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THERMO-STRESS ANALYSIS OF COATED AND NON-COATED ENGINE PISTON TO FIND EFFECTIVE HEAT BARRIER

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ABSTRACT

Todays car engines are technically advanced and consumes less fuel to achieve maximum power output. Every time research and development department optimize the performance of the engine. Cylinder head, connecting rod, crank shaft, cam shaft and piston are the most important parts of the engine. These parts always come under thermal and impact loading. However, piston comes under great impact of thermal stresses and loading. The temperature of the piston always increases while engine running and every time the cooling must be applied to piston. To avoid generation of heat by friction oil control ring is provided. It lubricates engine piston and avoid extensive friction and wear. But at the T.D.C. power stroke will generate the extensive heat and power which directly impinge on the piston top. During long term running of engine this heat on the engine top and thrust generated cause the piston material wear and damage. To avoid such damage, we can provide coating on the piston surface which will be thermal insulating material and tough enough to withstand on high impact loading. In this project thermal analysis of coated and non-coated piston will be carried out with the help of ANSYS 2020 R1 software, which is FEM tool. For that purpose, CAD model of Piston will be created in CATIA V5R21 Software. The temperature, thermal stresses and heat transfer rate will be compared with each other to find effectiveness of the thermal barrier coating. For coating of piston ceramic will be used which is thermal insulator and good adhesive.

Keywords: Coated and Non-coated Piston, ANSYS 2020 R1, CATIA V5R21, Thermal Stresses etc.

I. INTRODUCTION

The piston is the most essential part of a reciprocating engine. It helps to convert the chemical energy obtained by the combustion of fuel into useful mechanical power. The piston provides a means of conveying the expansion of the gases to the crankshaft, through the connecting rod, without loss of gas from above or oil from below. The piston is basically a cylindrical plug that moves up and down in the cylinder. It has a piston ring to provide a good seal between the piston and cylinder wall. Although the piston seems to be a simple part, it is actually quite complex from a design stand point. The efficiency and economy of the engine depending on the working of the piston . It must operate in the cylinder with minimum friction and it should be able to withstand the high explosive force generated in the cylinder and also the very high temperature ranging from 2,000°C to over 2,800°C during operation. The piston should be as strong as possible, however, its weight should be minimized as far as possible in order to reduce the inertia due to its reciprocating mass.

1.1 Piston Functions

- Receive the thrust produced by the combustion of the gas in the cylinder and transmit it to the connecting rod.
- Piston reciprocates in the cylinder as a gas-tight plug generating suction, compression, expansion, and exhaust strokes.
- Piston forms a guide and bearing to the small end of the connecting rod and takes the side thrust due to the obliquity of the rod.

The top portion of the piston is called the head. Ring grooves are cut on the circumference of the piston's upper portion of the piston. The parts below the ring grooves are called a skirt. The portions of the piston that separate the grooves are called the lands. Some pistons have a groove in the top land called a heat dam which reduces heat transfer to the rings. The piston bosses are those reinforced parts of the piston designed to hold the piston pin or wrist pin.

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1.2 Types of Piston

Following are the different **types of pistons** used in engine:

1) Lo-Ex" alloy Pistons
2) Invar Strut Pistons
3) Auto thermic Pistons
4) Bi-Metal pistons
5) Specialloid Pistons
6) Wellworthy Pistons

1.3 The Piston Must Possess the Following Qualities

- Rigidly to withstand high pressure.
- Lightness reduces the weight of the reciprocating masses and so enables higher engine speeds.
- Good heat conductivity reduces the risk of detonation so allowing a higher compression ratio.
- Silence in operation.
- Material having low expansion and provision to allow for different expansion rates of cast iron cylinder block and an aluminium piston.
- Correctly formed skirt to give uniform bearing under working conditions.

1.4 Material used for Piston

The material used for pistons is aluminium alloy. Aluminium pistons can be either cast or forged. Cast iron is also used for the piston. Cast iron is a universal material in the early years because it possesses an excellent wearing quality, coefficient of expansion, and general suitability in manufacture. But due to the reduction of weight in reciprocating parts, the use of aluminium for piston was essential. To obtain equal strength a greater thickness of metal is necessary, the same advantage of the light metal is lost. Aluminium is inferior to cast iron in strength and wearing qualities, and its greater coefficient of expansion necessitates greater clearance in the cylinder to avoid the risk of seizure. The heat conductivity of aluminium is about three times that of cast iron, and this combined with the greater thickness necessary for strength, enables and an aluminium alloy piston to run at much lower temperatures than a cast-iron one (200°C to 250°C as compared with 400° to 450°C).

