Internal Combustion Engines and Gas turbines Lab

Experiment No. 1

Object:- To Study four strokes spark ignition (S.I) Engine and differences between S.I. ad C.I engines.

Equipment: Four strokes S.I engine

Construction: - Four strokes SI engine consist of following main parts.

(i) Cylinder
(ii) Piston
(iii) Gudgeon pin or piston pin
(iv) Connecting rod
(v) Water jacket
(vi) Silencer
(vii) Small end of connecting rod
(viii) Big end of connecting rod
(ix) Crank pin
(x) Spark plug
(xi) Crank
(xii) Inlet valve
(xiii) Crank case
(xiv) Exhaust valve
(xv) Push rods
(xvi) Tappet
(xvii) Flywheel

Working Principle: - One working cycle of four strokes S.I engine is consisting of four processes.

(i) Suction process
(ii) Compression process
(iii) Working or Expansion process
(iv) Exhaust process

Each process is completed in one stroke of the piston and one working cycle completed in four strokes of piston that is suction, compression, expansion and exhaust strokes

Suction stroke:- Inlet valve is open . Piston come down or travel towards bottom dead centre position (BDC) and slight vacuum is created in the cylinder. Mixture of air and petrol, which is prepared is carburettor, enters the engine cylinder through inlet valve. In normal running of the engine, the ratio of air and petrol is I5: 1 but at the time of starting and acceleration, mixture is rich in nature as per the demand the engine. Suction process continues till the piston reaches at BDC.

Compression stroke:- Now piston travel towards top dead centre position (TDC). Inlet valve and Exhaust valve are closed . Valves are operated by cams mounted on cam shaft, crank shaft, tappet and push rods. Mixture is compressed adiabatically (PV=k) in clearance space. Due to compression its temperature and pressure increases. Now spark is produced in the compressed mixture by spark plug. Combustion of mixture takes place.

Expansion or Working or power stroke:- Due to combustion of charge, its pressure and temperature increases . Gases at high pressure push the piston towards BDC. Both the valves are still closed. Power is obtained at the crank shaft.

Exhaust stroke: - Now piston turn towards TDC. Exhaust valve is open. Burnt waste gases are thrown out side through Exhaust valve.
Again the inlet valve is open. Suction stroke started and processes are repeated.

Dead centre positions are over come due to the momentum of fly wheel.

In four stroke SI engine one working cycle is completed is two revolutions of the crank shaft.

Differences between SI and CI Engines.

Sr. No	**Spark Ignition Engines**	**Compression ignition Engines**
1	Petrol is used as fuel	Diesel oil used as fuel
2	Works on Otto cycle	Works on Diesel Cycle
3	Mixture of air and petrol is taken during suction stroke	Pure air taken during suction stroke
4	Spark plug is used to ignite the mixture	Fuel pump and fuel injector are used to inject the diesel oil in the cylinder and its combustion take place due to high temperature of air.
5	Compression ratio 7:1 to 10:1 is used	Compression ratio 14:1 to 18:1 is used

6	Thermal efficiency is low due to lower compression ratio (about 30%)	Thermal efficiency is higher due to higher compression ratio (35 to 40%)
7	For the same compression ratio Otto cycle is more efficient	For the same compression ratio , Diesel cycle is less efficient
8	Lighter and cheap	Heavy and Costly
9	Low maintenance	High maintenance
10	Quantitative governing is used	Qualitative governing is used

Answer the following questions

(i) Define compression ratio and expansion ratio.

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(ii) State numerical value of compression ratio used is CI engines

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(iii) Thermal efficiency of CI engine is more than SI engine, why?

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(iv) For the same compression ratio, Otto cycle is more efficient than Diesel cycle, Justify.

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(v) Why IC engines are cooled? Which type of cooling is used in two stroke SI engines?

(vi) What is function of fuel pump in CI engines?

(vii) What is function of fuel injector in CI engines

(viii) What is quantitative and qualitative governing used in IC engine? Which type of governing is used in SI engines?

(ix) How are the suction and exhaust valves operated in CI engines?

(x) What do you mean by MPFI system?

Experiment No.2

Object: - To study two Strokes S.I. engine and differences between two strokes and four strokes engines.

Equipment: - Two strokes spark ignition engine

Construction: - Two stroke spark ignition engines is consisting of following main parts.

- **(i) Cylinder**
- **(ii) Piston**
- **(iii) Deflector**
- **(iv) Piston pins or gudgeon pins**
- **(v) Piston rings**
- **(vi) Spark plug**
- **(vii) Connecting rod**
- **(viii) Small end of connecting rod**
- **(ix) Big end of connecting rod**
- **(x) Crank**
- **(xi) Spark plug**
- **(xii) Crank shaft**
- **(xiii) Closed crankcase**
- **(xiv) Inlet port**
- **(xv) Transfer port**
- **(xvi) Exhaust port**
- **(xvii) Fins on cylinder and cylinder head**
- **(xviii) Silencer**

Working Principle: - Assume that piston going towards top dead centre position (TDC) in case of vertical engine. As soon as piston covers the exhaust port, Compression of mixture of air and petrol starts. Compression is adiabatic (PV=K) process and temperature and pressure of mixture increases At the same time inlet port is open and fresh mixture of petrol and air from carburettor enters in the crank case. Mixture is compressed slightly in the

crank case due to clockwise movement of crank in the crank case. It helps the mixture to go to engine cylinder through transfer port.

At the end of compression process, spark is induced by spark plug and combustion of mixture takes place.

Due to combustion process the temperature and pressure of the gases increases. These gases at high pressure and temperature push the piston towards bottom dead Centre position. It is an expansion process.

Now first of all exhaust port uncovered by piston and waste gases start going outside. After some time transfer port is also open by the piston. As soon as transfer port is open, the fresh charge enters engine cylinder and deflected upward due to deflector. Deflected charge helps in pushing the exhaust gases outside but fresh charge remains in the engine cylinder. It is possible that part of fresh charge may escape outside along with burnt gases.

