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Design Analysis and Optimization of I.C. Engine Piston Using Finite ElementAnalysis (Ansys)

L.Nikhila & Dr.R Murugan

[1]M.Tech(CAD/CAM), Dept. of Mechanical Engineering, Balaji Institute of Technology & Science, Warangal Rural, Telangana, India

[2]Head, Dept. of Mechanical Engineering, Balaji Institute of Technology & Science, Warangal Rural, Telangana, India

Abstract: In *I.C. Engine, piston is most complex and imperative part consequently for smooth running of vehicle pistonshould be in proper working condition. Pistons fail mainly due to mechanical stresses and thermal stresses. Analysisof piston is done with boundary conditions, which includes pressure on piston head during working condition anduneven temperature distribution from piston head to skirt.The main purposes isto examine and analyze the thermal stress and maximum orminimum principal stresses, Vanishes stresses distribution onengine piston at the real engine condition during combustionprocess. The paper describes the optimization techniques withusing finite element analysis technique (FEM) to predict thehigher stress and critical region on that component. The stressconcentration on the piston head, piston skirt and sleeve arereduces by optimization with using computer aided design, ProENGINEER/ CREO software the structural model of a pistonwill be developed.*

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

I. INTRODUCTION

Developing IC Engine isn't something uncommon within the industrybut the cutting-edge fashion is to expand engines with high energypotential. This can be executed when the burden is much less andthe gas consumption is low.It has been reported by Cuddyet al that 10% weight reduction of the vehicle contributes 6-8% discount on fuel intake. That actually means thatthe engine designs need to be advanced. When we say approximatelyimproving engine design we additionally imply to enhance thelayout of its aspect. The piston is one of the essential additives of the engine. Hence, we must uselight-weight cloth like aluminum, titanium to layout thepiston which will reduce the burden due to the fact stepped forward enginedesigns require optimised engine components. Along withmuch less weight of the piston huge energy need to also beensured so as it is able to resist the pressure generated by using thecombustion inside the cylinder. After the materials are selectedthe piston dimensions are calculated in keeping with theprocesses and specifications are given in the system layoutand statistics ebook. Once the dimensions are received, the pistonis designed on CATIA V5R20. Finite element analysis FEAis used for stress evaluation through making the piston pin hollowconstant and making use of the boundary situations. Pressure isapplied to the piston head and the deformation and pressuredistribution is analyzed. If the stress received is much less than thetheoretical strain (calculated on the unique component of safety) thenour layout is secure. But if it's far more then the design is riskyand the aspect of safety wishes to be changed.

Engine pistons are one of the most complex components among all automotive and other industry fieldcomponents. The engine can be called the heart of a vehicle and the piston may be considered the mostimportant part of an engine. There are lots of research works proposing, for engine pistons, new geometries,materials and manufacturing techniques, and this evolution has undergone with a continuous improvementover the last decades and required thorough examination of the smallest details. Notwithstanding all thesestudies, there are a huge number of damaged pistons. Damage mechanisms have different origins and aremainly wear, temperature, and fatigue related. The fatigue related piston damages play a dominant role mainlydue to thermal and mechanical fatigue, either at room or at high temperature.

The main aim of this review is to study thevarious stresses acting improve quality of piston to withstand high thermal and structural stresses and at the same timereduce stress concentration the upper end of the piston. TheFEA is proposed to be carried out for standard four strokeengine piston and the result of analysis are compared formaximum stress. Different alloys of aluminium are tested formaximum stiffness at operating thermal and structural stressusing FEA.

II. RELATED WORKS

Heinz K. Junker, on this e book, MAHLE experts percentage their vast-primarily based, sizable technical understanding of pistons,inclusive of format, design, and trying out. They write detailed statistics on the entirety to do with pistons: their feature,requirements, types, and layout recommendations. They describe simulation of operational strength the use of finite element evaluation, and piston substances, cooling, and aspect trying out. Engine trying out, as well as for validating new simulation programsand systematically compiling design specs. [1]

Ch.Venkata Rajam et al, they designed, analyzed and optimized to piston which is stronger, lighter-weight withminimal cost and with less manufacturing time. In their paper they analyzed strain distribution in the numerous components of thepiston to recognise the stresses because of the fuel stress and thermal versions using with Ansys. The Piston of an engine isdesigned, analyzed and optimized by means of using photos software. The CATIA V5R16, CAD software program for performing thelayout phase and ANSYS 11.0 for analysis and optimization phases are used. They reduced the quantity of the piston by means of24%, the thickness of barrel is reduced via 31%, width of other ring lands of the piston is decreased by way of 25%, von-mises pressureis accelerated by way of sixteen% and deflection is increased after optimization. But all the parameters are well within designconsideration. [2]

Ekrem Buyukkaya et al, of their paper completed thermal examine on a conventional (uncoated) diesel piston,product of aluminum-silicon alloy and steel. And then, thermal analyse are done on pistons, coated with MgO–ZrO2

fabric via the use of ANSYS. From the obtained effects, the maximum temperature cost of the lined piston become proven atthe piston's combustion bowl lip. Therefore, this region should be lined oversensitivity. The maximum surface temperature ofthe lined piston with material which has low thermal conductivity is progressed about forty eight% for the AlSi alloy and35% for the metallic. The maximum floor temperature of the bottom steel of the coating piston is 261 °C for AlSi and 326 °Cfor steel, and also find out by means of using of ceramic coating, energy and deformation of the materials are advanced. [3]

