DESIGN AND FINITE ELEMENT ANALYSIS OF A PISTON OF INTERNAL COMBUTION ENGINE

[1]Dr. K. Prabhu, [2]Dr. S. Ramesh, [3]Mr. B. Rajendra Prasad, [4]Mr. V. Ravinder,
[1]Associate Professor, Dept. of Mechanical Engineering, Malla Reddy College of Engineering, Sec-100
[2]Associate Professor,Department of Mechanical Engineering, Malla Reddy College of Engineering, Sec-100
[3]Asst. Professor, Department of Mechanical Engineering, Malla Reddy College of Engineering, Sec-100
[4]Asst. Professor, Department of Mechanical Engineering, Malla Reddy College of Engineering, Sec-100

Abstract— This journal describes the stress distribution of the piston in four stroke engines by using FEM. Our main objectives is to Study and analyze the thermal stress and maximum or minimum principal stresses, Vanishes stresses distribution on engine piston during combustion process. The journal describes the optimization techniques with using finite element analysis method (FEM) to predict the higher stress and critical region on the component. The stress concentration on the piston head, piston skirt and piston sleeve are reduced by the optimization, using computer aided design (AUTO CAD), Pro- ENGINEER/ CREO software the structural model of a piston will be developed. Furthermore, the FEM analysis is done using Computer Aided Simulation software.

Keywords— FEA, Pro-E, ANSYS, Piston crown, Piston skirt, stress concentration, Thermal analysis.

I. INTRODUCTION

A piston is a cylindrical engine component that Reciprocates in the cylinder bore by forces produced during the combustion process. The combustion chamber is made gas-tight by the piston rings. In an engine, its transfer force from expanding gas in the cylinder to the crankshaft via connecting rod. As a main part in an engine, piston endures the cyclic gas pressure and the inertial forces at work, and this real working condition may cause the fatigue damage of piston, such as piston skirt wear, piston head or crown cracks and so on. The investigations denote that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure. On the other hand piston over heating-seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall. Understanding this, it's not hard to visually why oils with exceptionally high film strengths are very desirable. Good quality oils will offer provide a film that stands up to the most intense heat and the pressure loads of a modern high output engine. Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature. Finite element method (FEM) are commonly used for thermal Analysis. Due to the complicated working environment for the piston; on one hand, the finite element method (FEM) for the piston became more difficult, on the other hand, though there have many methods which are put forward to apply optimal design, the optimal parameters is not easy to determine. In this, the piston is used in low idle and rated speed gas engine. In order to enhance the engine performance.

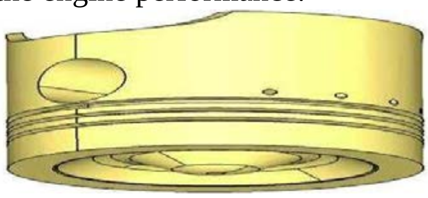


Fig.1 Piston of IC engine

It Is necessary for the piston to be optimized. The mathematical model of optimization is established firstly, and then the FEA is carried out by using ANSYS software. Based on the analysis of optimal result, the stress concentrates on the Upper end of piston has to be evaluated, which provides a better reference for redesign of the piston.

A. Properties of a Piston Material :
Aluminum silicon alloys are widely used in the production of pistons because of their

☐ High Strength,

☐ Low Density,

☐ High Thermal Conductivity,

☐ Good Cast Ability,

☐ Workability,

☐ Good Machinability ,

☐ High Temperature Resistance. B. Aspects of a IC Engine Piston:

The Piston of an IC engine should comprises of the following characteristics:

☐ High Strength to resist gas pressure.

☐ Should have minimum weight.

☐ Should able to reciprocate with minimum noise.

☐ Should seal the gas from top and oil from the bottom.

☐ Should disperse the heat generated during combustion.

☐ Should have good resistance to distortion under high loads and high temperature.

In this study the piston material we choose is AlSi12CuMgNi cast alloy with eutectic microstructure. As all the engine components around the combustion chamber experience significantly high temperatures and temperature gradients, the temperature dependent property materials has to be used.