Hence exhaust process and suction process take place is the same stroke. Piston after reaching the BDC has reverse direction and go towards TDC and process is repeated.

Applications: - Scooter and Bike engines

Differences between two strokes and four strokes engines

Sr. No.	Two Strokes engines	Four Strokes engines
1	Exhaust noise is more	It is less
2	For the same RPM, power is almost double	Power is less
3	Thermal efficiency is low	Thermal efficiency high
4	Ports are used	Valves are used
5	One working cycle completes in two strokes of piston or in one revolution of crank shaft	One working cycle completes in four strokes of piston or two revolution of crank shaft
6	Mechanical efficiency is more due to low power lost in friction	Mechanical efficiency is less due to higher power lost in friction
7	Crank case is closed	Crank case is open

Answer the following questions

(i) **Why the thermal efficiency of four strokes S.I. engines are more than two strokes S.I. Engines?**

(ii) **Mechanical efficiency of two strokes S.I. engines is more than four strokes S.I. engines why?**

(iii) **Exhaust noise from silencer in case of two stroke engines is more than four stroke engines why?**

(iv) **For the same RPM two stroke engines produce almost double power than four stroke engines why?**

(v) **What is the use of deflector used on the piston in case of two strokes S.I. Engines?**

(vi) **What do you mean by scavenging process? It is positive in case of four strokes engines and negative in two strokes engines, Explain.**

(vii) **In two stroke S.I. engines exhaust port is placed slightly at higher level than transfer port. Why?**

(viii) **Piston rings are used on the piston why?**

(ix) **What is optimum percentage of lubricant oil used in petrol in case of two strokes S.I. engines?**

(x) **What is compression ratio? State numerical value of compression ratio in two strokes and four stroke S.I. engines.**

<u>Experiment no. 3</u>

<u>Object:</u> To study battery ignition system for four cylinders S.I. engines and requirements of ignition system.

<u>Equipment:</u> Battery ignition system

<u>Construction</u>:- Battery ignition system is consisting of following main parts.

I. 6 or 12 volt battery
II. Ignition switch
III. Ammeter
IV. Primary winding and secondary windings of induction coil
V. Contact breaker point
VI. Square edge cam
VII. Distributor
VIII. Rotor arm of distributor
IX. Spark plugs
X. Condenser

<u>Working</u>: - Current from battery pass through the ignition switch if it is closed and it goes to primary winding of induction coil through ammeter. Now this current passes through contact breaker point. If contact breaker point is closed, it goes to earth, and earth to earth circuit is complete.

Since square edge cam , is mounted on the cam shaft which is rotating at a speed half of that crank shafts (four stroke engine) which open and close the contact breaker point. In case the contact break point is open, in that case there is change in lines of magnetic flux in the primary winding of inductinon coil and induced EMF is induced in the secondary winding induction coil. Magnitude of voltage of secondary current depends upon the number of turns in secondary winding of induction coil.

Primary winding consist of 200-300 turns of thick wire (20 SWG) and secondary winding is having……… number of turms of fine wire (SWG). Hence the secondary current has a voltage of 2000 to 30,000 volts.

Now high voltage current goes to distributor , where rotor arm, mounted on cam shaft, distbrute the high voltage to spark plugs in a specific firing order (say

1,3,4,2 Or 1,3,2,4). This specific firing order is adopted to get uniform torque on the crank shaft.

This high voltage current is sufficient to overcome the resistance of air gap between the two electrodes of spark pug and current jumps from central electrode to outer electrode and spark is produced. Combustion of charge takes place.

A condenser is also connected in parallel to contact breaker point to check the sparking at contact breaker point.

Requirements of Ignition system

(i) To supply high voltage current of order of 20000 to 30000 voltages to spark plug to induce spark at the spark plug gap.
(ii) Spark should take place at the correct time just before the compression stroke is completed.
(iii) System should function efficiently at all speed of the engine.
(iv) System should be light , compact and easy to maintain.
(v) It should not cause any interference in working system of the engine.

Applications: - Battery ignition system is used in car engines using SI engines

Answer the following question questions

(1) What is the of Battery ignition system? Where it is used?

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(2) What is the function of contact breaker point?

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(3) What is the function of condenser or capacitor used in parallel with contact breaker point?

(4) How the induced EMF is produced is the secondary winding of induction coil?

(5) What is the magnitude of voltage of secondary current?

(6) What is the function of distributor?

(7) What do you mean by firing order? In which firing order spark is produced in the four cylinders of the engine and why?

(8) Time to time spark plugs are cleaned, why?

(9) How much approximate air gap is required between two electrodes of spark plug?

(10) Why high voltage of order of 20,000 to 30,000 Volt is required to produce spark in spark plug?

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Experiment No.4

Object: - To study magneto ignition system for SI engine having four cylinders and differences between magneto and battery Ignition system.

Equpment: - Magneto Ignition system

Construction: - Magneto Ignition system has following mair parts.

(i) Permanent Magnet
(ii) Armature
(iii) Primary and secondary windings.
(iv) Contact breaker point
(v) Capacitor
(vi) Square edged cam
(vii) Distributor
(viii) Rotor arm
(ix) Spark plugs

Working principle: - In this system magnetic field in the core of primary and secondary winding is produced by rotating permanent magnet. As the magnet is rotated by crank shafts, the field is produced from positive maximum to negative minimum and back again.

As the Magnetie field from positive maximum changes to the negative minimum, the voltage and current are induced in the primary winding of induction coil.

Current in primary winding produces a magnetie field of its own, which keep the total magnetie filed almost constant.

This current in the primary goes to contact breaker point. If it is closed, it goes to earth and primary current circuit is completed.

In case , the contact breaker point is open by crank shaft, the magnetic field drop in the primary and high voltage current is produced the secondary winding. This high voltage current goes to distributor and distribute this current to spark plugs in a specific firing order (1-3-4-2). This specific firing order is adopted to produce uniform torque in the crank shaft.

