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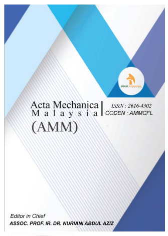

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RESEARCH ARTICLE

THERMAL STRESS ANALYSIS OF INTEGRATED COMBUSTION ENGINE PISTON USING CAE TOOLS (ALUMINUM SILICON ALLOY, ALUMINUM SILICON ALLOY STEEL)

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ABSTRACT

The main indention of this research work is to investigate and analyze the stress distribution of piston at actual engine Condition. In this paper thermal stress analysis is done by two different materials Aluminum Silicon alloy and Aluminum Silicon alloy steel. The parameter used for the analysis is operating temperature and material properties of piston. In I.C(internal combustion) Engine piston is most complex and significant part therefore for smooth running of vehicle piston should be in proper working condition. Piston fails mainly Due to mechanical stresses and thermal stresses. Analysis of piston is done with boundary conditions and uneven temperature distribution from piston head to skirt. The analysis predicts that due to temperature whether the top surface of the piston may be damaged during the operating conditions, because damaged parts are so expensive to replace and generally are not easily available. The CAD model is created Using CATIA V5 R20 software. CAD model is then imported into ANSYS12 software for geometry and meshing purpose. The FEA Performed by also using ANSYS14.

KEYWORDS

Aluminum, ic engine Piston, CATIA V5 R20, ANSYS14.

1. INTRODUCTION

Computer aided engineering analysis tools offer the tremendous advantage of enabling designers to consider virtually any molding option without incurring the expensive actual manufacturing of the machine parts and machine time associated to make machine component. The ability to try new concepts or idea on the computer gives the option to reduce the problems before beginning production. Additionally, designers can easily and quickly find the sensitivity of specific molding parameters on the quality and production of the final part (Alkidas, 1999; Bhagat and Jibhakate, 2012). The most complex parts can be simulated easily by CAE (computer aided engineering) tool Among engine components exposed to thermal effects, the piston is considered to be one of the most severely stressed, where a large amount of the heat(thermal) transferred to a coolant fluid goes through it, this amount depends on the thermal conductivity of the materials employed, the average speed and the geometry of the piston.

It is the moving part 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 by the way of a piston rod (Atish Gawale, 2012; Li, 2002). Piston endures the cyclic gas pressure and the inertial forces at work and this working Condition may cause the fatigue (continues loading condition) damage of piston, such as piston side wear, piston head or piston top cracks and so on. So there is a need to optimize the design of piston by considering different parameters in this project the parameters selected are thermal analysis of piston at various temperatures in various stroke (Sathishkumar and Kannan, 2019; Sathishkumar and Kannan, 2020).

This analysis could be helpful or useful for design engineer for modification of piston at the time of design. In this project we determine the thermal analysis form that we can find out the various zones or region where chances of damage of piston are possible. From analysis it is very simple to optimize the design of piston (ASM International, 2000). The main requirement of piston design is to measure the prediction of temperature distribution on the surface of piston which enables us to optimize the thermal aspects for design of piston at very low cost. Most of the pistons are made of an aluminum alloy (Al) which has thermal expansion coefficient, 85% higher than the cylinder bore material made of cast iron (CI). This leads to some differences between running and the design clearances (Kamo et al., 1989). Therefore, analysis of the piston thermal behavior is extremely significantly in designing more efficient compressor (Alkidas, 1999). Good sealing of the piston with the cylinder is the basic criteria to design of the piston. Also to improve or develop the mechanical efficiency and reduce the inertia force in high speed machines the weight of the piston also important major role (Alkidas, 2005). To allow for thermal expansion, the diameter of the piston must be smaller than that of the cylinder. The need to clearance is calculated by calculating the temperature difference between piston and cylinder and considering the coefficient of thermal expansion of piston (Carvalheira and Gonçalves, 2006; Ekrem, 2007).