As a result, carbonized oil does not form on the underside of the piston, and the crankcase, therefore, keeps cleaner. This cool-running property of aluminium is now recognized as being quite as valuable as its lightness indeed, pistons are sometimes made thicker than necessary for strength in order to give improved cooling.

1.5 Piston Clearance

Pistons are normally small in diameter than the bore of the cylinder. The area between the cylinder and the cylinder wall is called the piston clearance. Piston Clearance is Essential for the Following Reasons It provides a space for a film of lubricant between the piston and cylinder wall to reduce friction. It prevents piston seizure: Due to very high operating temperature, piston and cylinder block expand. The cylinder is getting cooled faster than the piston, hence enough clearance should be given for the piston to expand, failing which the piston seizure will result. If there is no clearance between the piston and cylinder, it will be difficult for the piston to reciprocate in the cylinder.

1.6 Piston-Head Shape or Piston Crown

The piston head is usually flat but shaped to suit the combustion chamber. The combustion space can be controlled by dishing or doming the piston crown and recess for the valve heads can also be machined into the crown.

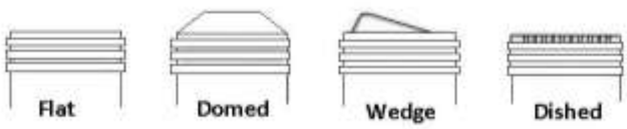

Figure1: Piston Head Shapes

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The compression ratio can be controlled by machining the combustion chamber in the piston, but it means that most of the heat of combustion has to be consumed through the piston instead of the cylinder head.

1.7 Expansion Control in Pistons

During operation, the piston runs many degrees hotter than the cylinder, because the cylinder is surrounded by cooling water. Hence this piston expands more than the cylinder. This expansion must be controlled in order to avoid the loss of adequate piston clearance. Such a loss may cause serious engine trouble. The problem is more accurate with aluminium pistons because aluminium expands more rapidly than iron with the rise of temperature. The expansion of the piston skirt can be controlled by several methods as follows.

1) By keeping heat away from the lower part of the piston.
2) By making Heat Dam
3) Cam grinding the piston
4) By using struts

II. LITERATURE SURVEY

Ch. Indira priyadarsini, "Thermal Analysis of Piston Crown Coated with Copper".[1]

S. Krishnamani* "Thermal Analysis of Ceramic Coated Aluminium Alloy Piston using Finite Element Method".

ZihaoShu 1. "Thermal Analysis of Mullite Coated Piston Used in a Diesel Engine". [3]

S.Punithan1, "Thermal Analysis Coated Diesel Engine Piston For Various Coating ANSYS Thickness". [4]

Syed Arif Ali1, "Static and Thermal Analysis Of Piston With Different Thermal Coatings". [5]

Atthuru Kalyan1,"Static and Thermal Analysis of a Piston with Different Thermal Barrier Coatings". [6]

2.1 Outcomes from review

1) FEA Tools are the best suitable tools for the Piston Testing.
2) Thermal analysis of engine piston can predict temperature contours on piston body.
3) Coatings on piston can reduce the chances of failure of piston.
4) Ceramic coatings are more effective and can prevent heat transfer through metal body.

III. PISTON ANALYSIS AND RESULTS

Fully parametric FEM piston model design is created. Analysis is carried out by considering the combination of the each design with the material selected and at different temperatures. The analysis is carried out in ANSYS 2020 R1 software showing the difference between coated and non-coated piston with different temperatures in following figure.