Differences between battery and magneto ignition system

Sr. No	**Battery Ignition system**	**Magneto Ignition system**
1	Current for primary winding of induction coil is provided by battery.	Current is primary winding is produced by a magnet rotating in a fixed armature.
2	If battery is discharged , the system will fail to work.	There is no such of difficulty in this system.
3	Spark intensity is good even at low speed	Spark intensity is poor at low speed
4	Spark intensity is poor at high speed. Efficiency of the system decreases.	Spark intensity is good at high speed . Effciency of the system improves.
5	Starting is easy	Starting is slightly difficult
6	Less costly	More costly
7	Maintaince is more and occupy more space	Mantenance is less. It is more compact
8	Used in cars using SI engines	Used in two wheelers engines, racing cars, air craft etc.

Answer the following question

(i) What is aim of magento ignition system and where it is used?

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(ii) How the high voltage is induced in the secondary of induction coil?

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(iii) How the permanent magnet is rotated?

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(iv) State the three major differences between battery and magneto ignition systems.

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(v) On what factor, the shape of cam is used?

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(vi) Opening and closing of contact breaker point depends upon?

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(vii) Magneto ignition systems prefered for Aeroplanes, why?

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Experiment No. 5

Aim: - Study of carburettor with compensating and starting Jet devices.

Equipment: - Carburettor with compensating and starting Jet devices.

Construction: - Carburettor with compensating and starting Jet devices consist of following main parts.

(i) Venturi
(ii) Venturi Throat
(iii) Throttle valve
(iv) Fuel nozzle
(v) Main Jet
(vi) Compensating Jet
(vii) Float Chamber
(viii) Float
(ix) Needle Valve
(x) Starting Jet
(xi) Air Control screw

Working Principle: - Air from air filter enters the venturi, converging in section. Due to converging section, air velocity increases and its pressure decreases. At throat of the venturi, area of cross sections is minimum, velocity is maximum and pressure is minimum.

Pressure in float chamber over the petrol surface is atmospheric and pressure at the tip of fuel nozzle at throat of venturi is lower than atmospheric pressure. Due to this pressure difference, petrol from fuel nozzle comes out in the form of spray and mixed with air and a homogenous mixture of air and petrol is formed.

This mixture of air and petrol enters the engine cylinder through throttle valve to run the engine.

Petrol (Fuel) enters the float chamber from petrol tank through needle valve attached with float. Float keep the level of petrol in float chamber constant.

In the carburettor having only main jet, during acceleration, velocity of air at throat increases, pressure also decreases up to higher extent and quantity of petrol coming that of fuel nozzle also increases. But amount of petrol coming out fuel nozzle is about 2 ½ times than exact requirement.

This tendency of main jet is compensated by compensating jet. Compensating jet is made around main jet and allows constant quantity of petrol at all speeds. The combination of main jet and compensating jet provide right quantity of petrol in air as per speed and load on the engine as per requirement.

In this carburetor discussed above at the time of starting, small volume of air enters at throat of venturi and small quantity petrol comes out fuel nozzle. This mixture strength is not enough to start the engine. At the time of starting, the engine requires rich mixture (Air: Fuel ration of 9:1). This mixture is provided by starting jet. Starting jet take air from venturi and petrol from float chamber and provide a rich mixture just after the throttle valve and help to start the engine.

Answer the following questions

(i) What is the aim of carburettor? And where it is used?

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(ii) What is the draw back in simple carburettor?

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(iii) What is function of Compensating Jet?

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(iv) What is the function of staring Jet?

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(v) What is function of float in float chamber?

(vi) What is the advantage of venturi portion?

(vii) What is function of throttle valve?

(viii) Why fuel nozzle is placed at the throat of the venturi.

(ix) Mention the air fuel ratio required by the engine during...

(a) Starting time

(b) Normal running

(c) Acceleration

(x) Carburetor has been replaced by MPFI system in S.I. engine, why?

Experiment No.-6

Aim: - Determination of Brake power (BP), friction power (FP) and Indicated power (IP) of four stroke four cylinder diesel engine with rope break dynamometer.

Equipment:

(i) Engine :- Four stroke, four cylinder, vertical, water cooled, self governed diesel engine

(ii) Rope brake dynamometer:- Rope brake dynamometer, spring balances and loading screw

(iii) Calibrated fuel burette for fuel consumption measurement

(iv) Orifice meter, fitted to air inlet tank with water manometer for air intake measurement

(v) Multi-channel digital temperature indicator for temperature measurement at various points

(vi) Exhaust gas calorimeter to measure heat carried away by exhaust gases.

Procedure:-

(i) Fill up sufficient diesel in diesel tank

(ii) Check the level of lubricant oil in the sump by oil dip stick. It should be up to top edge of the flat

Portion provided over the dip stick

(iii) Fill up water in manometer up to half of manometer height

(iv) Start the water supply and see water is flowing through engine jacket, brake drum and exhaust

Gas calorimeter

(v) Release the loading screws, so that there is no tension in the rope.

