>
<tr><td>T_{wi}</td><td>T_{wo}</td><td>T_{ci}</td><td>T_{co}</td><td>T_{gi}</td><td>T_{go}</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Calculations:

1. Full Load (W): Power = W N / 2719.2
   P = W N / 2719.2

   P → kW
   W → Kgf
   N → rpm

   $$7.36 = \frac{W \times 1500}{2719.2}$$

   W = 13.33 Kgf

2. Actual volume of air (V_{act}): $V_{act} = C_d \sqrt{(2gH)}\, \pi d^2/4$, m^3/sec

   $H = (h/100) \times (\rho_{water}/\rho_{air}) =$, m of air

   Here $C_d \rightarrow 0.62$
   $d \rightarrow 20 \text{ x}10^{-3}$ m
   $g \rightarrow 9.81$ m/sec^2
   h → manometer reading in cm of water
   $\rho_{water} \rightarrow 1000$ Kg / m^3
   $\rho_{air} \rightarrow P / RT$ Kg / m^3
   P → Atm. Pressure = 1.0132 bar =1.0132 x 10^5 N/m^2
   R → Gas constant for air = 0.287 x10^3 J/Kg-°K

3. Theoretical volume of air (V_{th}): $V_{th} = (\pi D^2/4) \times L \times N/(2\times60)$, m^3/sec

4. Volumetric efficiency (η_{vol}): $\eta_{vol} = (V_{act} / V_{th}) \times 100$

5. Mass of air (m_{air}): $m_{air} = V_{act} \times \rho_{air}$, Kg/sec

6. Mass of fuel (m_f): $m_f = (10 \text{ cc} /1000) \times (1/t) \times$ Sp. gravity of oil , Kg/sec

7. Air fuel ratio (A/F): $A/F = m_{air} / m_f$

8. Brake power (B.P): B.P = W N / 2719.2 | B.P → kW

		B.P = kW	W→ Kgf N → rpm
9.	Frictional power (F.P):	From Graph F.P = , kW	
10.	Indicated power (I.P):	I.P = B.P + F.P	I.P → kW B.P → kW F.P → kW
11.	Indicated Specific Fuel Consumption (ISFC):	ISFC = m_f / I.P Kg/kW-hr	m_f → Kg/hr I.P → kW
12.	Brake Specific Fuel Consumption (BSFC):	BSFC = m_f / B.P Kg/kW-hr	m_f → Kg/hr B.P → kW
13.	Mechanical efficiency (η_{mech}):	η_{mech} = (B.P / I.P) × 100	
14.	Indicated thermal efficiency (η_{ith}):	η_{ith} = (I.P / m_f×CV) × 100	m_f → Kg/hr I.P → kW CV→ kJ/Kg
15.	Brake thermal efficiency (η_{bth}):	m_f → Kg/sec η_{bth} = (B.P / m_f×CV) × 100	I.P → kW CV→ kJ/Kg
16.	Indicated mean effective pressure (p_{mi}):	I.P = p_{mi} × ($\pi D^2/4$) × L × N/(2x60) p_{mi} = N/m² = bar	I.P → W L → m D → m N → rpm
17.	Brake mean effective pressure (p_{mb}):	B.P = p_{mb} × ($\pi D^2/4$) × L × N/(2x60) p_{mb} = N/m² = bar	B.P → W L → m D → m N → rpm

Calculated Values:

Sl. No.	W Kgf.	V_{act} m^3/sec	V_{th} m^3/sec	η_{vol} %	m_{air} Kg/sec	m_f Kg/sec	A/F	B.P kW
1								
2								
3								
4								
5								
6								

F.P kW	I.P kW	η_{mech} %	η_{ith} %	η_{bth} %	ISFC Kg/kW-hr	BSFC Kg/kW-hr	p_{mi} bar	p_{mb} bar

GRAPHS:

B.P **Vs** m_f
A/F
η_{mech}
η_{bth}
η_{ith}
BSFC
ISFC

Heat Balance Sheet:

Calculations:

1. Heat supplied (Q): $\mathbf{Q} = m_f \times C_v$, kJ/min | $m_f \rightarrow$ Kg/min, $C_v \rightarrow$ kJ/Kg
2. Heat equivalent to BP (q_1): $q_1 = BP \times 60$,kJ/min | B.P $\rightarrow$ kW
3. Heat carried away by cooling water (q_2): $q_2 = m_w cp_w (T_{wo} - T_{wi})$,kJ/min | $m_w \rightarrow$ Kg/min, $cp_w \rightarrow$ 4.1827 kJ/Kg-°K
4. Heat carried away by exhaust gases (q_3):
   $q_3 = m_g cp_g (T_{gi} - T_\infty)$,kJ/min