A piston is a component of reciprocating IC-engines

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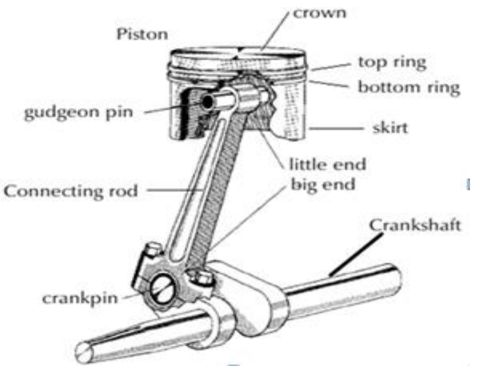


Figure 1: Piston Assembly

2. PISTON MATERIAL'S

2.1 Aluminum Silicon Alloy

2.2 Aluminum Silicon Alloy Steel

The most commonly used materials for pistons of internal combustion engines are cast iron, aluminum alloy, forged aluminum, cast steel. The cast iron pistons are used for moderately rated engines with piston speeds below 6.9 m / s and aluminum alloy Pistons are used for highly rated engines running at higher piston speeds (Uzun et al., 1999). It may be noted

1) Since the coefficient of thermal expansion for aluminum is about 2.87 times that of cast iron, therefore, a greater clearance must be provided between the piston and the cylinder wall in order to prevent seizing of the piston.

2) Since the aluminum alloys used for pistons have high heat conductivity (nearly 4.5 times that of cast iron),therefore, these pistons ensure high rate of heat transfer and thus keeps down the temperature difference between the center and edges of the piston head or piston crown.

3) Since the aluminum alloys are about three times lighter than cast iron, therefore, its mechanical strength is high at low temperatures, but they lose their strength (about 60%) at temperatures above 335°C. Sometimes, the pistons of aluminum alloys are coated with aluminum oxide by an electrical method

Table 1: Materials

S/No	Matrix Material	Reinforcement Material
1	Aluminium	Silicon
2	Aluminium	Silicon (steel 4140)

Table 2: Material Property's

S/No	Material	AlSi Alloy	AlSi (4140 Alloy steel)
1	Young's modulus [GPa]	**90**	**210**
2	Poisson's ratio	**0.3**	**0.3**
3	Thermal conductivity [W/m °K]	**155**	**42.6**
4	Thermal expansion 10−6 [1/°C]	**21**	**12.3**
5	Specific heat [J/kg °C]	**960**	**473**
6	Density [kg/m3]	**2700**	**7850**

3. DESIGN CONSIDERATIONS OF 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.

3.1 Piston Function Design Requirement

1. Easily move to the reciprocating motion inside of cylinder

2. Reducing friction between the connecting rod and piston pin

3. There is no strain occurring the wrist pin

4. Piston move even at minimum (low) pressure

3.2 Piston Structural Design Requirement

1. Piston designed in cylindrical shape because easily Move to the up & down direction

2. Piston should be a compact size

3. Piston head geometry (curve, flat) should be in correct shape so that in gives maximum efficiency

4. DIMENSIONS OF PISTON

Table 3: Piston Dimensions

S/NO	PARAMETERS	DIMENSION (mm)
1	Piston Diameter	80
2	Piston Height	92
3	Skirt Height	63
4	Piston Inner Diameter	58.9
5	Radial Thickness	3.9

5. THE BOUNDARY CONDITIONS

1) Temperature Level of piston head =573K (273+300)

2) Temperature Level of piston ring =493K (273+220)

3) Temperature Level of piston skirt= 463K (190+273)

4) Temperature Level of piston bottom portion = 243K (273+70)