(vi) Start the engine with the help of auto ignition key

(vii) Load the engine with loading screw and set the balance difference to say 2 Kgs

(viii) Open the burette filling cock, take sufficient diesel in burette and close the cock

(ix) Now turn the selector cock to engine and note down the time required for 20 ml fuel consumption

(x) Note down the brake drum speed with tachometer

(xi) Note down difference in two limbs of manometer

(xii) Note the following temperatures from digital thermometer

(xiii) Note down jacket cooling water and calorimeter water flow rates

(xiv) Take 5 sets of reading for different load

T1 = Inlet temp of cooling water to engine jacket

T2 = outlet temp of cooling water from engine jacket

T3 = Inlet temp of cooling water to gas calorimeter

T4 = outlet temp of cooling water from gas calorimeter

T5 = Inlet temp of exhaust gases to gases to gas calorimeter

T6 = outlet temp of exhaust gases from gas calorimeter

Observation Table

S.N	Type of reading	Set No.-1	Set No.-2	Set No.-3	Set No.-4	Set No.-5
1	Load W = (W1-W2)Kg					
2	Time for 20ml fuel consumption, t_f Sec					
3	Manometer difference hw cm.					
4	Time for 1 liter of calorimeter water t_c sec					
5	Time for 1 liter of engine jacket water					
6	Water inlet temp to engine jacket T1 ^oC					
7	Water outlet temp from engine jacket T2 ^oC					
8	Water inlet temp to calorimeter T3 ^oC					

9	Water outlet temp from calorimeter T4 ^oC					
10	Inlet temp of exhaust gases to calorimeter T5 ^oC					
11	Outlet temp of exhaust gases from gas calorimeter T6 ^oC					
12	Engine speed RPM					

Formula for calculations

(1)Brake power (BP)

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

Where T= Torque = Force x distance

= (W1-W2)xradius of brake drum

= (W1-W2) x9.8x0.15 Nm (when W1 & W2 are in Kg)

N= Engine RPM

(2) Fuel consumption (F.C)

Let t_f = time required for 20 ml of fuel consumed by engine

$$\text{Fuel consumption} = \frac{20 \times 3600}{T_f \times 1000} \times 0.78 \text{ Kg/hr}$$

(3) Specific fuel consumption (SFC)

SFC = Fuel consumption in kg/BP/hr.

(4) Heat supplied by fuel (H_F)

HF = Fuel consumption x calorific value of fuel

= fuel consumption in kg x 42630 kJ/Kg

Where calorific value of fuel = 42630 KJ/Kg

(5) Friction power (F.P)

Plot the graph between F.C Vs BP for different sets of readings

Extend the line of graph backside till it cuts the X-axis

The power on negative scale at which FC is zero, is the friction power. The plot is known as willian's Line.

(6) Indicated power (IP)

IP= BP + FP Kw

(7) Heat equivalent to IP

H_{IP}= IPx3600 KJ/hv

= IP KJ/Sec.

(8) Mechanical efficiency (η_m)

$$\eta_m = \frac{BP}{IP} \times 100\%$$

(9) Brake thermal efficiency (η_{BT})

$$\eta_{BT} = \frac{\text{Heat equivalent to BP}}{\text{heat supplied by fuel}} \times 100\%$$

(10) Indicated thermal efficiency (η_{IT})

$$\eta_{IT} = \frac{\text{Heat equivalent to IP}}{\text{Heat supplied by fuel}} \times 100\%$$

$$= \frac{\text{IP in KJ/sec.}}{\text{Fuel supplied per sec x calorific value in KJ/Kg}}$$

(11) Air consumption (ma)

Air head across the orifice (Ha)

$$Ha = \frac{hw}{100}(1000-\rho a)$$

Where hw = reading on water manometer in cm

ρa = density of air

$$\rho a = \frac{P}{287\,(T+273)}$$

P = atmospheric pressure $N/m^2 = 10^5\ N/m^2$

T = absolute ambient temp in ^oK

Mass of air (ma)

$$= 0.62 \times 4.9 \times 10\text{-}4 \sqrt{2gHa \times 3600 \times \rho a}$$

Where Cd of orifice = 0.62

Area of orifice = $4.9 \times 10^{-4} m^2 = 0.000314\ m^2$

Orifice dia = 0.02m

(12) Air-fuel-ratio (AFR)

$$AFR = \frac{ma}{FC} = \frac{\text{mass of air consumed}}{\text{fuel consumption}}$$

(13) Heat balanced sheet

Credit side is heat supplied by fuel. Debit side consist of following parameters

Credit	Debit	%
Heat supplied by fuel = calorific value of fuel x mass of fuel x mass of fuel (kg)	(1)Heat equivalent to BP (2)Heat taken away water of engine jacket (3)Heat taken by water of gas calorimeter (4)unaccounted heat loss by radiation	 100%

(14) Heat equivalent to BP = BPx3600 KJ/hv

(15) Heat taken away by water = m x Cp(ΔT)of engine jacket (Hjw)

Where Cp = sp heat of water = 4.18 KJ/kg^{o}K

$\Delta t = T_2\text{-}T_1$

(16) Determination of mass of air consumption

Let A = Area of orifice in m^2

d = dia of orifice in cm

hw = head of water in cm in manometer

cd = coefficient of discharge

ρ_a = density of air in kg/m^3 at atmospheric conditions

ρ_w = density of water in kg/m^3 = 1000 kg/m^3

Let H = head if air in meters

$$H \times \rho_a = \frac{h_w}{100} \times \rho_w$$

$$H = \frac{h_w}{100} \frac{x \rho_w}{\rho_a} = \frac{hw \times 100}{100 \quad \rho_a} = \frac{10h_w}{\rho_a} \text{ meters}$$

Velocity of air passing through the orifice is given by

$$Ca = \sqrt{2gH} \text{ m/sec} = \sqrt{2g.\frac{10h_w}{\rho_a}} \text{ m/sec}$$

Volume of air passing through the orifice

$$Va = cd \times A \times Ca$$

$$= cd \times A \sqrt{\frac{20ghw}{\rho_a}}$$

$$= 14cdA\sqrt{\frac{hw}{\rho_a}}$$

Mass of air passing through the orifice

$$Ma = Va.\ \rho_a$$

$$=14cdA\ \rho_a\sqrt{\frac{hw}{\rho_a}}$$

$$=14cdA\sqrt{\rho_a hw}$$

Where

$A = \frac{\prod}{4} (d/100)$

$Ma = 0.066cd\ d^2 \sqrt{\rho a h w}$ kg/min

Heat carried away by exhaust gases

From the heat balance of calorimeter

Heat given by exhaust gases

= heat taken by water of gas calorimeter

OR $m_{eg}\, cp_g\, (T5\text{-}T6) = m_{wc} c_{pwc}\, (T4\text{-}T3)$

Where M_{eg} = mass flow rate of exhaust gases

C_{peg} = speed of exhaust gases

M_{wc} = Mass flow rate of calorimeter water

C_{pwc} = specific heat of water =4.18 KJ/Kg^{o}K

Hence

$$= M_{eg}.C_{pg} = \frac{M_{wc}.C_{pwc}(T4-T3)}{(T5-T6)}$$

Hence heat carried away by exhaust gases

$= M_{eg}.C_{pg}(T5-Ta)$

Where Ta = Room temperature

Experiment No.-7

Object: - To determine Mechanical efficiency, Brake thermal efficiency and indicated thermal efficiency of four strokes, four cylinder diesel engine.