   To calculate '$m_g cp_g$:'
   $m_g cp_g (T_{gi} - T_{go}) = m_{cw} cp_w (T_{co} - T_{ci})$
   $\Rightarrow m_g cp_g = [\, m_{cw} cp_w (T_{co} - T_{ci})\,] / (T_{gi} - T_{go})$
   $\Rightarrow m_g cp_g =$
5. Unaccounted heat losses: $q_4 = Q - (q_1 + q_2 + q_3)$,kJ/min

Sl. No	Heat Input	kJ/min	%	Sl. No	Heat expenditure	kJ/min	%
1	Heat supplied to the engine	Q =	100	1	Heat equivalent to Brake Power	q_1 =	$\frac{q_1}{Q} \times 100$
				2	Heat carried away by cooling water	q_2 =	$\frac{q_2}{Q} \times 100$
				3	Heat carried away by exhaust gases	q_3 =	$\frac{q_3}{Q} \times 100$
				4	Radiation and unaccounted losses	q_4 =	$\frac{q_4}{Q} \times 100$
	Total	**Q =**	**100**		**Total**	**$\sum q$ =**	100

Specimen Calculation

Sl. No.	W Kgf.	N rpm.	Manometer Reading h, cm. Of water	Time for 10 cc of fuel consumption t, Sec	Room temp T_∞, °C.
1	1	1559	7.8	33	25
2	2				
3	3				

Time for 1000 cc of water collection T, Sec.		Water					
		Engine jacket °C		Calorimeter °C		Exhaust gas °C	
Engine jacket (m_w, Kg/min)	Calorimeter (m_{cw}, Kg/min)	3	2	1	3	4	6
		T_{wi}	T_{wo}	T_{ci}	T_{co}	T_{gi}	T_{go}
14	23	23	30	23	29	183	53

Calculations:

1. Full Load (W):

Power = W N / 2719.2

P = W N / 2719.2

P → kW

W → Kgf

N → rpm

$$7.36 = \frac{W \times 1500}{2719.2}$$

W = 13.33 Kgf

2. Actual volume of air (V_{act}):

$V_{act} = C_d \sqrt{(2gH)}\, \pi d^2/4$

$V_{act} = 0.62 \sqrt{(2gH)}$, m^3/sec

$\pi d^2/4 = 6.997 \times 10^{-3-}$ m^3/sec

H = (7.8/100) × (1000/1.1847) , m of air

=65.84m water

Here
- $C_d \rightarrow 0.62$
- $d \rightarrow 20 \times 10^{-3}$ m
- $g \rightarrow 9.81\ m/sec^2$
- h → manometer reading in cm of water
- $\rho_{water} \rightarrow 1000\ Kg / m^3$
- $\rho_{air} \rightarrow P / RT\ Kg / m^3$
- P → Atm. Pressure = 1.0132 bar $= 1.0132 \times 10^5\ N/m^2$
- R → Gas constant for air $= 0.287 \times 10^3$ J/Kg-°K

3. Theoretical volume of air (V_{th}):

$V_{th} = (\pi D^2/4) \times L \times N/(2\times60)$, m^3/sec

$V_{th} = (\pi(102\times10^{3)})^2/4) \times 116\times10^{-3} \times 1559/(2\times60)$