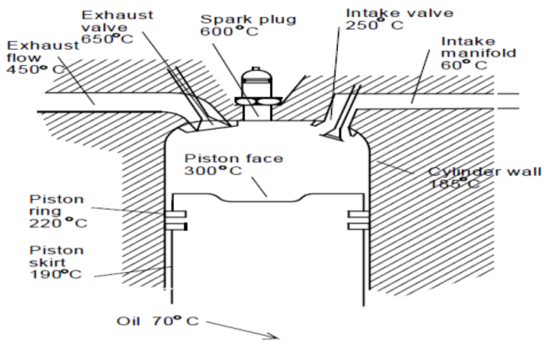


Figure 2: boundary conditions

6. FINITE ELEMENT MODEL

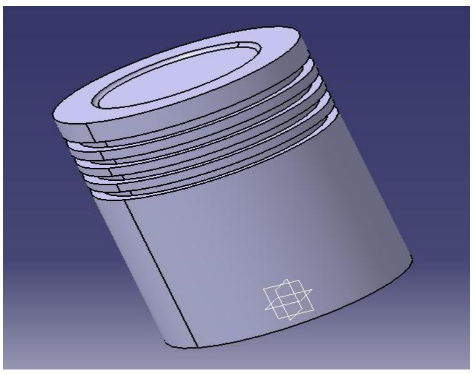


Figure 3: CATIA V5R20 Model

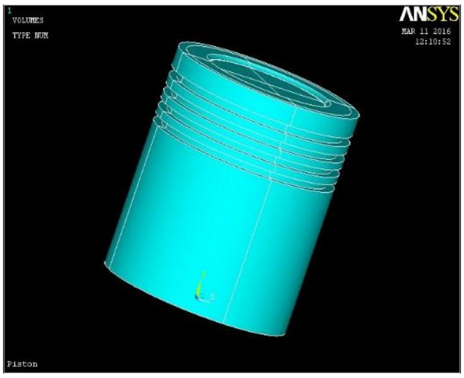
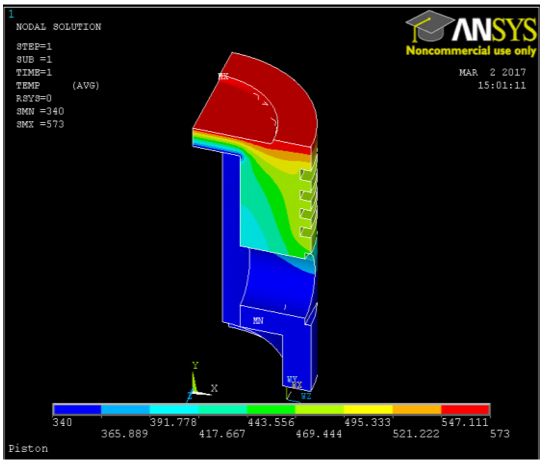


Figure 4: Imported ANSYS Model

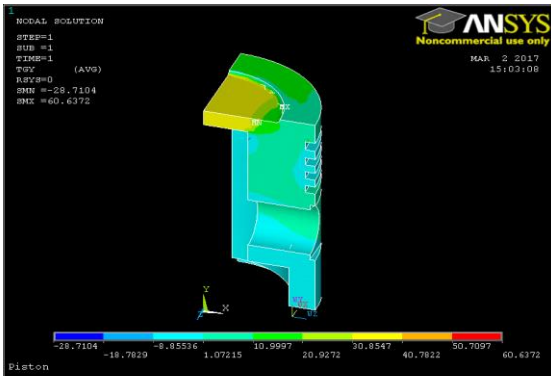
7. Result and Discusssion

The piston is divided four equal parts because the full piston analysis takes long time so the **symmetric** condition is to be applied

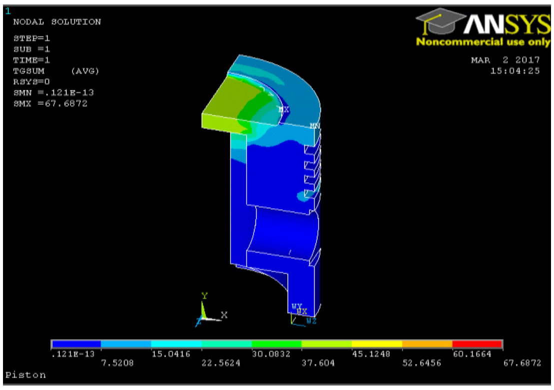
7.1 Aluminum alloy



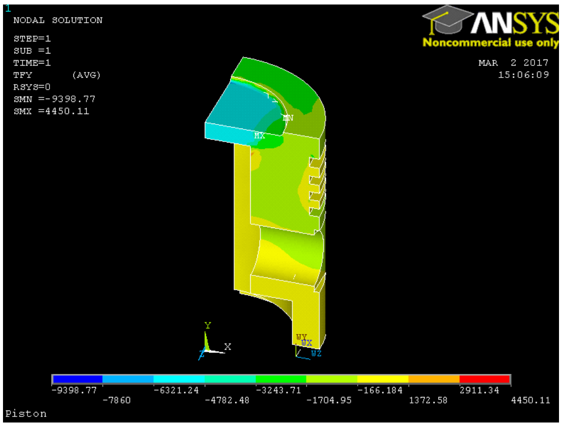
(i) Nodel Temperature



(ii) Thermal Gradient (Ydirection)

