EFFECT OF BOWL GEOMETRY OF PISTON ON SFC FOR SINGLE CYLINDER DIESEL ENGINE

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ABSTRACT

In automobile sector required to transmit more and more power with maximum fuel consumption with higher efficiency. Piston is the part that transmits the power with the help of connecting rod. a piston is an important component of reciprocating engine helps to convert energy obtained by the combustion of fuel in cylinder into useful mechanical power. The clearance between liner and piston is 100 micron. Piston is reciprocated in cylinder wall, so that linear motion is converted into rotary with the help of piston.

Piston is made up of Al material with sustained high temperature. Heat are dissipated some critical area to be considered i.e. piston bowl, piston ring, skirt length etc. There are two method manufacture of piston mainly they are powder metallurgy and permanent die casting. The size as well as the distribution of these particles depend on the solidification rate, the faster the rate, smaller the size and finer the distribution. At higher transformation temperature and with lowest cooling rate, coarse formed. The solidification process from the melt phase the atom moves randomly in melt depend upon cooling .crystal nuclei from the melt .the nuclei flow in liquid solidification temperature to give polycrystalline. Aim of project design, manufacture test different bowl geometry's which would improve the exhaust emission and fuel economy of diesel engine.

Keyword: *- SFC: Specific fuel consumption, FEA: finite element analysis, MP : mass of the piston (Kg) , V :volume of the piston (mm3), TH : thickness of piston head (mm) .*

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1. INTRODUCTION

A piston is an important component of reciprocating engine helps to convert energy obtained by the combustion of fuel in cylinder into useful mechanical power. It is like a disc which reciprocates within a cylinder. It is either moved by the fluid or it moves the fluid which enters the cylinder. A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. Pistons are cast from aluminum alloys. For better strength and fatigue life, some racing pistons may be forged instead. Early pistons were of cast iron, but there were obvious benefits for engine balancing if a lighter alloy could be used.

In order to increase the efficiency of operation and better functionality, the piston material should satisfy the following requirements:

- Light weight
- Good wear resistance
- Good thermal conductivity
- High strength to weight ratio
- Free from rust
- Easy to cast
- Easy to machine
- Non magnetic
- Non toxic

Piston should be designed and fabricated with such features to satisfy the above requirements.

A recessed area located around the circumference of the piston issued to retain piston ring. These rings are expandable and split in type. They are used to provide a seal between piston and cylinder wall. Three such rings employed in a diesel engine are

1. Compression ring
2. Wiper or second compression ring
3. Oil ring

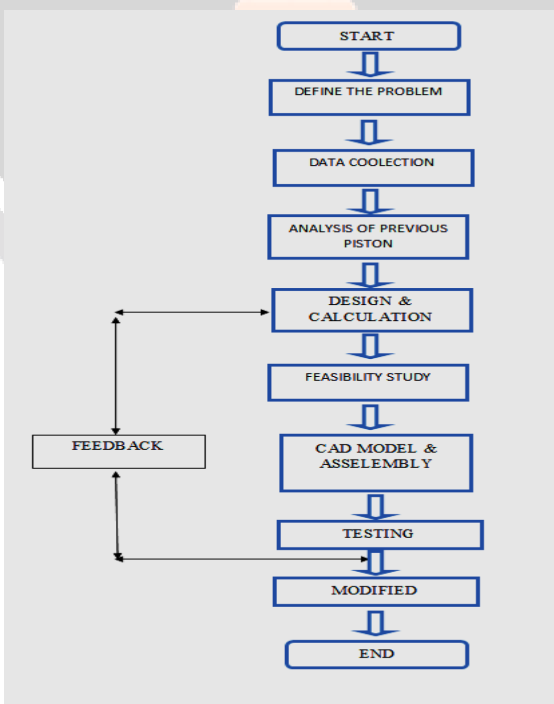
Objective

Objective 1: The objective of the development is to improve the power output from same weight of the engine i.e. 10-15% more power at the speed range 1500 to 2600 rpm.

Objective 2: To improve in fuel economy to a level of 220gm/kWhr @ 1500-2200rpm and 265gm/kWhr and less @ 2400- 2600 rpm. Other engine parameter and performance as per current engine .The max Oil consumption level should as per customer specification.

