Research Paper

THERMAL ANALYSIS OF A PISTON OF RECIPROCATING AIR COMPRESSOR

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ABSTRACT

In this study, the wok is carried out to measure the distribution of the temperature on the top surface of the piston. which predicts that due to temperature weather the top surface of the piston may be going to damaged or broken during the operating conditions because damaged or broken parts are so expensive to replace and generally are not easily available. So it is possible to recover the damage or broken parts due to thermal analysis before taking into operations. It can be seen from that the prescribed operating temperature inside the cylinder penetrates the piston crown through nearly 75 % of its thickness before piston ring dissipates some of heat.

KEYWORDS Piston, Boundary conditions, Thermal analysis, ANSYS.

1. INTRODUCTION:

It is important to calculate the piston temperature distribution in order to reduce the thermal stresses and deformations within acceptable levels. The temperature distribution enables us to optimize the thermal aspects of the piston design at lower cost, before the first prototype is constructed. As much as 60% of the total engine mechanical power lost is generated by piston ring assembly. Most of the pistons are made of an aluminum alloy which has thermal expansion coefficient, 80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behavior is extremely crucial in designing more efficient compressor.[5]

Damage and broken parts are so expensive to replace and generally are not easily available. So to avoid this problem it needs design of a new part, copy of an existing part, recovery of a damaged or broken part, improvement of model precision and inspection of numerical model.[2]

The main requirement of a piston is a good sealing of the cylinder. The Second is that the weight of the piston and the entire crank mechanism is a minimum, particularly for high speed machines, in order to reduce the inertia force and to improve the mechanical efficiency. In horizontal machines a small piston weight reduces the risk of its seizing. To allow for thermal expansion, the diameter of the piston must be smaller than that of the cylinder. The necessary clearance is calculated by estimating the temperature difference between piston and cylinder and considering the coefficient of thermal expansion of piston.[3]

2. TEMPERATURES IN PISTON:

The strong periodic fluctuations of temperature in a cylinder cause temperatures to vary in the upper most layer of the piston crown. A large part of the heat absorbed by the piston crown during the expansion stroke is released to the coolant by the piston ring zone and by the cylinder wall. The amplitudes of these fluctuations have magnitude of about 10-40^0 C on the surface and subside inwardly within a few millimeters according to exponential function. [4]

A large part of the heat absorbed by the piston crown during the expansion stroke is released to the coolant by the piston ring zone and by the cylinder wall. Depending on the design of the engine and the piston and influenced by the operating mode and the piston velocity, between 20 and 60% of the amount of heat that accumulates in a piston crown is primarily released by the piston rings. A small portion of the heat is transferred to the fresh gas during gas exchange. The lubricating and cooling oil that reaches a piston’s inner wall absorbs the rest of the dissipated heat.

3. MATERIAL OF PISTON:

Piston should be made of a material with good friction properties, of high strength, and capable of producing good casting having good machining properties. The requirement of small thermal expansion is also important for high gas temperature, where good thermal conductivity is also desirable. The advantage of aluminum alloy piston is that they do not damage the cylinder in case of jamming. [3]

Piston aluminum alloys are a special group of industrial aluminum alloys, which have high mechanical properties at elevated temperatures (approximately up to 350^{0}C). Simultaneously, these alloys are resistant to sudden temperature changes. Due to this, in the design of this type of alloys, their mechanical and thermal strains have to be critically considered without ignoring their environment aggressiveness during exploitation. [1]

4. PISTON DESIGN

Main Piston Dimensions

A Piston’s functional elements include the piston crown, ring zone, piston land, piston pin and skirt. The main piston dimensions are closely interrelated to the main engine dimensions and the dimensions of the other components. The compression height which i.e. the distance between the center of the pin and the upper edge of the piston top land which is the main piston dimension other than cylinder diameter. Also mass of piston plays a major role in high speed compressor.