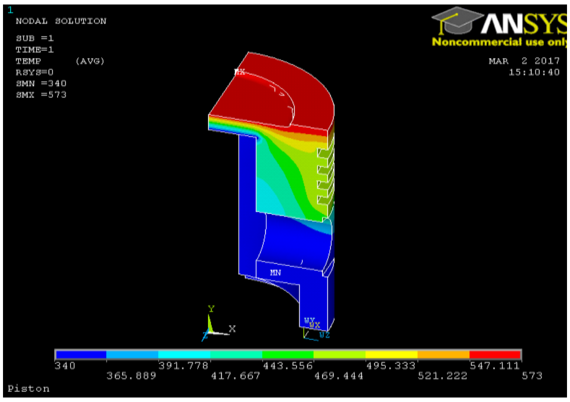


(iii) Thermal Gradient Vector Sum

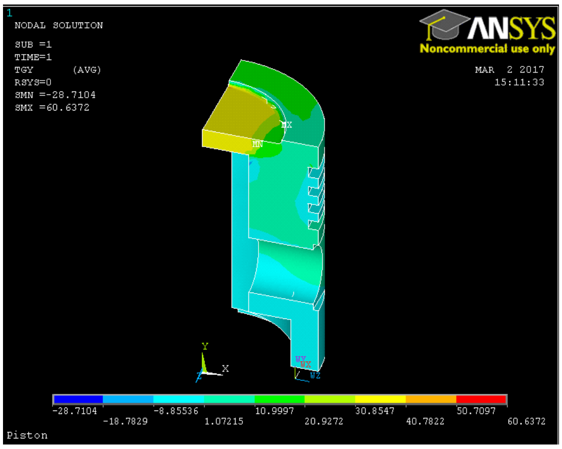


(iv) Thermal Flux

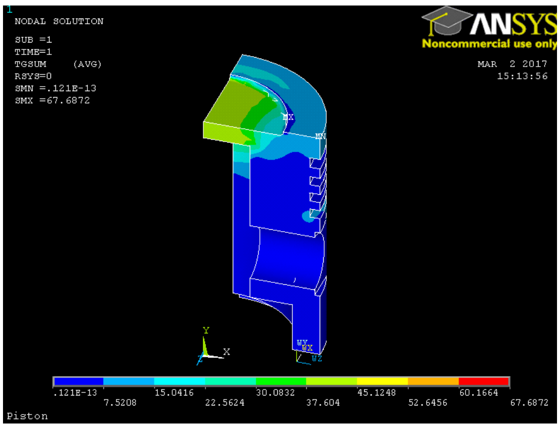
7.2 Aluminum Alloy Steel



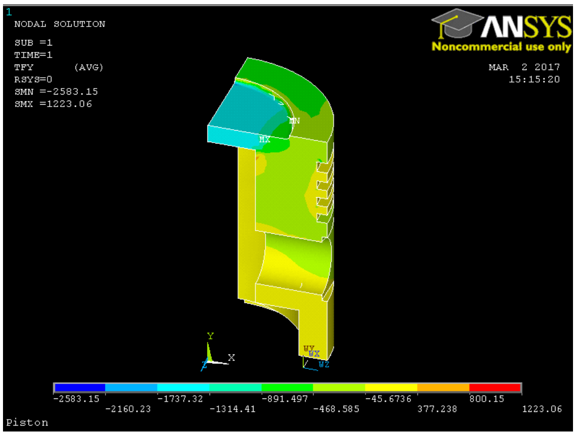
(i) Nodal Temperature



(ii)Thermal gradient (Ydirection)



(iii)Thermal gradient vector sum



(iv) Heat flux

8. Conclusion

Aluminum silicon alloy should be used as a piston Material as it has minimum thermal stress and mechanical distortion in same working condition as that of cast iron and structural steel as piston material. Its lighter in weight thus Conceded good mechanical strength at low Temperatures and high heat (thermal) conductivity thus high rate of heat transfer is possible between the centre and edge of the piston head. Use of CAE software eliminates the human effort in determination of stress, distortion values and so are referred as good tool for piston mechanical as well as thermal analysis. Compare thermal flux on aluminium silicon alloy and aluminium silicon alloy steel. The aluminium silicon alloy is withstand the high thermal load it shown in above results so aluminium silicon alloy is suitable material for piston

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