Equipment:

(vii) Engine :- Four stroke, four cylinder, vertical, water cooled, self governed diesel engine

(viii) Rope brake dynamometer:- Rope brake dynamometer, spring balances and loading screw

(ix) Calibrated fuel burette for fuel consumption measurement

(x) Orifice meter, fitted to air inlet tank with water manometer for air intake measurement

(xi) Multi-channel digital temperature indicator for temperature measurement at various points

(xii) Exhaust gas calorimeter to measure heat carried away by exhaust gases.

Procedure:-

(xv) Fill up sufficient diesel in diesel tank

(xvi) Check the level of lubricant oil in the sump by oil dip stick. It should be up to top edge of the flat

Portion provided over the dip stick

(xvii) Fill up water in manometer up to half of manometer height

(xviii) Start the water supply and see water is flowing through engine jacket, brake drum and exhaust

gas calorimeter

(xix) Release the loading screws, so that there is no tension in the rope.

(xx) Start the engine with the help of auto ignition key

(xxi) Load the engine with loading screw and set the balance difference to say 2 Kgs

(xxii) Open the burette filling cock, take sufficient diesel in burette and close the cock

(xxiii) Now turn the selector cock to engine and note down the time required for 20 ml fuel consumption

(xxiv) Note down the brake drum speed with tachometer

(xxv) Note down difference in two limbs of manometer

(xxvi) Note the following temperatures from digital thermometer

T1 = Inlet temp of cooling water to engine jacket

T2 = outlet temp of cooling water from engine jacket

T3 = Inlet temp of cooling water to gas calorimeter

T4 = outlet temp of cooling water from gas calorimeter

T5 = Inlet temp of exhaust gases to gases to gas calorimeter

T6 = outlet temp of exhaust gases from gas calorimeter

S.N	Type of reading	Set No.-1	Set No.-2	Set No.-3	Set No.-4	Set No.-5
1	Load W = (W1-W2)Kg					
2	Time for 20ml fuel consumption, t_f Sec					
3	Manometer difference hw cm.					
4	Time for 1 liter of calorimeter water t_c sec					
5	Time for 1 liter of engine jacket water					
6	Water inlet temp to engine jacket T1 ^oC					
7	Water outlet temp from engine jacket T2 ^oC					
8	Water inlet temp to calorimeter T3 ^oC					
9	Water outlet temp from calorimeter T4 ^oC					

10	Inlet temp of exhaust gases to calorimeter T5 ^oC					
11	Outlet temp of exhaust gases from gas calorimeter T6 ^oC					
12	Engine speed RPM					

(xxvii) Note down jacket cooling water and calorimeter water flow rates

(xxviii) Take 5 sets of reading for different load

Observation Table

Formula for calculations

(1)Brake power (BP)

$$BP = \frac{2\pi NT}{1000x60} KW$$

Where T= Torque = Force x distance

= (W1-W2)xradius of brake drum

= (W1-W2) x9.8x0.15 Nm (when W1 & W2 are in Kg)

N= Engine RPM

(2) Fuel consumption (F.C)

Let t_f = time required for 20 ml of fuel consumed by engine

$$\text{Fuel consumption} = \frac{20 \times 3600}{T_f \times 1000} x0.78 \text{ Kg/hr}$$

(3) Specific fuel consumption (SFC)

SFC = Fuel consumption in kg/BP/hr.

(4) Heat supplied by fuel (H_F)

HF = Fuel consumption x calorific value of fuel

= fuel consumption in kg x 42630 kJ/Kg

Where calorific value of fuel = 42630 KJ/Kg

(5) Friction power (F.P)

Plot the graph between F.C Vs BP for different sets of readings

Extend the line of graph backside till it cuts the X-axis

The power on negative scale at which FC is zero, is the friction power. The plot is known as willian's Line.

(6) Indicated power (IP)

IP= BP + FP Kw

(7) Heat equivalent to IP

H_{IP}= IPx3600 KJ/hv

= IP KJ/Sec.

(8) Mechanical efficiency (η_m)

$$\eta_m = \frac{BP}{IP} \times 100\%$$

(9) Brake thermal efficiency (η_{BT})

$$\eta_{BT} = \frac{\text{Heat equivalent to BP}}{\text{heat supplied by fuel}} \times 100\%$$

(10) Indicated thermal efficiency (η_{IT})

$$\eta_{IT} = \frac{\text{Heat equivalent to IP}}{\text{Heat supplied by fuel}} \times 100\%$$

$$= \frac{\text{IP in KJ/sec.}}{\text{Fuel supplied per sec x calorific value in KJ/Kg}}$$

(11) Air consumption (ma)

Air head across the orifice (Ha)

$$Ha = \frac{hw}{100}(1000\text{-}\rho a)$$

Where hw = reading on water manometer in cm

ρa = density of air

$$\rho a = \frac{P}{287\,(T+273)}$$

P = atmospheric pressure $N/m^2 = 10^5\ N/m^2$

T = absolute ambient temp in ^oK

Mass of air (ma)

$$= 0.62 \times 4.9 \times 10\text{-}4 \sqrt{2gHa \times 3600 \times \rho a}$$

Where Cd of orifice = 0.62

Area of orifice = $4.9 \times 10^{-4} m^2 = 0.000314\ m^2$

Orifice dia = 0.02m

(12) Air-fuel-ratio (AFR)

$$AFR = \frac{ma}{FC} = \frac{\text{mass of air consumed}}{\text{fuel consumption}}$$