5. DESIGN DATA OF COMPRESSOR:

- Power Capacity : 5 H.P
- Speed : 1440 R.P.M
- Piston Displacement : 500 LPM
- Atmospheric Pressure : 1.01325 bar
- Working Pressure : 10 bar
- Temperature on top surface of Piston : 81.97^0 C

The above data is taken for the design of piston through which various geometries of the piston can be found out which are mentioned below. The material of the piston is Aluminum alloy 6061.

- Total Length of Piston : 77.91 mm
- Diameter of Piston : 100 mm
- Thickness of Head or Crown : 6 mm
- Axial thickness of Piston Ring : 6 mm
- Width of other ring land : 4.5mm
- Length of Skirt : 31.41mm
- Length of Ring Section : 32 mm

Fig.1 shows the solid model of the piston under study. This model is generated by Creo Elements which is the new version of PRO-E WILDFIRE 5.0.

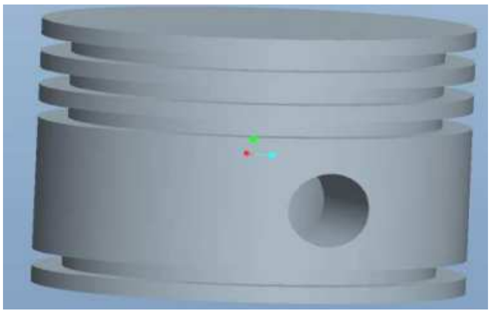

Fig.1 Piston solid model generated by Creo-Elements

The above model is meshed using standard mechancial shape cheking in ANSYS workbench using 78058 nodes and 45534 elements. A mesh convergence analysis showed that this level of mesh refinement is adequate to perform both the static and thermal analysis of the model.

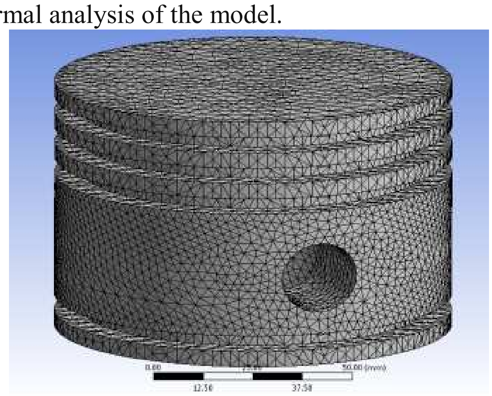

Fig.2 Meshing in ANSYS of the Piston

6. Advantages of Thermal analysis

- It gives prediction of Components characteristics such as dynamics and friction
- It predicts the defects in the components in the particular area.
- It gives capacity to resists the temperature.
- Amount of heat transfer can be find out.
- It is also used to measure temperature distibution.
- Development cost can be reduced.
- Distortions of the shape can also be minimized.

7. Boundary Conditions for thermal analysis

The thermal analysis of piston is important from different perspectives. First, the highest temperature of any point in piston must not exceed more than 66% of the melting point temperature of the alloy. This limit temperature for the current engine piston alloy is about 640 K. Temperature distribution leads to thermal deformations and thermal stresses. The piston thermal deformation has an important role in piston skirt design which has a potential to reduce friction and piston slap [5]. It is generally assumed for the piston temperature to remain constant throughout a working cycle and not dependent on operating states. In this design the thermal stresses must be considered indicating the importance of piston thermal analysis. Fig.3 and Fig. 4 shows the heat transfer coefficient for the piston at different positions.