= 0.01231 m^3/sec

4. Volumetric efficiency (η_{vol}):

$\eta_{vol} = (V_{act} / V_{th}) \times 100$

$= (6.997\times10^{-3} / 0.01231) \times 100 = 56.856\%$

5. Mass of air (m_{air}):

$m_{air} = V_{act} \times \rho_{air} = 6.997\times10^{-3} \times 1.187$

$= 8.29\times10^{-3}$ Kg/sec

6. Mass of fuel (m_f):

m_f = (10 cc /1000)× (1/t) × Sp. gravity of oil , Kg/sec

m_f = (10 cc /1000)× (1/33) × 0.8= 2.424×10^{-3} Kg/sec

7. Air fuel ratio (A/F):

$A/F = m_{air} / m_f = 8.29\times10^{-3} / 2.424\times10^{-3} = 34.21$

8. Brake power (B.P):

B.P = W N / 2719.2

= 3x1559x /

2719.2=1.7199 kW

9.	Frictional power (F.P):	From Graph F.P = 1.1 , kW	
10.	Indicated power (I.P):	I.P = B.P + F.P =2.8199 kW	I.P → kW B.P → kW F.P → kW
11.	Indicated Specific Fuel Consumption (ISFC):	ISFC = m_f / I.P Kg/kW-hr ISFC = 2.424x10-^{3} /2.8199 =0.309 Kg/kW-hr	m_f → Kg/hr I.P → kW
12.	Brake Specific Fuel Consumption (BSFC):	BSFC = 2.424x10-^{3} / 1.7199 =0.507Kg/kW-hr	m_f → Kg/hr B.P → kW
13.	Mechanical efficiency (η_{mech}):	η_{mech} = (B.P / I.P) × 100 =(1.7199 / 2.8199) × 100=60.99%	
14.	Indicated thermal efficiency (η_{ith}):	η_{ith} = (I.P / m_f×CV) × 100 =(2.8199/2.424x10-^{3} ×43000) × 100 = 27%	m_f → Kg/hr I.P → kW CV→ kJ/Kg
15.	Brake thermal efficiency (η_{bth}):	m_f → Kg/sec η_{bth} = (B.P / m_f×CV) × 100% = (1.7199 / 2.424x10-^{3} ×43000) × 100 =27%	I.P → kW CV→ kJ/Kg
16.	Indicated mean effective pressure (p_{mi}):	I.P = p_{mi} × (πD²/4) × L × N/(2x60) =2.28 bar N/m² bar	I.P → W L → m D → m N → rpm
17.	Brake mean effective pressure (p_{mb}):	B.P = p_{mb} × (πD²/4) × L × N/(2x60) p_{mb} = 1.38bar	B.P → W L → m D → m N → rpm

Heat Balance Sheet:

Calculations:

1. Heat supplied (Q): $\mathbf{Q} = m_f \times C_v$ $= 0.6155 \times 43000 = 711.04$, kJ/min | $m_f \rightarrow$ Kg/min, $C_v \rightarrow$ kJ/Kg

2. Heat equivalent to BP (q_1): $q_1 = BP \times 60$,kJ/min $= 2.26 \times 60$ $= 135.72$, kJ/min | B.P $\rightarrow$ kW

3. Heat carried away by cooling water (q_2): $q_2 = m_w cp_w (T_{wo} - T_{wi})$ $= 4.29 \times 4.1827 (306-297)$ $= 161.4$, kJ/min | $m_w \rightarrow$ Kg/min, $cp_w \rightarrow 4.1827$ kJ/Kg-°K

4. Heat carried away by exhaust gases (q_3):
   $q_3 = m_g cp_g (T_{gi} - T_\infty)$
   $= (2.61 \times 4.187 \times 10)/202 = 0.5404$,kJ/min
   To calculate '$m_g cp_g$:'

5. Unaccounted heat losses: $q_4 = Q - (q_1 + q_2 + q_3)$ $= 711.04 - 278.15 = 432.89$,kJ/min

Sl. No	**Heat Input**	**kJ/min**	**%**	**Sl. No**	**Heat expenditure**	**kJ/min**	**%**
1	Heat supplied to the engine	Q =	100	1	Heat equivalent to Brake Power	q_1 =135.72, kJ/min	$\frac{q_1}{Q} \times 100$ =19.08
				2	Heat carried away by cooling water		$\frac{q_2}{Q} \times 100$
				3	Heat carried away by exhaust gases		$\frac{q_3}{Q} \times 100$
				4	Radiation and unaccounted losses		$\frac{q_4}{Q} \times 100$
	Total	**Q =**	**100**		**Total**	**$\sum q$ =**	100

EXPERIMENT NO. 7

MORSE TEST

AIM: To determine the frictional of the given multi cylinder spark ignition engine.

APPARATUS: Engine setup, thermometer, tachometer.

THEORY: Morse Test is applicable to multi-cylinder engines. The engine is run at desired speed and output is noted. Then one of the cylinders is cut out by short circuiting spark plug. Under this condition other cylinders "motor" this cut cylinder. The output is measured by keeping speed constant to original value. The difference in output is measure of the indicated power of cut-out cylinder. Thus, for each cylinder indicated power is obtained to find out total indicated power.

PROCEDURE:

1. The engine is started and allowed to turn for some time.
2. The engine is loaded to max. Value by using hydraulic dynamometer and throttle position is adjusted to get the desired rate speed; load and speed values are noted.
3. Current supplied to sparkling of internal cylinder is stopped by operating lever.
4. Load is now decreased to bring spring back to original value without altering the position. Reading of the spring balance is noted down.
5. Now current supplied to spark plug of 2nd cylinder is stopped soon after the current supply to the spark plug of the original rated speed the load is varied.
6. In the same manner the experiment is repeated for different out-off the engine.