(13) Heat balanced sheet

Credit side is heat supplied by fuel. Debit side consist of following parameters

Credit	Debit	%
Heat supplied by fuel = calorific value of fuel x mass of fuel x mass of fuel (kg)	(1)Heat equivalent to BP (2)Heat taken away water of engine jacket (3)Heat taken by water of gas calorimeter (4)unaccounted heat loss by radiation	 100%

(14) Heat equivalent to BP = BPx3600 KJ/hv

(15) Heat taken away by water = m x Cp(ΔT)of engine jacket (Hjw)

Where Cp = sp heat of water = 4.18 KJ/kg^oK

$\Delta t = T_2 - T_1$

(16) Determination of mass of air consumption

Let A = Area of orifice in m^2

d = dia of orifice in cm

hw = head of water in cm in manometer

cd = coefficient of discharge

ρ_a = density of air in kg/m^3 at atmospheric conditions

ρ_w = density of water in kg/m^3 = 1000 kg/m^3

Let H = head if air in meters

$$H \times \rho_a = \frac{h_w}{100} \times \rho_w$$

$$H = \frac{h_w \times \rho_w}{100 \quad \rho_a} = \frac{hw \times 100}{100 \quad \rho_a} = \frac{10h_w}{\rho_a} \text{ meters}$$

Velocity of air passing through the orifice is given by

$$Ca = \sqrt{2gH} \text{ m/sec} = \sqrt{2g. \frac{10h_w}{\rho_a}} \text{ m/sec}$$

Volume of air passing through the orifice

$$Va = cd \times A \times Ca$$
$$= cd \times A \sqrt{\frac{20ghw}{\rho_a}}$$
$$= 14cdA\sqrt{\frac{hw}{\rho_a}}$$

Mass of air passing through the orifice

$$Ma = Va. \rho_a$$
$$=14cdA\, \rho_a\sqrt{\frac{hw}{\rho_a}}$$
$$=14cdA\sqrt{\rho_a hw}$$

Where

$$A = \frac{\pi}{4} (d/100)$$

$$Ma = 0.066cd\, d^2 \sqrt{\rho a h w} \text{ kg/min}$$

Heat carried away by exhaust gases

From the heat balance of calorimeter

Heat given by exhaust gases

= heat taken by water of gas calorimeter

OR $m_{eg}\,cp_g$ (T5-T6) = $m_{wc}c_{pwc}$ (T4-T3)

Where M_{eg} = mass flow rate of exhaust gases

C_{peg} = speed of exhaust gases

M_{wc} = Mass flow rate of calorimeter water

C_{pwc} = specific heat of water =4.18 KJ/Kg^{o}K

Hence

$$= M_{eg}.C_{pg} = \frac{M_{wc.}C_{pwc}(T4\text{-}T3)}{(T5\text{-}T6)}$$

Hence heat carried away by exhaust gases

= $M_{eg}.C_{pg}$(T5-Ta)

Where Ta = Room temperature

Answer the following questions

(1) Define Mechanical efficiency of an engine.

____

____

(2) Define brake thermal efficiency of an engine.

____

____

(3) Define Indicated thermal efficiency of an engine.

____

____

(4) When the load on the engine will increase, whether the speed of engine will increase or decrease?

____

____

(5) When the load on the engine increases, how the constant speed is maintained?

____

____

(6) What is the percentage of total heat supplied by fuel is removed by cooling media in water jacket around cylinder.

____

____

(7) What is the percentage of total heat supplied by fuel is taken away by lubricant oil and heat lost by radiation.

____

____

(8)Volumetric efficiency of water cooled engine is higher than that of air cooled engine, why?

____

____

(9)Torque developed by the engine is maximum at maximum volumetric efficiency and maximum speed of the engine, why?

____

____

(10) Which type of governing is used in Diesel engines?

____

____

Experiment No.-8

Object: - To draw heat balance sheet for four stroke, four cylinder diesel engines.

Equipment:

(xiii) Engine :- Four stroke, four cylinder, vertical, water cooled, self governed diesel engine

(xiv) Rope brake dynamometer:- Rope brake dynamometer, spring balances and loading screw

(xv) Calibrated fuel burette for fuel consumption measurement

(xvi) Orifice meter, fitted to air inlet tank with water manometer for air intake measurement

(xvii) Multi-channel digital temperature indicator for temperature measurement at various points

(xviii) Exhaust gas calorimeter to measure heat carried away by exhaust gases.

Procedure:-

(xxix) Fill up sufficient diesel in diesel tank

(xxx) Check the level of lubricant oil in the sump by oil dip stick. It should be up to top edge of the flat

Portion provided over the dip stick

(xxxi) Fill up water in manometer up to half of manometer height

(xxxii) Start the water supply and see water is flowing through engine jacket, brake drum and exhaust

gas calorimeter

(xxxiii) Release the loading screws, so that there is no tension in the rope.