Objective 3: As additional project scope as feasibility study of the engine to find suitable solution for Genset application meeting CPCB-2 emission norms. The feasibility will cover possibities of max rating @1500 rpm and suitable hardware to meet required level of emission by means of engine hardware improvement or with external solution like EGR system

2. METHODOLOGY



3. CALCULATION

The piston is a disc which reciprocates within a cylinder. It is either moved by the fluid or it moves the fluid which enters the cylinder. The main function of the piston of an internal combustion engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod. The piston

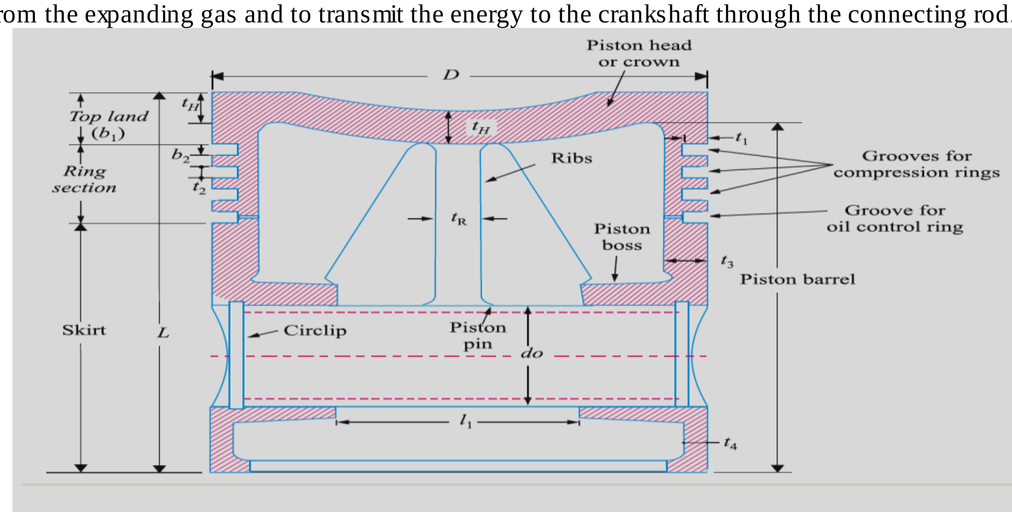


fig1:-Piston for IC engine

also disperse a large amount of heat from the combustion chamber to the cylinder walls.

The piston of internal combustion engines are usually of trunk type as shown in Fig.1 such pistons are open at one end and consists of the following parts:

1. Head or crown. The piston head or crown may be flat, convex or concave depending upon the design of combustion chamber. It withstands the pressure of gas in the cylinder.

2. Piston rings. The piston rings are used to seal the cylinder in order to prevent leakage of the gas past the piston.

3. Skirt. The skirt acts as a bearing for the side thrust of the connecting rod on the walls of cylinder.

4. Piston pin. It is also called Piston pin or wrist pin**.** It is used to connect the piston to the connecting rod.

Design Considerations for a Piston

In designing a piston for I.C. engine, the following points should be taken into consideration:

1. It should have enormous strength to withstand the high gas pressure and inertia forces.

2. It should have minimum mass to minimize the inertia forces.

3. It should form an effective gas and oil sealing of the cylinder.

4. It should provide sufficient bearing area to prevent undue wear.

5. It should disperse the heat of combustion quickly to the cylinder walls.

6. It should have high speed reciprocation without noise.

7. It should be of sufficient rigid construction to withstand thermal and mechanical distortion.

8. It should have sufficient support for the piston pin.

Analytical Design

mp = mass of the piston (Kg)

V = volume of the piston (mm3)

th = thickness of piston head (mm)

D = cylinder bore (mm)

pmax = maximum gas pressure or explosion pressure (MPa)

σt = allowable tensile strength (MPa)

σut = ultimate tensile strength (MPa)

F.O.S = Factor of Safety = 2.25

k = thermal conductivity =174.15(W/m C)

Tc = temperature at the Centre of the piston head (^{0}C)

Te = temperature at the edge of the piston head (^{0}C)

HCV = Higher Calorific Value of fuel (KJ/Kg) = 47000 KJ/Kg (petrol)

BP = brake power of the engine per cylinder (KW) =4KW.

Value obtained experimentally considering the following conditions.

N=1500rpm, Compression Ratio (r_c) =16.5, fully loaded condition.

m = mass of fuel used per brake power per second (Kg/KW s) =0.25/3600 (Kg/KW s).

Value obtained experimentally considering the following conditions:

B.P=4KW, CV=47000Kj/kg (petrol), N=1500, fully loaded condition.

C = ratio of heat absorbed by the piston to the total heat developed in the cylinder = 5% or 0.05

b = radial thickness of ring (mm)

Pw = allowable radial pressure on cylinder wall (N/mm^2) = 0.042 MPa

h2 = axial thickness of piston ring (mm)

t1 = thickness of piston barrel at the top end (mm)

t2 = thickness of piston barrel at the open end (mm)

do = outer diameter of piston pin (mm)

Calculation of Dimensions Of Piston For Analysis*:*

Thickness of Piston Head (tH) : The piston thickness of piston head calculated using the following Grashoff's formula,

$t_H = D \sqrt{(3p)/(16\sigma_t)}$ in mm

P= maximum pressure in N/mm²

D= cylinder bore/outside diameter of the piston in mm

σt=permissible tensile stress for the material of the piston.