SPECIFICATIONS:

Type: 4 stroke, four cylinder car engine with hydraulic loading.

Rated power= 10HP (1.36kw)

Rated speed: 1500 rpm

Distance between the centers of dynamometer to the point spring balance loading= 43.5cm

TABULAR COLUMN:

Condition of the engine	W N	N rpm	BP kW	IP kW	η_m
All cylinders firing (BP)					
Cylinder 1 is cut off (BP1)					
Cylinder 2 is cut off(BP2)					
Cylinder 3 is cut off(BP3)					

W= Load applied on the engine through dynamometer when all cylinders firing, N
W_1= Load applied on the engine when cylinder 1 cut-off,N
W_2= Load applied on the engine when cylinder 2 cut-off, N
W_3= Load applied on the engine when cylinder 3 cut-off,N
BP= Brake power of the engine when all cylinders firing, kW= WN/K
BP_1= Brake power of the engine when cylinder 1 is cut-off= W_1N/K
BP_2= Brake power of the engine when cylinder 2 is cut-off =W_2N/K
BP_3= Brake power of the engine when cylinder 3 is cut-off =W_3N/K
K= Dynamometer constant=______

R= Distance between the centers of dynamometer to the point spring balance loading
IP= Indicated power of the engine=$IP_1+IP_2+IP_3$
IP_1= Indicated power of the cylinder 1=$BP-BP_1$
IP_2= Indicated power of the cylinder 2=$BP-BP_2$
IP_3= Indicated power of the cylinder 3=BP-
$BP_3$$\eta_m$= Mechanical efficiency
η_m= ____

RESULT:

EXPERIMENTNO. 8

SAYBOLT VISCOMETER

AIM: To determine the viscosity of the given sample of oil.

APPARATUS USED:

Say Bolt Viscometer, 60ml flask, thermometer & stopwatch.

EXPERIMENTAL SETUP:

The viscometer consists of oil cup of 30mm diameter and 90 mm height. The cup is provided by water bath which is heated electrically. The oil cup has an orifice at its bottom which can be opened or closed using a cork plug. The plug is opened while collecting the oil sample in the 60CC flask. There is a provision for inserting the thermometer to note down the temperature of the oil.

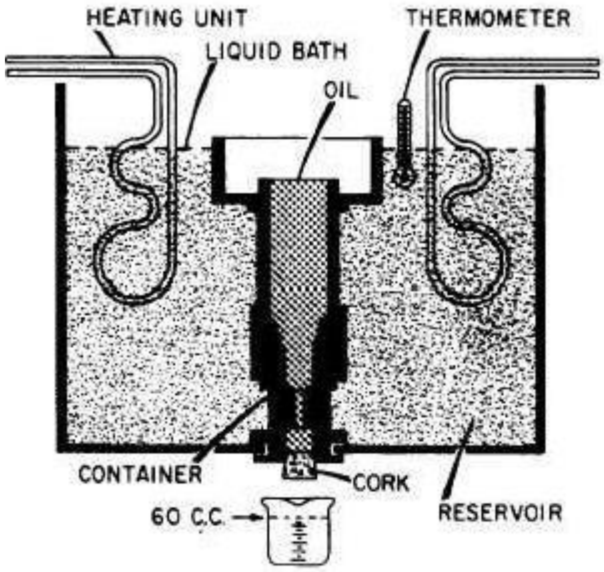


Fig.3: Experimental Setup of Saybolt Viscometer

PROCEDURE:

1. The Orifice is closed using cork plug.
2. The oil cup is filled with the given sample of oil and the lid is closed.
3. The initial oil temperature is recorded.
4. The flask is placed below the orifice and the plug is opened.
5. The time taken to collect 60 cc of oil is noted.
6. The orifice is closed and the oil collected is transferred back to the cup.

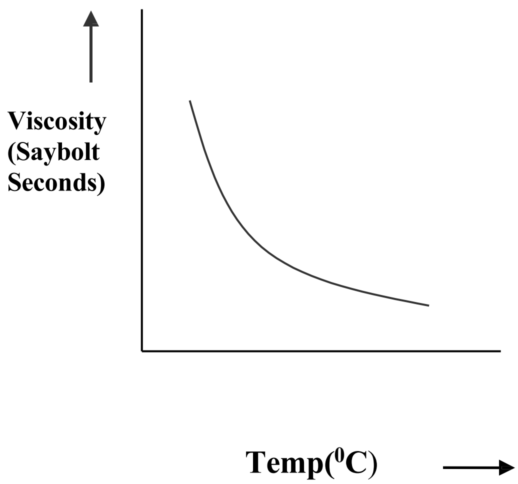
The oil is heated and for every 5^0C rise in temperature, the above procedure is repeated

Type of oil Used:

TABULAR

Trial no.	Temperature (^{0} C)	Time taken (seconds)	Viscosity (say bolt seconds)
1			
2			
3			
4			
5			
6			

Plot a graph of viscosity in say bolt seconds v/s temperature in ^{0}C



Viscosity in saybolt's second were determined and relevant graphs were drawn. Viscosity varies with temperature and has negative exponential trend.