According to the thermal analysis results maximum piston temperature reaches approximately 374°C, therefore the cyclic behavior of material is considered at 20, 150, 250 and 350 °C.

C. Engine Specifications:
The engine we are considering in this article is a four-cylinder four -stroke air cooled type Bajaj Kawasaki diesel engine.

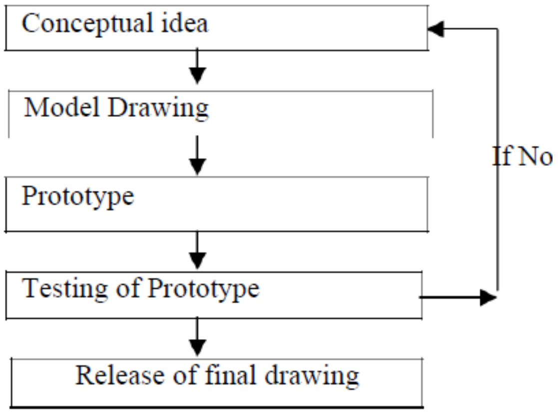
The engine specifications are mentioned below:

PARAMETERS	VALUES
Engine Type	Four stroke, diesel engine
Induction	TCIC
Number of cylinders	4 cylinder
Bore	74 mm
Stroke	70 mm
Length of connecting rod	97.6 mm
Displacement volume	99.27 cm^3
Compression ratio	16
Maximum power	21.6 KW at 7000 rpm
Maximum Torque	86 Nm at 3500 rpm
Number of revolutions/cycle	2

Table 1. Engine specifications

II. CAE APPROACH

Computer-Aided-Engineering (CAE) is the computer software to aid in engineering in analyzing tasks. In this standard approach conception ideas are converted into sketches or engineering drawing. With the assistance of this drawings, the prototypes i.e. product which appearance as that of final product are created. It is launched in the market after testing of prototype which gives acceptable results. The thing is, product is launched after doing several practical testing and many trial and error procedures which consumes more time and cost too [1]. Figure 2 depicts the flow process adopted for typical design approach.



system. It is a computer predicated method that breaks geometry into element and link a series of equation to every, which are then solved simultaneously to evaluate the outward behavior of the complete system. It is utilizable for perplexed geometry, loading, and material properties where exact analytical solution are difficult to obtain. Most often utilized for structural, thermal, fluid analysis and simulation.

III. METHODOLOGY

During the working cycle operation, the piston is exposed to the high gas pressure and high temperature because of combustion. Simultaneously the piston is fortified by a minute terminus of the connecting rod with the Gudgeon pin. Therefore the methodology for analyzing the piston is considered as the gas pressure given 180 bar is applied uniformly over the crown (top surface/face of the piston) and all degrees of liberation for nodes at upper moiety of piston pin bossed in that piston pin is going to fine- tune. By Considering the fit between piston pin and piston is clearance fit. Only the upper moiety of piston pin boss is considered to be fine-tuning during the analysis.

A geometrical model of piston is prepared by modeling software's like PRO-e/ CREO, CATIA V5 and be modeled and analysed in the analysis software ANSYS.

C. Finite element model:

The element selected for meshing of the piston model is SOLID187 tetrahedron type of element which is a higher order tetrahedral element. The mesh count for the selected model is 71,910 of nodes and 41,587 number of elements. The figure below is the meshed model of the piston.

A. Material properties of piston:

- Material of Piston: - Cast aluminum alloy 201.0
- Young's Modulus [E] – 71 GPa
- Poisson's ratio [μ] – 0.33
- Tensile strength – 485 MPa
- Yield strength – 435 MPa
- Shear strength –290 MPa
- Elongation – 7 %