Heat Flow through the Piston Head (H)

The heat flow through the piston head is calculated using the formula

$H = 12.56 * t_H * k * (Tc-Te)$ KJ/sec

Where

k=thermal conductivity of material which is 174.15W/mC

Tc = temperature at center of piston head in °C.

Te = temperature at edges of piston head in °C.

(Tc-Te)=75°C for Aluminum alloy.

On the basis of the heat dissipation, the thickness of the piston head is given by:

H = [C x HCV x m x BP]

Radial Thickness of Ring (t1):

$t_1 = D\sqrt{3p_w/\sigma_t}$

Where,

D = cylinder bore in mm

Pw= pressure of fuel on cylinder wall in N/mm². Its value is limited from 0.025N/mm² to 0.042N/mm².

Axial Thickness of Ring (t2)

The thickness of the rings may be taken as

$t_2 = 0.7t_1$ to t_1

Number of rings (n_r)

Minimum axial thickness (t_2)

$t_2 = D/(10*n_r)$

n_r = 3 rings.

Width of the top land (b1)

The width of the top land varies from

$b_1 = t_H$ to $1.2\ t_H$

Width of other lands (b2):

Width of other ring lands varies from

$b_2 = 0.75t_2$ to t_2

Maximum Thickness of Barrel at the top end (t3):

Radial depth of the piston ring grooves (b) is about 0.4 mm more than radial thickness of the piston rings(t_1),therefore

$b = 0.4 + t_1 =$

$t_3 = 0.03*D + b + 4.5$ mm

Thickness of piston barrel at the open end (t_4):

$t_4 = 0.25\ t_1$ to $0.35\ t_1$)

Piston pin diameter (d_o):

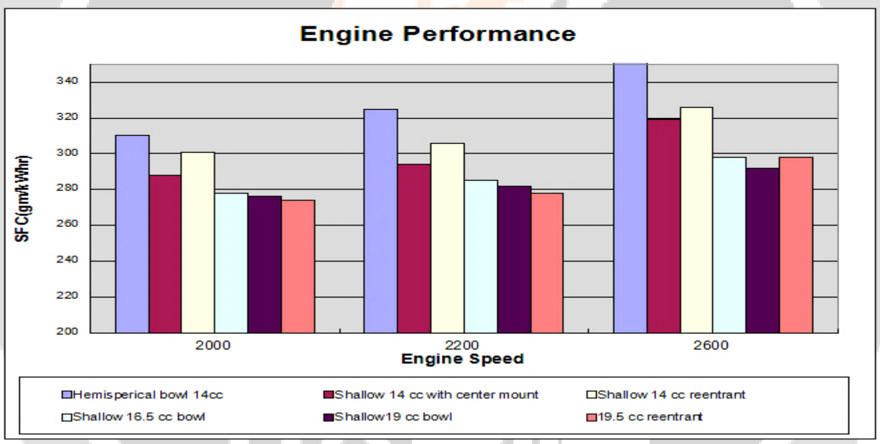
d_o=0.03D

Fig2-Considering the above calculations, the model has been designed in CATIA.

4. RESULT

1) Specific fuel consumption with different bowl shape at different engine RPM.

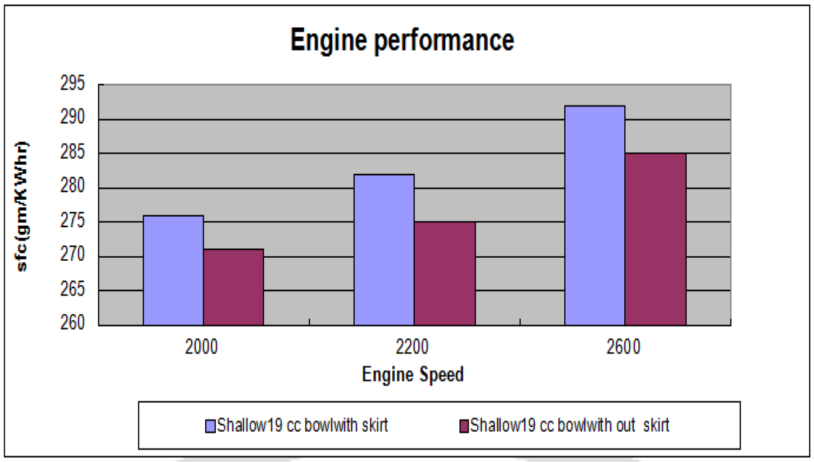
bowl shapes	2000	2200	2600
Hemispherical bowl 14cc	310	325	356
Shallow 14 cc with center mount	288	294	319
Shallow 14 cc reentrant	301	306	326
Shallow 16.5 cc bowl	278	285	298
Shallow19 cc bowl	276	282	292
19.5 cc reentrant	274	278	298



Results: Increased in bowl volume is giving good improvement in SFC. 19 cc is found to be optimized bowl volume without any cold starting issue. Reentrant shape is giving better SFC at lower engine speed and shallow bowl at higher speed. This is due to turbulence produced at higher speed due to re-entrant shape.