RESULT

EXPERIMENT- 9

PERFORMANCE TEST ON TWO STROKE PETROL ENGINE TEST RIG
(Two Stroke, Single Cylinder, Rope Brake Dynamometer)

AIM: To conduct a performance load test on the engine and to determine Brake Power, Brake Specific Fuel Consumption, Brake Thermal Efficiency and Volumetric efficiency.

APPARATUS USED Petrol Engine coupled to an Rope Brake Dynamometer, Tachometer, Stopwatch.

PROCEDURE

1. Start the engine by kick holding frame handle provided for the same in the base.
2. Now the engine will run at the rated speed of 750 rpm.
3. Allow the brake drum cooling water by operating the gate valve for a less flow.
4. Increase the accelerator screw rod gradually clock wise to run the engine at 3000rpm (approx.) take reading to no load condition.
5. Load the engine in the order of ¼, ½, ¾ and full load by varying accelerator screw rod of engine to meet speed of 3000rpm approximately.
6. Note down all the required parameters mentioned below,
   a) Speed of the engine (N) from digital rpm indicator
   b) Fuel consumption from burette
   c) Quantity of air from manometer.
   d) Repeat steps to increase the load on the engine.
      i. ¼ load
      ii. ½ load
      iii. ¾ load
      iv. Full load
7. Tabulate the results and plot the characteristic curves.

FC	vs	BP
SFC	vs	BP
BTE	vs	BP
η_{Vol}	vs	BP

8. To stop the engine after the experiment is over reducing the load simultaneous decreasing the speed gradually and switch off engine using on/off switch provided on the panel board and close the cooling water gate valve of brake drum.

ENGINE SPECIFICATION

MAKE	:	BAJAJ
BHP	:	2.5 HP
SPEED	:	300RPM
NO. OF CYLINDER	:	ONE
COMPRESSION RATIO	:	7.4:1
BORE	:	54mm
STROKE	:	54mm
ORIFICE DIAMETER	:	20mm
TYPEOF IGNITION	:	FLY WHEE MAGNETO
TYPE OF COOLING	:	AIR COOLED
TYPE OF STARTING	:	KICK START

ROPE BRAKE DYNAMOMETER

MAKE	:	TTE
BRAKE DRUM	:	MILD STEEL
ROPE DIAMETER	:	10mm
HANGER WEIGHT	:	1/2 Kgs
LOADING ARM RADIUS	:	100mm

TABULAR COLUMN

Sl. no	Load (% of full load)	Dead Weight W		Spring balance Reading S		Effective Load	Speed N rpm	Manometer difference h=h2-h1 m	Time taken for 25cc of fuel t Sec	Fuel consumption FC kg/hr	Heat input Q KW
		Kgs	N	Kgs	N	We N					
1	0										
2	25										
3	50										
4	75										
5	100										

BP (KW)	SFC (kg/kW hr)	BTE (%)	Volumetric Efficiency η_{Vol}

CALCULATIONS

$$\mathbf{BP}= \frac{2x\,\Pi\,x\,N\,x\,T}{60\,x\,1000} \quad \mathbf{kW}$$

Where,

T= Torque in N/m

$$\mathbf{T}=\frac{9.81(W-S)(D+d)}{2} \quad \mathbf{N\text{-}m}$$

N= speed of the engine in RPM

W= dead weight in kg+ hanger weight ½ kg

in N S= spring balance reading in N

D= diameter of brake drum in

m(190mm) d= diameter of the rope

in m.

$$\boldsymbol{Fuel\ Consumption} = \frac{X\ x\,0.72\,x\,3600}{t\ x\,1000} \quad \text{kg/hr}$$

Where X cc is volume of fuel in t

secs. Density of fuel for (petrol) =

0.072 gms/cc

Specific Fuel Consumption =**SFC** = $\frac{FC}{BP}$ kg/kWh

Actual Volume of Air Flow into the cylinder at RTP (Va)