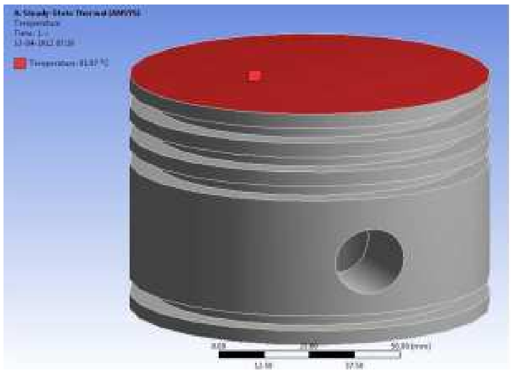

Fig.3 Thermal boundary condition for Piston Head

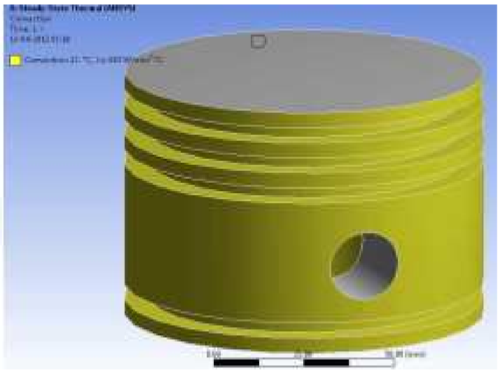

Fig.4 Thermal Boundary Condition for Piston Length

8. RESULTS AND DISCUSSIONS

Fig. 5 shows the temperature distribution within piston below. It can be seen from Fig.5 that the prescribed operating temperature inside the cylinder penetrates the piston crown through nearly 75 % of its thickness before piston ring dissipates some of heat. The average piston temperature beneath the piston ring is about 65^0C.

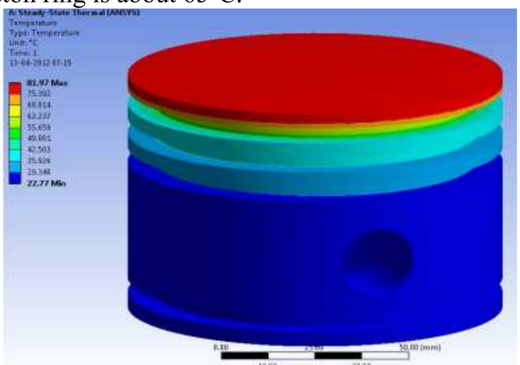

Fig. 5 Temperature Profile Distribution of the Piston.

Fig. 6 shows the total heat flux flows on the top surface of the piston as well as from side of the piston length. It can be seen from the Fig. 6 that from the top surface of the piston 0.33223 to 0.41528 W/mm^2 amount of heat transfer.

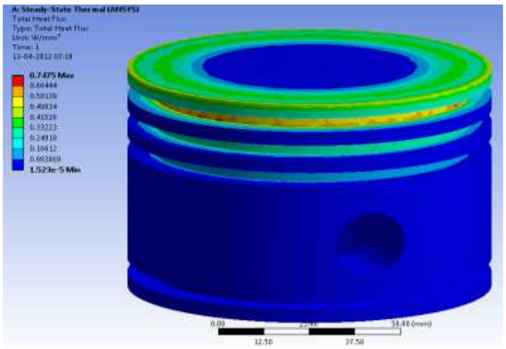

Fig. 6 Total Heat Flux Transfer

Fig. 7 shows that the material of the piston will work well under the prescribed operating conditions and the design is safe to resist the pressure of 10 bar or 10 Mpa.

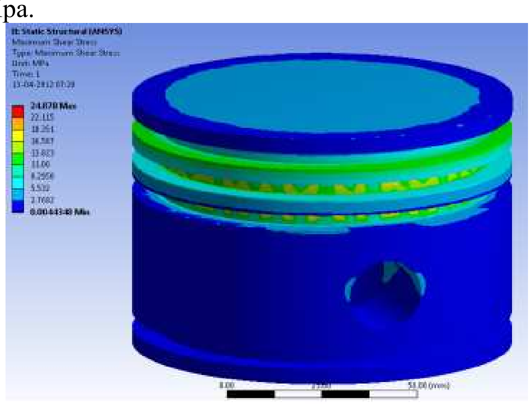

Fig. 7 Shear Stress Distribution

9. CONCLUSION

The results of this study show that the stresses which are produced during the operations are less than the design stress. Also the distribution of the temperature is in prescribed limit. The average piston temperature beneath the piston ring is about 65^0C. so the design is safe to resists specified temperature and pressure.

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