2) Specific fuel consumption with different 19 cc shallow bowl with different skirt at RPM.

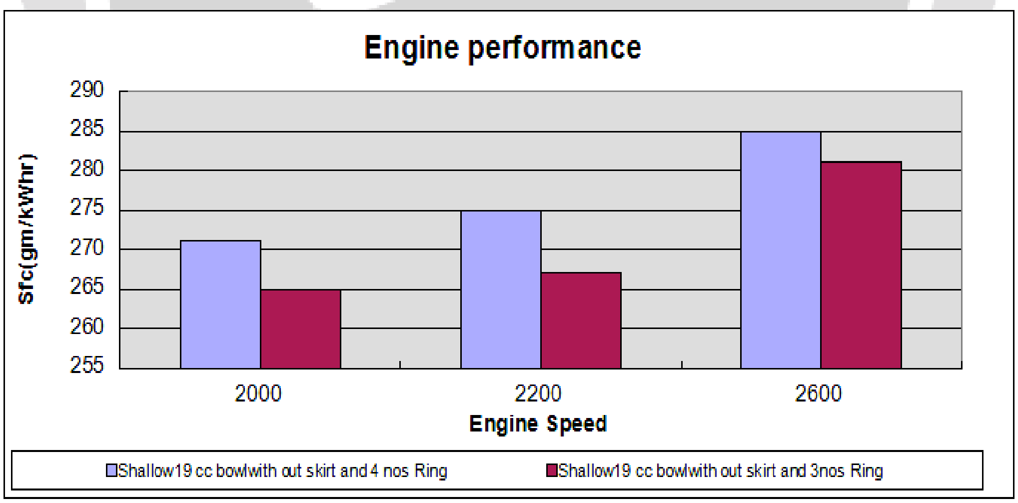
Bowl shapes	2000	2200	2600
Shallow19 cc bowl with skirt	276	282	292
Shallow19 cc bowl without skirt	271	275	285



Results: Lower skirt of the piston lower the viscous friction loss hence improves in SFC. Engine with lower skirt piston run for endurance for any wear in piston skirt, it is found that with CH4 oil grade no abnormal wear found on the skirt area both thrust and anti-thrust side.

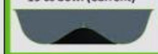
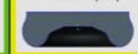
3) Specific fuel consumption with different 19 cc shallow bowl numbers of rings at different engine RPM.

bowl shapes	2000	2200	2600
Shallow19 cc bowl without skirt and 4 no's Ring	271	275	285
Shallow19 cc bowl without skirt and 3nos Ring	265	267	281



Results: Less no ring and ring tension also lower the viscous friction loss hence improves in SFC. Engine with lower less piston rings run for endurance for any wear in piston skirt, it is found less no ring improve liner life.

Piston Bow Optimization

	(Old) 		19 cc bowl (Current) 	19 cc bowl (New) 	17.5 cc bowl (New) 
Bowl Volume cc	16	15	19	19	17.5
Compression Ratio	19cc	20	16.5	16.5	17
Cold Starting	7	9	5	3	3
Smoke starting	Very High	low	low	low	
Smoke at full Load	Very High	Yes	No	No	TBD
SFC@2200 Gm/kwhr	>320	>300	265	282	TBD
NOX	NA	NA	NA	NA	TBD

5. CONCLUSION

Compared to the traditional design method of the piston ,an experimental method is lower in cost of development as well lead time .Some basic mathematical calculation of piston design in structural and combustion would sufficient to optimize the design. Design and development of piston also initiate to design some other components e.g. Camshaft, Injector and pump for proper compatible and Optimization. In the subject development, it is found proper calculation of piston bowl volume, compression ratio, and cam valve timing, ring number, ring tension, skirt area etc. are very important to improve the specific fuel consumption and load capability.

As the engine operate on wide speed range from 1800 rpm to 2600rpm, hence swirl at high need to be properly designed otherwise will lead to thermal losses. Hence shallow and lower re-entrant shape is suitable for engine.3 no's ring is sufficient for the design as compression ratio lowed compared to earlier design hence lower pick cylinder pressure. As this type of piston does not have offset hence thrust load is lower which call for lower skirt length. Cam shaft, Injector and Pump also optimized to match the fuel injection match with Bowl design, injection jet velocity and timing.

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