Thermal Analysis of Piston of IC engine

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ABSTRACT

Piston is a reciprocating part of engine which converts thermal energy into mechanical energy. There is thermo-mechanical load on the Piston. There is fatigue failure due to cyclic thermal and mechanical loading .To increase the life of the piston ,there has been more research going on in modifying the design of the piston ,changing the material and also changing the method of the manufacturing. In this paper thermal stress distribution is shown for the simple piston and reduced skirt length piston. by changing the geometry of the piston and it is suggested that which piston is better for same thermal load. Steady state thermal analysis of the Piston have been done in ANSYS 14.5.

KEYWORDS

Thermal stress, ANSYS 14.5, Heat flux, Thermal analysis.

1.INTRODUCTION

The piston is reciprocating part of the engine which undergo thermo-mechanical loading.In engine combustion of the fuel takes place due to which lot of amount of heat is liberated which leads to increase in the temperature rise and high pressure is also produced which falls on the piston.The temperature of the piston may lie within the range of 300-600 k and pressure increased value upto 15 MPa.So the requirement for the design of the piston is its strength so that it can withstand maximum pressure and high temperature resistant material so that it can tolerate maximum temperatures, and thermal stresses get minimized.in addition to the strength and temperature resistant of the material, it should be light weight.piston is connected to the connecting rod ,piston reciprocating motion is transferred to the crankshaft through connecting rod.light weight reduces the inertial force to start the motion.it decreases fuel consumption and increases its efficiency. The material of the piston should be chemically stable and should have low thermal expansibility.[2]

The piston undergoes various changes with the passage of the time according to the requirement and for improving it performance. For example in case of the diesel engine ,there is high temperature of the piston so its material should be capable to tolerate more temperature. Usually bowl shape on the crown surface of the piston is preferred in diesel engine ,in addition to reducing the inertial forces it also ensures mixing of the air and fuel.

Now a days ,there is advancement in the material by improving the properties such

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as stiffness, temperature resistant, lightness and chemically stable. Not whole piston can be made of ceramic material because it is costly so coating is suggested over the crown surface of the piston because of the above properties. It not only reduces thermal stresses but also minimize heat rejection from the engine.[4]

Its advantage is that it reduces the exhaust gas temperature and minimize emissions also by complete combustion of the unburned hydrocarbons. This is known as TBC(thermal barrier coating).This also reduces the fuel consumption.[10]

it reduces heat flux into the piston hence protecting the material of the piston.

The idea of changing the piston geometry is to decrease the mass of the piston and increasing the rotary speed of the engine.Changing the piston geometry by reducing the piston skirt length. It was done without the change of the piston material. All changes were done to improve useful efficiency.

2.GOVERNING EQUATION

By the burning of the fuel lot of amount of heat generated which falls on the different-different part of the engine .different part of the engine undergo different temperature and according to that heat transfer takes place.so heat transfer takes place due to conduction, convection and radiation .Mainly convection phenomena is considered for the heat transfer phenomena .

$$Q = h\,A\,\Delta T$$

Q is the amount of the heat to be transferred

h is the heat transfer coefficient

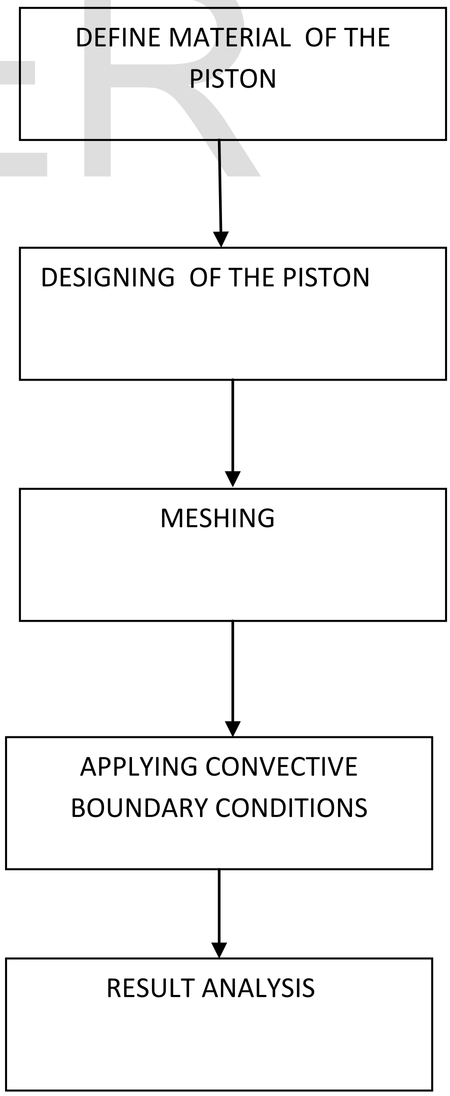
A is the area for the heat transfer

ΔT is the temperature difference between the surface temperature of the piston and the ambient temperature .