(xxxiv) Start the engine with the help of auto ignition key

(xxxv) Load the engine with loading screw and set the balance difference to say 2 Kgs

(xxxvi) Open the burette filling cock, take sufficient diesel in burette and close the cock

(xxxvii) Now turn the selector cock to engine and note down the time required for 20 ml fuel consumption

(xxxviii) Note down the brake drum speed with tachometer

(xxxix) Note down difference in two limbs of manometer

(xl) Note the following temperatures from digital thermometer

T1 = Inlet temp of cooling water to engine jacket

T2 = outlet temp of cooling water from engine jacket

T3 = Inlet temp of cooling water to gas calorimeter

T4 = outlet temp of cooling water from gas calorimeter

T5 = Inlet temp of exhaust gases to gases to gas calorimeter

T6 = outlet temp of exhaust gases from gas calorimeter

S.N	Type of reading	Set No.-1	Set No.-2	Set No.-3	Set No.-4	Set No.-5
1	Load W = (W1-W2)Kg					
2	Time for 20ml fuel consumption, t_f Sec					
3	Manometer difference hw cm.					
4	Time for 1 liter of calorimeter water t_c sec					
5	Time for 1 liter of engine jacket water					
6	Water inlet temp to engine jacket T1 ^oC					
7	Water outlet temp from engine jacket T2 ^oC					
8	Water inlet temp to calorimeter T3 ^oC					
9	Water outlet temp from calorimeter T4 ^oC					
10	Inlet temp of exhaust gases to calorimeter T5 ^oC					
11	Outlet temp of exhaust gases from					

	gas calorimeter T6 ^oC					
12	Engine speed RPM					

(xli) Note down jacket cooling water and calorimeter water flow rates

(xlii) Take 5 sets of reading for different load

Observation Table

Formula for calculations

(1)Brake power (BP)

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

Where T= Torque = Force x distance

= (W1-W2)xradius of brake drum

= (W1-W2) x9.8x0.15 Nm (when W1 & W2 are in Kg)

N= Engine RPM

(2) Fuel consumption (F.C)

Let t_f = time required for 20 ml of fuel consumed by engine

$$\text{Fuel consumption} = \frac{20 \times 3600}{T_f \times 1000} \times 0.78 \text{ Kg/hr}$$

(3) Specific fuel consumption (SFC)

SFC = Fuel consumption in kg/BP/hr.

(4) Heat supplied by fuel (H_F)

HF = Fuel consumption x calorific value of fuel

= fuel consumption in kg x 42630 kJ/Kg

Where calorific value of fuel = 42630 KJ/Kg

(5) Friction power (F.P)

Plot the graph between F.C Vs BP for different sets of readings

Extend the line of graph backside till it cuts the X-axis

The power on negative scale at which FC is zero, is the friction power. The plot is known as willian's Line.

(6) Indicated power (IP)

IP= BP + FP Kw

(7) Heat equivalent to IP

H_{IP}= IPx3600 KJ/hv

= IP KJ/Sec.

(8) Mechanical efficiency (η_m)

$$\eta_m = \frac{BP}{IP} \times 100\%$$

(9) Brake thermal efficiency (η_{BT})

$$\eta_{BT} = \frac{\text{Heat equivalent to BP}}{\text{heat supplied by fuel}} \times 100\%$$

(10) Indicated thermal efficiency (η_{IT})

$$\eta_{IT} = \frac{\text{Heat equivalent to IP}}{\text{Heat supplied by fuel}} \times 100\%$$

$$= \frac{\text{IP in KJ/sec.}}{\text{Fuel supplied per sec x calorific value in KJ/Kg}}$$

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hw = head of water in cm in manometer

cd = coefficient of discharge

ρ_a = density of air in kg/m^3 at atmospheric conditions

ρ_w = density of water in kg/m^3 = 1000 kg/m^3

Let H = head if air in meters

$$H \times \rho_a = \frac{h_w}{100} \times \rho_w$$

$$H = \frac{h_w \times \rho_w}{100\ \rho_a} = \frac{hw \times 1000}{100\ \rho_a} = \frac{10h_w}{\rho_a} \text{ meters}$$

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Mass of air passing through the orifice

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$$=14cdA\sqrt{\rho_a hw}$$

Where

$$A = \frac{\Pi}{4} (d/100)$$

$$Ma = 0.066cd\ d^2 \sqrt{\rho a hw} \text{ kg/min}$$

Heat carried away by exhaust gases

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Heat given by exhaust gases

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OR $m_{eg}\, cp_g\, (T5-T6) = m_{wc} c_{pwc}\, (T4-T3)$

Where M_{eg} = mass flow rate of exhaust gases

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M_{wc} = Mass flow rate of calorimeter water

C_{pwc} = specific heat of water =4.18 KJ/Kg^{o}K

Hence

$$= M_{eg}.C_{pg} = \frac{M_{wc}.C_{pwc}(T4-T3)}{(T5-T6)}$$

Hence heat carried away by exhaust gases

$= M_{eg}.C_{pg}(T5-Ta)$

Where Ta = Room temperature

Experiment No. 9

Object: - To study open cycle constant pressure combustion gas turbine with inter cooler, regenerator and reheater

Equipment:-

(i) Compressor
(ii) Intercooler
(iii) Regenerator
(iv) Combustion chamber
(v) Gas Tribune
(vi) Reheater
(vii) Electric generator

Working Principle

(i) **LP Compressor**: - In open cycle gas turbine cycle air in taken from atmosphere. It in compressed in low pressure compressor adiabatically

(ii) **Inter Cooler: -** After LP sage of compressor, air in passed through inter cooler, where air in cooled by means of water at constant pressure. Air cooled in inter cooler to decrease the work done required to compress the air in HP stage of compressor.

(iii) **HP Compressor :-** Air in finally compressed in HP stage of compressor adiabatically

(iv) **Regenerator:** - Regenerator in used to reheat the compressed air by means of exhaust gases from gas turbine.

(v) **Combustion Chamber: -** In combustion chamber heat in added to air at constant pressure by combustion of fuel.

(vi) **HP Gas Turbine: -** Gases at high pressure and high temperature are expanded in HP stage of gas turbine. Expansion take place adiabatically.

(vii) **Reheater:** - Gases after high pressure stage of gas turbine are reheated in reheater to increase their temperature and constant pressure.

(viii) **LP Gas turbine: -** After reheater, gases are further expanded in low pressure stage of gas turbine.

(ix) **Generator: -** Electric generator in coupled with gas turbine to generate electric power.

T-S diagram for open cycle gas turbine with inter cooler, regenerator and reheater in shown in Fig-II.

Process:-

1-2 - Adiabatic compression of air in LP stage of air compressor.