B. The geometrical representation of an IC Engine piston used for FEA.:

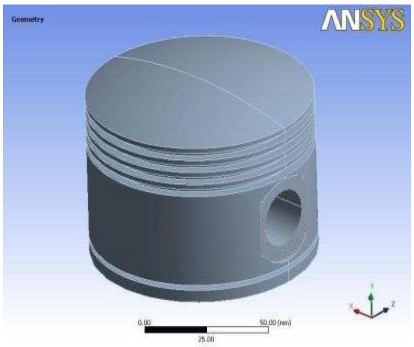


Fig. 4 Basic Geometry of a IC engine piston

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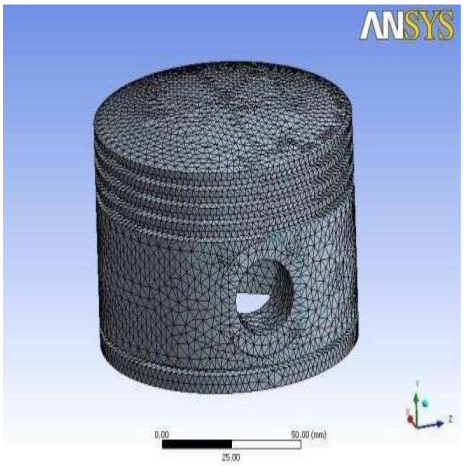


Fig.5 Meshed model of piston

D. Loading & boundary conditions:

The loading and boundary conditions considered for the analysis are showed in the below figure. The uniform pressure of 18 MPa is applied on crown of the piston (top red color) and the model is constrained on upper moiety of piston pin aperture as shown by violet color.

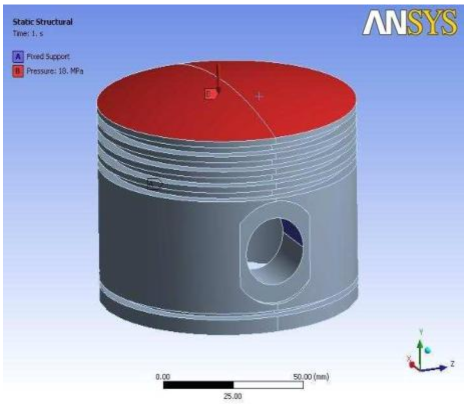


Fig.6 Loading and boundary conditions on piston

IV. RESULTS AND DISCUSSION

A. Total deflection:

The maximum deflection in the piston geometry due to the application of gas pressure observed at the central portion of the piston crown is is 0.29669 mm.

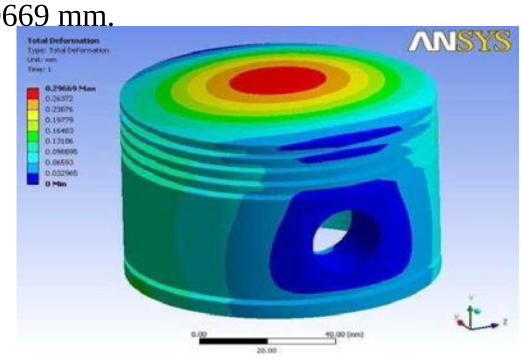


Fig.7 Total deflections on the piston head

B. Maximum principal stress:

The distribution of localized and observed at inner side of piston pin boss in the figure below. The overall maximum stresses in the piston body at the inner side of piston crown and piston boss is resulted as 231.25N/mm2.