Different surfaces of the piston undergoes different thermal load .the crown surface undergoes high temperature variation . Temperature variation along with the piston crown surface is observed.

3. METHODOLOGY

For the steady state thermal analysis of the piston following steps are executed



Numerical approach has been used designing and simulating the model .ANSYS 14.5 has been used to carry out this approach .Parameters for the designing of the piston are evaluated on basis of the strength and amount of the heat transfer through the surfaces of the piston.so every part of the piston is evaluated on the basis of these two factors. designing of the piston has been done with the following dimensions in the design modeller of the steady state thermal of the ANSYS 14.5. mass of the piston is 4.6068kg and volume 5.8685e-004 m³.

3.1 MODELLING OF THE PISTON

Dimensions of the spark ignition engine piston are as follows:-

Piston part	Dimension (mm)
Length of the piston	152
Cylindrical bore/outside dia. Of the piston	140
Thickness of the piston head	9.036
Radial thickness of the piston ring	5.24
Axial thickness of ring	5
Width of the top land	10
Width of the other ring land	4

Table 3.1

DIFFERENT GEOMETRY OF THE PISTON

a.simple geometry piston

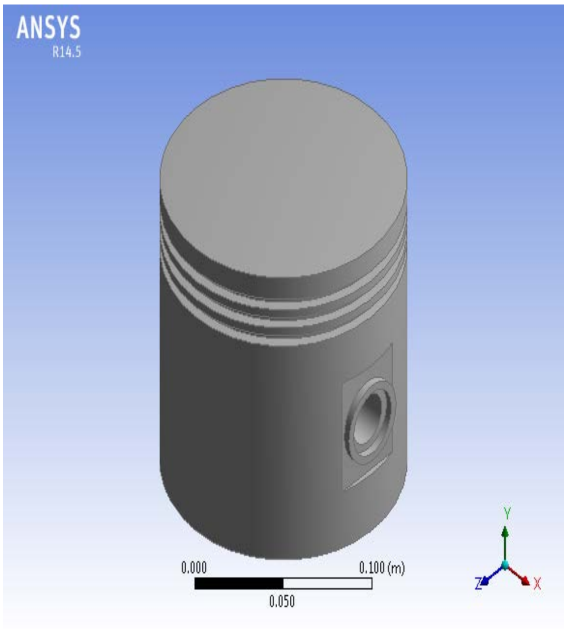


Fig.1

b.Reduced skirt length piston

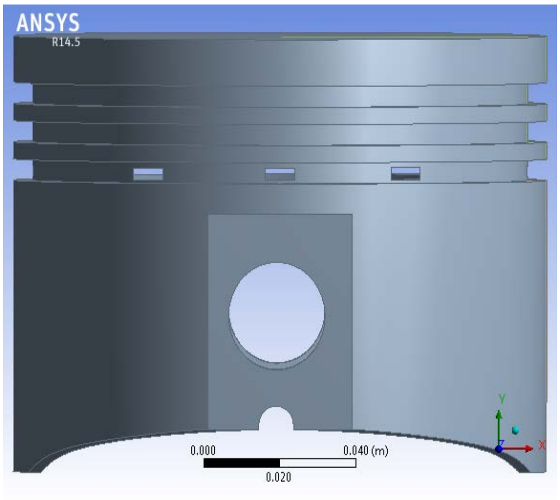


Fig.2

3.2 MESHING OF THE MODELS

Meshing of the model is done by using triangular nodes.meshing of the various

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shapes have been done the no of the nodes, elements and the mass have been shown in the table.