1-2 - Actual compression of air in LP stage of compressor

2-3 - Cooling of air in inter cooler at constant pressure.

3-4 - Adiabatic compression of air in HP stage of compressor.

3-4 - Actual compression of air in HP stage of compressor/

4-5 - Heating of air in regenerator by exhaust gases.

5-6 - Heat addition to air in combustion chamber at constant pressure.

6-7 - Adiabatic expansion of gases in HP stage of gas turbine.

6-7 - Actual expansion of gases in HP stage of gas turbine.

7-8 - Reheating of gases in reheater at constant pressure.

8-9 - Adiabatic expansion of gases in LP stage of gas turbine.

8-9 - Actual expansion of gases in LP gas turbine.

Experiment No. 10

Object: - To study centrifugal compressor and differences between centrifugal and Axial compressors.

Equipment: - Centrifugal compressor and Axial compressors.

Construction: - Centrifugal compressor is consisting of following main part.

1. **Vane or Blades**

The vanes could be of three types

(a) Backward curved vanes.
(b) Radial curved vanes.
(c) Forward curved blades

Fig II – show the relative performance of these vanes. Centrifugal effects on the curved blades create bending moment and produce increased stresses, when reduce the maximum speed at which the impeller can run.

Normally backwards /vanes with β_2 between 20-25° are employed except in cases, where high head is major consideration

Sometimes compromise is made between the low energy transfer (Backward curved vanes) and high outlet velocity (forward curved vanes) by using radial vanes.

Advantage of radial vanes:-

(a) Can be manufactured easily
(b) Lower unit blade stress
(c) Free from complex bending stresses
(d) Equal energy conversion in impeller and diffuser, giving high pressure ratio with good efficiency.
In view of the above reasons, the impeller with radial vanes has been the logic choice of designers.

2. **Impeller: -** The impeller is a disc filled with radial vanes. The impeller is generally forged or die cast of low silicon aluminum alloy. The impeller may be single eyed or double sided (having eye on either side of compressor, so that air is drawn in on both sides). The advantage of double sided impeller is subjected to approximately equal forces in an axial direction.

3. **Casing: -** The casing surrounds the rotating impeller.

4. **Diffuser: -** The diffuser is housed in a radial portion of the casing. Diffuser may have vanes also, and in that case it is called vaned diffuser.

Working Principle

Air enters through the eye of impeller with a low velocity C_1 and atmospheric pressure P_1. Depending upon the centrifugal action of the impeller, the air moves radial outward and during its movement it is guided by impeller vanes. The impeller transfers the energy of the drive to the air causing a rise both in static pressure (P_2) temperature and increase in velocity (C_2)

The air now enters the diverging passage called diffuser, where K E of air is converted in to pressure energy with the result that there is further rise in static pressure. Let the increased pressure and reduced velocity be P3 and C3

For the radial vane impeller, the diffuser contributes about one half of the overall static pressure rise.

In the vane diffuser, the vanes are used to remove the whirl of the fluid at a higher rate than this possible by a simple increase in radius, thereby reducing length of flow path and diameter. The vane diffuser is advantageous when overall size is important as in the case of air craft engines.

The number of diffuser vanes has a direct bearing on the size and efficiency of the diffuser. When the number of diffuser passages is less than number of impeller passages, a more uniform total flow results.

Fig- III shows a typical vaned diffuser. There is clearance between the impeller and vane leading edges amounting to about 10 to 20% of the diameter for the compressors. This space constitutes a vane less diffuser and its function are.

(1) To smooth out velocity variation between the impeller tip and vanes.
(2) To reduce circumferential pressure gradient at impeller tip.
(3) To reduce MECH number at entry to the vanes.

The changes in pressure and velocity of air passing through the impeller and diffuser are shown in FIG IV

Axial flow Compressor

In an axial flow compressor, the flow proceeds throughout the compressor in a direction parallel to the axis of the machine.

Construction:-

An Axial flow compressor consist of adjacent rows of rotor (moving blades) and stator (fixed) blades. The rotor blades are mounted on the rotating drum and stator blades are fixed to the casing of stator. One stage of the machine comprises a row of rotor blades and followed by a row of stator blades.

For efficient operation, the blades are of aerofoil section based on aerodynamic theory. The blades are so designed that wasteful losses due to shock and turbulence are prevented and blades are free from stalling troubles (the blades are said to be stalled when air stream fails to follow the blade contour)

The annular area is reduced from inlet to outlet of the compressor. Due to this pressure and absolute Velocity of air increases.

Fixed blades (i) convert part of the KE of air in to pressure energy. This conversion is achieved by diffusion process carried out in diverging blade passage. (ii) Guide blades redirect the fluid flow so that entry to the next stage is without shock.

Working Principle:-

Work in put to the rotor shaft is transferred by moving blades to the air. The blades are so arranged that the space between the blades form diffuser passages, hence the Velocity of air relative to the blades is decreased, as the air passes through them and there is rise in pressure. The air is then further diffused in the stator blades, which are also arranged, to form diffuser passes. Stator blades guide the air, so that it can be allowed to pass a second row of moving rotor blades. Five to fourteen stages can be used.

Comparison of centrifugal and axial flow compressors.

Sr. No	Aspect	Centrifugal Compressor	Axial flow Compressor
1.	Type of flow	Radial	Axial
2.	Pressure ratio per stage	About 4.5:1	1.2:1
3.	Isothermal Efficiency	80 to 82%	86 to 88%
4.	Frontal Area	Larger	Smaller
5.	Flexibility of operation	More	Less
6.	Part load performance	Better	Poor
7.	Effect of deposit formation on the surface of impeller	Performance not adversely effected	Performance adversely effected
8.	Starting torque required	Low	High
9.	Delivery pressure possible	Up to 400 bar	Up to 20 bar
10.	Application	Refrigerators air-conditioning plant super charging, gas pumping	Jet engines, gas turbines units.