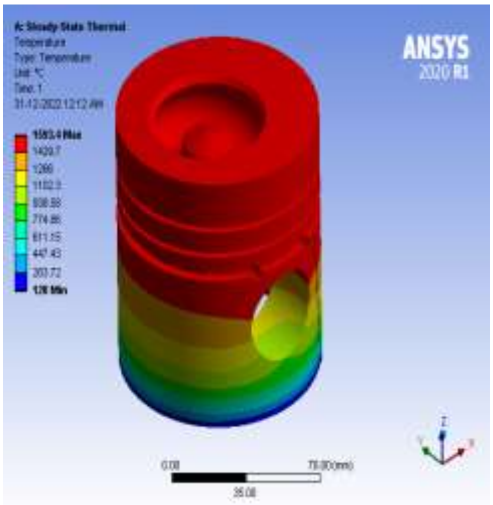

Fig.1.1: Temperature Contours obtained at 1500^{0}C

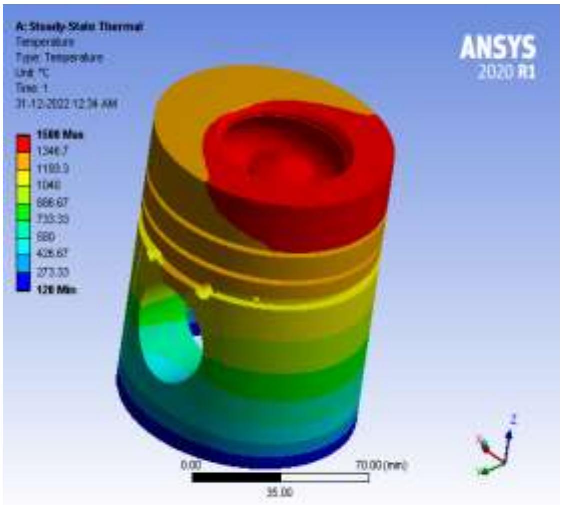

Fig.1.2: Temperature Contours obtained at 1500^{0}C

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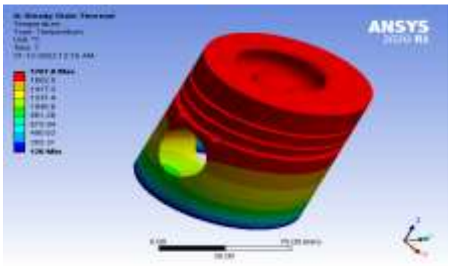

Fig.1.3: Temperature Contours obtained at 1750^0C

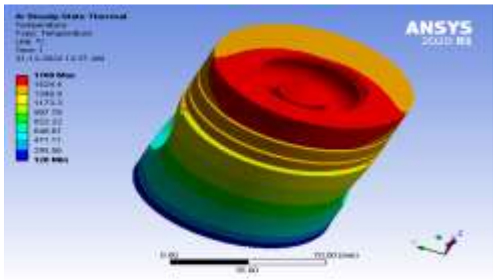

Fig.1.4: Temperature Contours obtained at 1750^0C

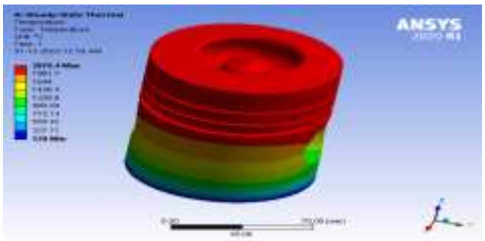

Fig.1.5: Temperature Contours obtained at 2000^0C

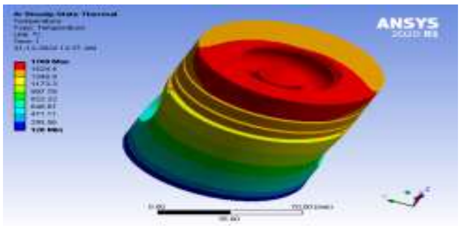

Fig.1.6: Temperature Contours obtained at 2000^0C

By observing all above analysis results, we found that the Coated piston propagate less heat compared with non-coated piston. Hence by applying ceramic coat on the piston we can improve the life of the piston.

IV. CONCLUSION

This is clear that the ceramic material is the best suitable material for the coating of engine piston. Due to this coating piston temperature reduces and the ultimately chances of failure reduces. It also increases the life of the piston. The Piston with ceramic coating is highly recommended to improve the life of the piston. Varying coat will provide the concentration on the maximum heating zone. Hence the dense coat in heating zone will improve the combustion volume by reducing coat layer on other spots.

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