	SIMPLE SHAPE PISTON	REDUCED SKIRT LENGTH OF PISTON
MASS	4.6068 kg	3.3705 kg
ELEMENT	6563	61481
NODES	12964	35753

Table 3.2

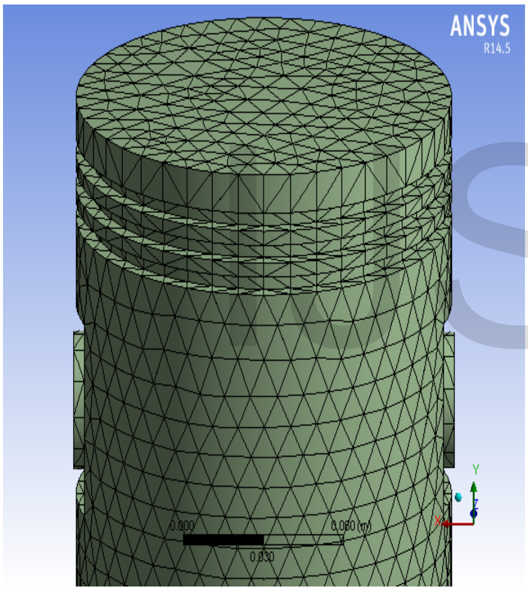

Fig.3

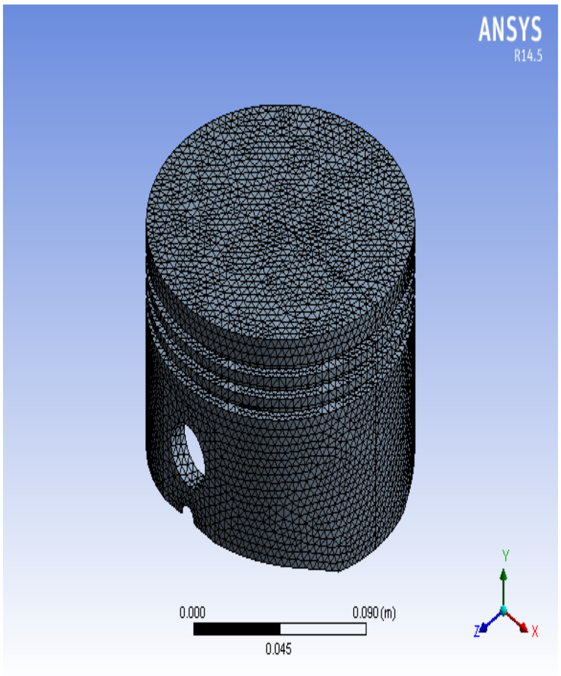

Fig.4

3.3 BOUNDARY CONDITIONS FOR SIMULATION

Piston part are undergo convective heat transfer .from the list it is evident that the crown surface of the piston undergo highly convective condition and ring grooves also undergo highly convective heat transfer condition but the temperature difference is low .all the models undergo same simulating conditions.for simulating these models heat transfer coefficient and surface temperature of the piston are listed below

Piston part	Temperature(k)	Heat transfer coefficient(w/m^2 k)
PC	961.02	2376.5
PH	768.82	80
1^{st} GUP	387.9	4000
1^{st} GMP	961.02	0

1st GLP	387.9	4000
Ring land 1	511.26	792.16
2nd GUP	383.05	3500
2nd GMP	961.2	0
2nd GLP	383.05	3500
Ring land 2	530.48	792.16
3rd GUP	378.86	3500
3rd GMP	961.02	0
3rd GLP	378.86	3500
OSP	792.16	348
ISP	353	80

Table 3.3.1

GUP groove upper part, GMP groove medium part, GLP groove lower part, OSP outside surface of piston, ISP inside surface of piston,PC piston crown,PH piston head.

3.4 ANALYSIS OF THE RESULT

The convective heat transfer phenomena depends on the three factors the heat transfer coefficient of the medium in which heat transfer is taking place , surface area for the heat transfer to take place and temperature difference between the surrounding and surface temperature of the part of the piston.the requirement condition is to maximize the heat transfer for the safety of the material otherwise because of the high temperature material will get melt.

3.4.1 TEMPERATURE VARIATION OVER THE CROWN SURFACE OF THE PISTON

3.4.1.1 Temperature variation over the crown surface of the simple piston

It has been evident from the fig.2 that the temperature is maximum at the centre of the crown surface of the piston and minimum in the piston skirt length part