$V_a = C_d \times A \times \sqrt{2gh_a \frac{\rho_w}{\rho_a}} \times 3600 \ m^3/hr$

Where, C_d co-efficient of discharge = 0.62

A= area of cross section of orifice = $\frac{\pi(d2)}{4}$ in m^2

d = dia of orifice = 20mm = 2.0 cm

h = ($h_a \frac{\rho w}{\rho a}$) in m

ρ_a = 1.193 kg/m^3 (density of air)

ρ_w = 1000 kg/m^3 (density of

water) h= manometer reading

in m

h_a = Head of air

SWEPT VOLUME (V_s) = $\frac{\pi}{4}$ D^2 x L x N x 60 in m^3/hr

Where;

D is dia of piston = 0.054

in m L is Stroke length =

0.054 in m

N is speed of the engine = in RPM

VOLUMETRIC EFFICENCY (η_{Vol}) = $\frac{Va}{Vs}$ x 100 %

BRAKE THERMAL EFFICIENCY $\frac{BP}{Q}$ **X 100 %**
(BTE) =

Q = $\frac{FC}{3600}$ X C_v kW

Where FC = Fuel Consumption in kg/hr

C_v = Calorific value of petrol = 45.5 x 10^3 kJ/kg

Result

EXPERIMENT-10

PERFORMANCE TEST ON FOUR STROKE SINGLE CYLINDER VARIABLE COMPRESSION RATIO PETROL ENGINE TEST RIG COUPLED TO DC GENERATOR

AIM: To conduct a performance test on the VCR engine for different compression ratios and to draw the heat balance sheet.

DESCRIPTION OF THE TEST RIG

The VCR Engine is a single cylinder, Air Cooled, SI type petrol engine. It is coupled to a loading dynamometer, which is the case is a DC Generator and Resistive Load Bank. The overhead cylinder head made of Cast Iron is water cooled externally and has an counter position above the original piston in the main engine. The counter piston is actuated by a screw road mechanism.

PROCEDURE

1. Put on main panel board socket to 5 amps/230 v AC plug point near the rig.
2. Connect the water source of ¼'' line to auxiliary cylinder head.
3. Provide a water drain line of ¼'' as outlet from auxiliary cylinder head.
4. Check the lubricating oil level in the sump once a while (for every 10 hours of running)
5. Fill up the petrol in the tank mounted on the panel frame.
6. Open the petrol cock provided underneath the petrol tank and in the burette.
7. Start the engine by wounding the rope around the pulley of magneto fly wheel and pull the rope at once to start (if not started try once again)
8. Now the engine will run at 750 rpm respectively.
9. Engage the governor lever towards engine flywheel to run at 3000rpm(approx) to take no load observation.

10. Load the engine in by operating thermostat knob down wise gradually and simultaneously watch the speed engine upto 2800 to 3000rpm
11. Note down all the required parameters mentioned below,
    a) Speed of the engine (n) from digital rpm indicator
    b) Fuel consumption from burette
    c) Quantity of air from manometer.
12. epeat steps to increase the load on the engine.
    a) ¼ load 2) ½ load 3) ¾ load 4) Full load
13. With the results obtained from above said parameters and the calculations, draw the characteristic curves.

FC	vs	BP
SFC	vs	BP
BTE	vs	BP
η_{Vol}	vs	BP

14. For changing compression ratio to the other level bring engine to normal speed that is ideal speed by reducing the load and simultaneously.
15. Unscrew the lever on the compression ratio wheel changing the ratio by operating the wheel and lock the lever without engine stopping
16. By rotating clock wise the compression ratio decrease and start coming up to 2.5:1
17. By rotating anti-clock wise the compression ratio increase and start moving up to 10:1.

ENGINE SPECIFICATION

BHP	:	2.5 HP
RATED SPEED	:	300RPM
NO. OF CYLINDER	:	ONE
BORE	:	70mm
STROKE	:	66.7mm
COMPRESSION RATIO	:	2.5:1 to 10:1

DC GENERRATOR SHUNT WOUND

RATED VOLTAGE : 220 V DC

RATED SPEED : 3000

RATING : 2.2 kW Max.

TABULAR COLUMN

Sl. no	Load (% of full load)	Ammeter Reading	Voltmeter Reading	Speed N rpm	Manometer difference h=h2-h1 m	Time taken for 25cc of fuel t Sec	TC_1	TC_2	TC_3	TC_4	TC_5
		I Amps	V Volts								
1	0										
2	25										
3	50										
4	75										
5	100										

Fuel Consumption FC Kg/hr	Heat input Q kW	BP KW	SFC kg/KW-hr	BTE (%)	Volumetric Efficiency η_{Vol}

TC1 – Exhaust gas inlet to calorimeter

TC2 – Exhaust gas outlet from calorimeter

TC3 – Water inlet to Calorimeter

TC4 – Water outlet from calorimeter

TC5 – Air passing over the Engine.