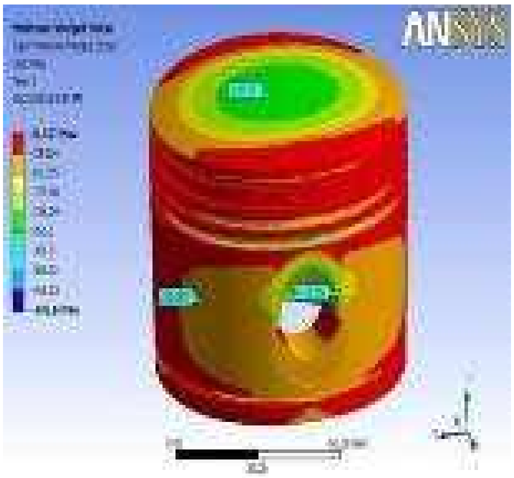


Fig.8 Maximum principal stress on piston

C. Minimum principal stress

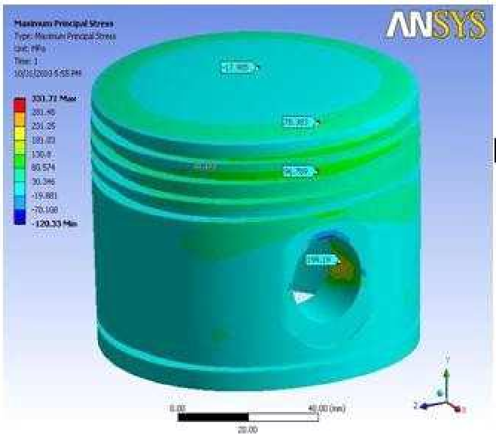


Fig.9 minimum principal stress on piston

The above figure shows the distribution of the minimum principle stresses induced within the piston body. The most maximum values of equivalent stresses are goes up to -376.74 N/mm2, which are highly localized and observed at inner side of piston crown & skirt junction. The overall maximum stresses in the piston body is - 250.5 N/mm2 at the top of piston crown.

D. Von mises stresses:

The above Figures 10.1 and 10.2 show the distribution of Von mises stresses induced within the piston body. The utmost maximum values of equivalent stresses are goes up to 200.97N/mm2.

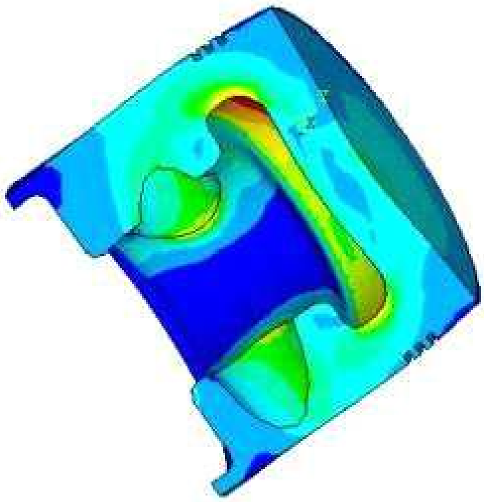


Fig. 10.1 Von mises stress

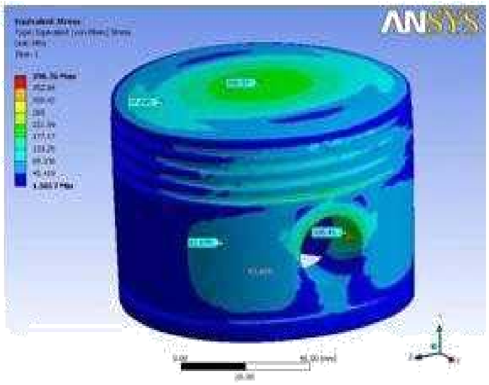
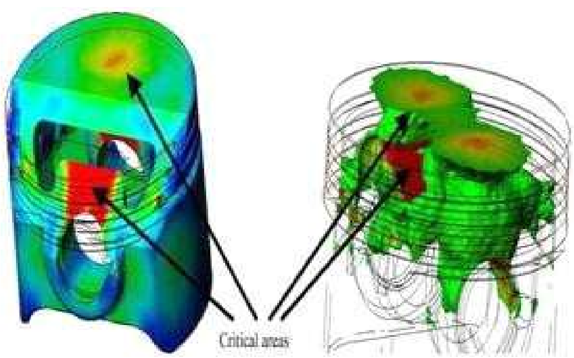


Fig. 10.2 Von mises stress

E. Stress distribution on the piston body:
The critical area is observed on the piston head and piston pin hole region.
Figure 11 shows stress concentration at various point in piston.



V. CONCLUSION

The Piston skirt may appear deformation during the cyclic operation, which usually results in the crack on the upper end of piston head. Due to the deformation, the greatest stress concentration is caused on the crown, it may leads to the failure of the piston when the stiffness of the piston is not enough, and the crack generally appeared at the point A which may gradually expand and even cause splitting aacross the piston vertically. The stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have enough stiffness.
Also from analysis various results are obtained like The maximum deflection occurred about 0.29669mm due to the application of 180bar gas pressure on crown of piston, 231.25N/mm2 of maximum principal stress is ascertained, - 250.5 N/mm2 of minimum principal stress is ascertained. Also von mises stress of 200.97N/mm2 is observed.

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