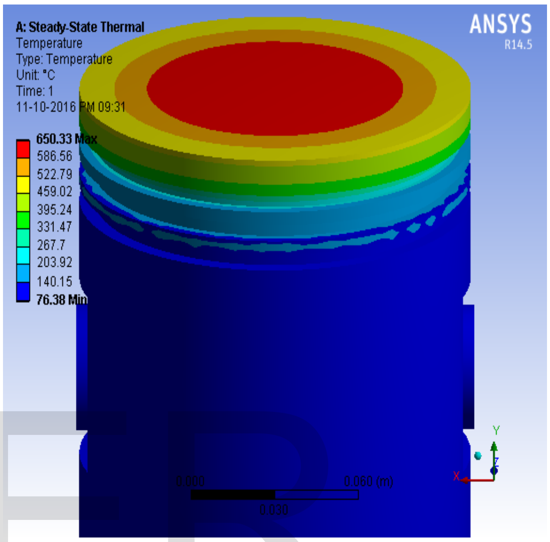

Fig .5

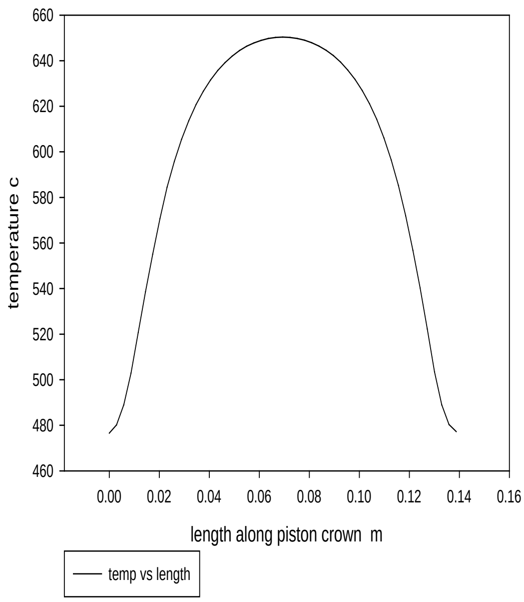

fig.6

3.4.1.2 temperature variation over the crown surface of the reduced skirt length piston

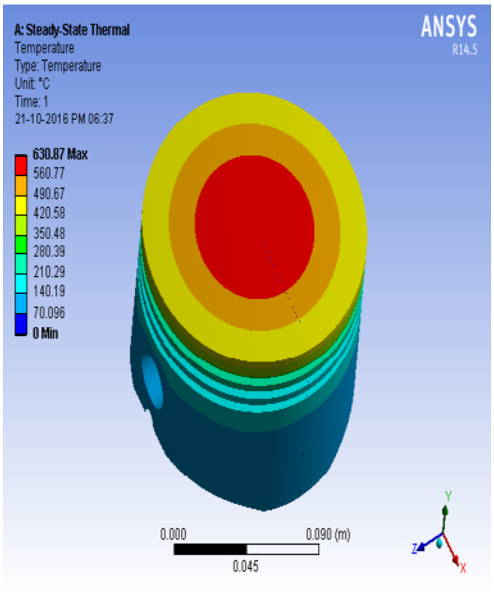

Fig.7

temperature variation over piston crown surface of reduced skirt length piston

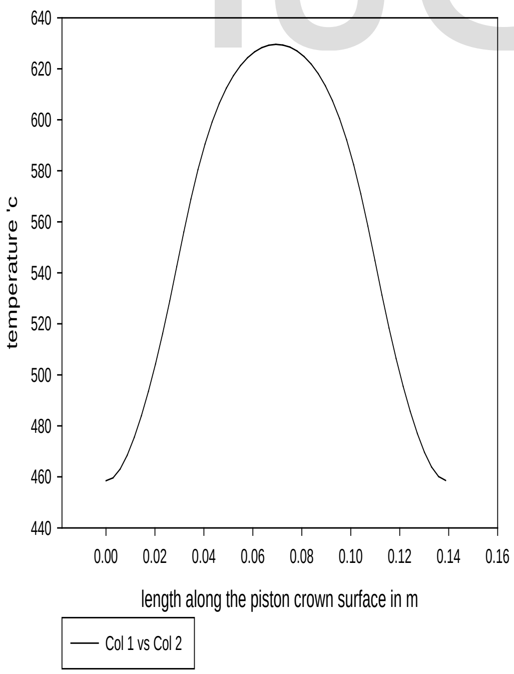

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Fig.8

3.4.2 TOTAL HEAT FLUX VARIATION OVER THE SURFACE OF THE PISTON CROWN

Heat flux actually represents the amount of the heat transfer by the surface according the heat transfer coefficient condition, temperature condition and surface area