HEAT BALANCE SHEET

Heat Input per second	**kW**	**%**	**Heat Expenditure per second**	**kW**	**%**
Heat supplied by the combustion of fuel	**Q**	**100%**	a) Heat in BP		
			b) Heat carried by exhaust gas		
			c) Heat carried away by water		
			d) Heat Unaccounted = Q - (a+b+c)		
Total	**Q**	**100**			**100**

Calculations:

$$BP = \frac{2x\,\Pi\,x\,N\,x\,T}{60\,x\,1000} \quad kW$$

Where,

T= Torque in N/m

$$T = \frac{9.81(W-S)(D+d)}{2} \quad N\text{-}m$$

N= speed of the engine in RPM

W= (dead weight in kg+ hanger weight ½ kg) in N

S= spring balance reading in N

D= diameter of brake drum in m(190 mm)

d= diameter of the rope in m.

$$Fuel\ Consumption\ = \frac{X\ x\,0.720\,x\,3600}{t\ x\,1000} \quad kg/hr$$

EXPERIMENT-11

ANALYSIS OF DESIGN & DEVELOPMENT IN INTERNAL COMBUSTION ENGINES

Aim

To study and analyze the design parameters, performance characteristics, and development trends of a single-cylinder internal combustion engine through experimental investigation of fuel consumption, efficiency, power output, and emission levels in an Energy Conversion Lab setup.

Apparatus Used

- Single-cylinder 4-stroke diesel or petrol engine (water-cooled)
- Eddy current or rope brake dynamometer
- Fuel measurement system (burette and stopwatch)
- Air intake system with manometer and orifice meter
- Crank angle encoder and cylinder pressure sensor
- Digital temperature sensors (exhaust, coolant, oil)
- Exhaust gas analyzer (for CO, HC, NOx)
- Data Acquisition System with engine analysis software (LabVIEW/Engine Soft)
- Tachometer
- Thermocouples and pressure gauges

Working Principle

An **Internal Combustion Engine (ICE)** is a heat engine where combustion of fuel occurs inside the cylinder. This combustion generates high-pressure gases that move the piston, converting **chemical energy** into **mechanical energy**.

Depending on fuel and ignition type:

- **Spark Ignition (SI)** engines follow the **Otto cycle**
- **Compression Ignition (CI)** engines follow the **Diesel cycle**

Design Parameters:

- **Bore (D)** and **Stroke (L)**
- **Compression Ratio (CR)**
- **Clearance Volume (Vc)** and **Swept Volume (Vs)**
- **Brake Power (BP)** and **Indicated Power (IP)**

Experimental Setup

The experimental setup includes a **single-cylinder engine** connected to a **dynamometer** for measuring torque and speed. Fuel flow is measured using a **burette**, and air flow using an **air box with orifice meter**. Sensors collect pressure and temperature data, while a gas analyzer measures emissions. The entire system interfaces with a **Data Acquisition System** for real-time analysis.

Procedure

1. Ensure all connections are secure and the engine is filled with fuel and coolant.
2. Start the engine and allow it to warm up until it reaches steady-state operating temperature.
3. Set the desired engine load using the dynamometer.
4. Measure and record:
    - Engine speed (RPM)
    - Torque from dynamometer
    - Fuel consumption over a timed interval (using burette)

- Air intake using manometer readings
- Temperatures (coolant, exhaust, inlet)
- Emission levels using gas analyzer
- Cylinder pressure and crank angle (for P-θ diagram)

Load (%)	**Speed (RPM)**	**Torque (Nm)**	**Fuel Used (ml)**	**Time (s)**	**Exhaust Temp (°C)**	**CO (%)**	**HC (ppm)**
0	1500	0	5	60	130	0.1	120
25	1500	5	8	60	160	0.3	170
50	1500	10	12	60	190	0.4	220
75	1500	15	18	60	220	0.5	280
100	1500	20	25	60	250	0.6	330

Calculations

Brake Power (BP):

$$BP = 60 \times 1000 / 2\pi NT \text{ (kW)}$$

2. Fuel Consumption (kg/hr):

$$\text{Fuel Consumption} = \left(\frac{\text{Fuel volume (ml)} \times \text{Density}}{\text{Time (s)}} \right) \times 3600$$