3.4.2.1 total heat flux variation over surface of the simple piston

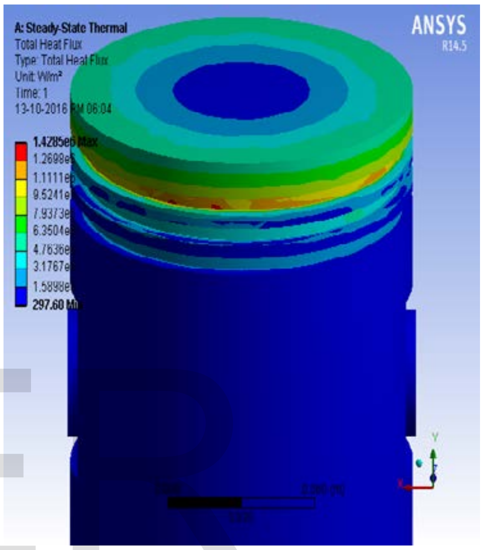

Fig .9

heat flux variation along with the length of the crown surface of the piston

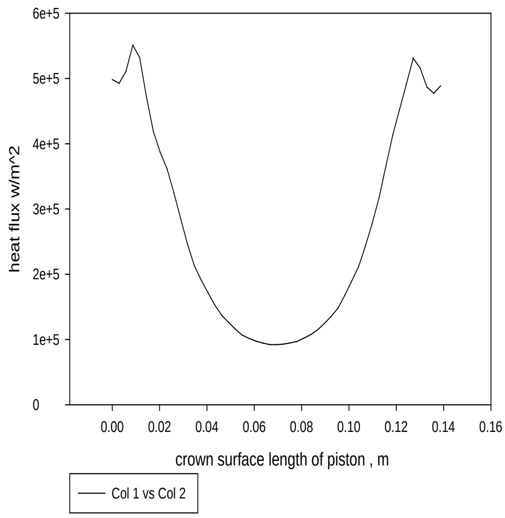

Fig.10

3.4.2.1 Total heat flux variation over the reduced skirt length piston

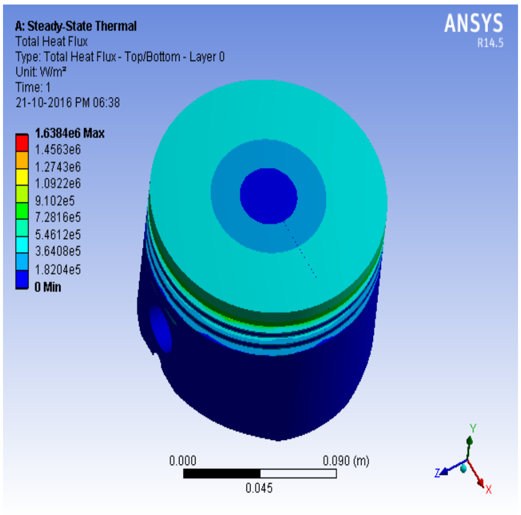

Fig.11

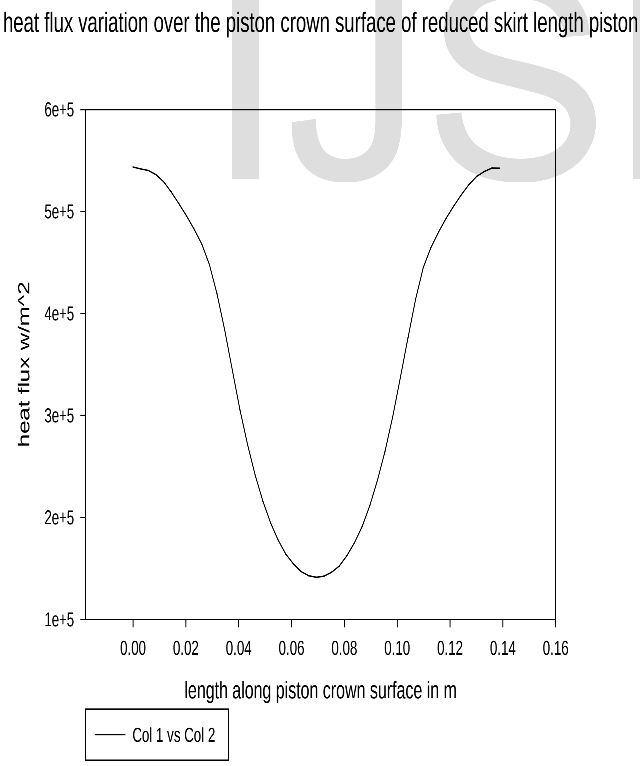

Fig.12

4.CONCLUSION

Thermal analysis shows the thermal load on different areas of the piston .it helps in predicting the critical areas of the piston so that we can choose the suitable material for the piston and also structure of the crown of the piston. It can be demonstrated from the above graphical data and figures that reduced skirt length piston temperature reduced by 10-20’ as compared to simple piston while boundary conditions are same.Similarly total heat flux variation also reduced in case of reduced skirt length piston as compare to simple piston. Piston failure occurs because of thermo-mechanical overload by insufficient intercooling thermo-mechanical overload by over fuelling .

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