3. Specific Fuel Consumption (SFC):

$$SFC = \frac{\text{Fuel Consumption (kg/hr)}}{BP}$$

4. Brake Thermal Efficiency (η_bth):

$$\eta_{bth} = \frac{BP \times 3600}{\text{Fuel Consumption (kg/hr)} \times \text{CV of fuel}} \times 100$$

5. Mechanical Efficiency (η_mech):

$$\eta_{mech} = \frac{BP}{IP} \times 100$$

Graphs & Analysis

1. **Brake Power vs. Load**
2. **BSFC vs. Load**
3. **Brake Thermal Efficiency vs. Load**

Results

- Maximum Brake Power achieved at full load = ___ kW
- Minimum Specific Fuel Consumption = ___ g/kWh
- Maximum Brake Thermal Efficiency = ___ %

EXPERIMENT-12

STUDY OF PROCESS OPTIMIZATION IN ENGINES

AIM: To study and analyze various engine operating parameters and apply process optimization techniques to improve engine performance, fuel efficiency, and emission characteristics under different conditions

Apparatus Used

- Single-cylinder 4-stroke IC engine (diesel/petrol)
- Eddy current or hydraulic dynamometer
- Fuel measurement setup (burette, stopwatch)
- Air intake system with orifice meter and manometer
- Emission analyzer (for CO, HC, NOx)
- Cylinder pressure sensor with crank angle encoder
- Temperature sensors (inlet, exhaust, coolant)
- Variable control systems (for injection timing, valve timing, or compression ratio if available)

Working Principle

Process Optimization in Engines:

Process optimization refers to the adjustment of **engine parameters** to achieve maximum efficiency and minimal emissions without compromising performance.

Common Optimization Parameters:

- **Injection timing** (for CI engines)
- **Spark timing** (for SI engines)
- **Air-Fuel ratio**
- **Compression ratio**
- **Valve timing (VVT)**
- **Engine load and speed**

Experimental Setup

The engine is mounted on a test bed and connected to:

- A dynamometer for load control and torque measurement.
- Fuel flow and air intake measurement systems.
- Sensors to record temperature, pressure, and crank angle.
- An emission analyzer to monitor exhaust gases.
- A DAQ system to record and analyze real-time performance data.

Optimization trials are conducted by **varying parameters** like injection/spark timing, A/F ratio, or load

Procedure

- Start the engine and allow it to reach steady operating conditions.
- Set a baseline run with standard factory settings.
- Measure and record performance at different loads (0%, 25%, 50%, 75%, 100%).
- Vary one optimization parameter at a time, such as:
- Advancing or retarding ignition/injection timing
- Lean or rich air-fuel mixtures
- Changing compression ratio (if variable)
- For each variation:
- Record speed, torque, fuel consumption, temperatures
- Measure emissions using the gas analyzer
- Save pressure-crank angle data for P-θ analysis
- Repeat the test for each optimized parameter setting.
- Analyze how performance changes with each variation

Observations and Readings

Load (%)	Speed (RPM)	Torque (Nm)	BP (kW)	Fuel Flow (ml/min)	CO (%)	HC (ppm)	Efficiency (%)
25	1500	4.8	0.75	8	0.3	160	18
50	1500	9.6	1.50	14	0.4	220	24
75	1500	14.5	2.27	20	0.6	290	28
100	1500	19.5	3.05	28	0.8	350	30

Calculations

❖ Brake Power (BP):

$$BP = \frac{2\pi NT}{60 \times 1000}$$

❖ Specific Fuel Consumption (SFC):

$$SFC = \frac{\text{Fuel Consumption (kg/hr)}}{BP}$$

❖ Brake Thermal Efficiency:

$$\eta_{bth} = \frac{BP \times 3600}{\text{Fuel Flow Rate (kg/hr)} \times \text{CV of fuel}}$$

Graphs & Analysis

Plot the following graphs for baseline and optimized cases:

1. **Brake Power vs. Load**
2. **BSFC vs. Load**
3. **Brake Thermal Efficiency vs. Load**
4. **CO and HC Emissions vs. Load**
5. **Effect of Spark/Injection Timing on Efficiency**

Results

- Optimized spark/injection timing improved brake thermal efficiency by ___% at medium loads.
- Best air-fuel ratio for minimum CO emissions: ___
- Specific fuel consumption reduced by ___% under optimized conditions.
- Emission levels were minimized while maintaining acceptable power output.
- Peak cylinder pressure occurred closer to TDC with optimized timing, indicating improved combustion.

-