Muhammet Cerit in his paper decided the temperature and the pressure distributions in a partial ceramic coveredspark ignition engine's piston. Effects of coating thickness and width on temperature and stress distributions have beeninvestigated inclusive of comparisons with outcomes from an uncoated piston. It is found that the coating surfacetemperature growth with increasing the thickness in a lowering charge. Surface temperature of the piston with 0.4 mmcoating thickness turned into expanded as much as eighty two °C. The ordinary strain at the lined surface decreases with coating thickness, upto about 1 mm for which the cost of stress is the minimum. However, it rises when coating thickness exceeds 1mm. As for bond coat surface, growing coating thickness, the ordinary strain decreases gradually and the maximum shearstress rises in a reducing fee. The most effective coating thickness was found to be near 1 mm under the given conditions. [4]

Xiqun Lu et al, inverse warmth transfer approach is employed to behavior thermal numerical evaluation on a four-ringarticulated piston of marine diesel engine and decide the coefficient of heat transfer at each interface within the thermalmachine. The secondary movement of piston and piston ring, and the lubrication oil film has been considered in estimating thecoefficient of warmth transfer values. They manufactured steel plugs have been installed inside the head of an articulated piston andthe piston skirt to measure the temperature distribution of them. A Series of thermal couples have been used for cylindertemperature size. The boundary condition for numerical simulation is verified with test result and carried outto expect the temperature distribution of a brand new piston layout which had small alternate of piston head profile and one much lessring scheme. [5]

III. METHODS AND METHODOLOGY

A piston is a component of reciprocating CI-engines. It isthe moving component that is contained by a cylinder and ismade gas-tight by piston rings. In an engine, its main purposeis to transfer force from expanding gas in the cylinder to thecrankshaft via a piston rod. Piston endures the cyclic gaspressure and the inside mechanical/thermal forces at work,and this operating condition may cause the fatigue damage ofpiston, like piston side wear, piston head cracks and so on.

In engine, always transfer of heat takes place due to differencein temperature. Thus, there's heat transfer to the gases duringintakes stroke and the 1st of the compression stroke, howeverthe throughout combustion and expansion processes the heattransfer happen from the gases to the walls. So the pistoncrown, piston ring and the piston skirt should have enoughstiffness which can endure the pressure and the frictionbetween contacting surfaces. Additionally, as an main part inengine, the operating condition of piston is directly associatedwith the reliability and durability of engine.

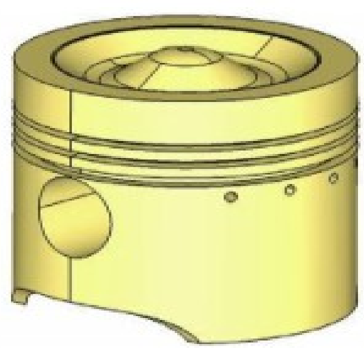

Fig.1 Piston in CI engine

The engine used for this work is a four cylinder fourstroke air cooled type Bajaj Kawasaki diesel engine. Theengine specifications are given in Table.1.

A. Finite element analysis: FEA implement is the mathematical idealization ofauthentic system. It is a computer predicated method thatbreaks geometry into element and link a series of equation toevery, which are then solved simultaneously to evaluate thedemeanor of the complete system. It is utilizable for quandarywith perplexed geometry, loading, and material propertieswhere exact analytical solution are arduous to obtain. Mostoften utilized for structural, thermal, fluid analysis, howeverwide applicable for other type of analysis and simulation.

Table .1 Engine specifications

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

B. Methodology of piston analysis: The Piston during the working condition exposed to thehigh gas pressure and high temperature gas because ofcombustion. At the same time it is fortified by the minutem terminus of the connecting rod with the avail of piston pin(Gudgeon pin). Therefore the methodology for analyzing thepiston is considered as; the gas pressure given 180bar isapplied uniformly over top surface of piston (crown) andapprehended all degrees of liberation for nodes at upper amoiety of piston pin boss in that piston pin is going to finetune. Considering the type of fit between piston pin and pistonis clearance fit. Only the upper a moiety of piston pin boss isconsidered to be fine-tuning during the analysis.

C. 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 % [4-5]

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D. Geometry: The below image shows the geometry of piston foreign usedfor FEA.A geometrical model of piston is prepared by modelingsoftware's like CREO software or CATIA V5 which can alsobe modeled in the analysis software's like ANSYS. Figure.2show the piston engendered by CAD software for furtheranalysis.

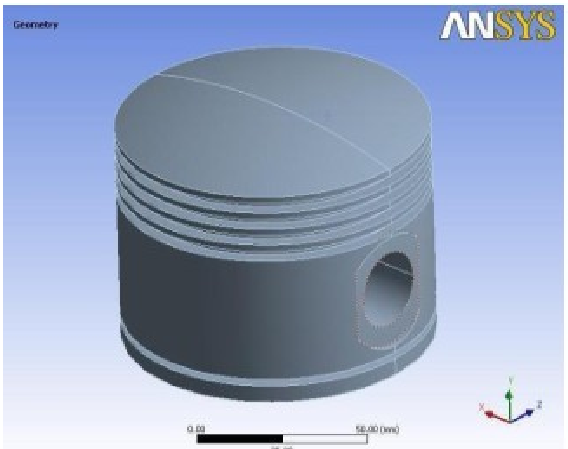

Fig. 4 Geometry of piston

E. Finite element model: The element type selected for meshing in the pistonmodel is SOLID187 tetrahedron type of element which ishigher order tetrahedral element. The mesh count for themodel contain 71910 number of nodes and 41587 number ofelements. Figure.3 shows the meshed model of piston.

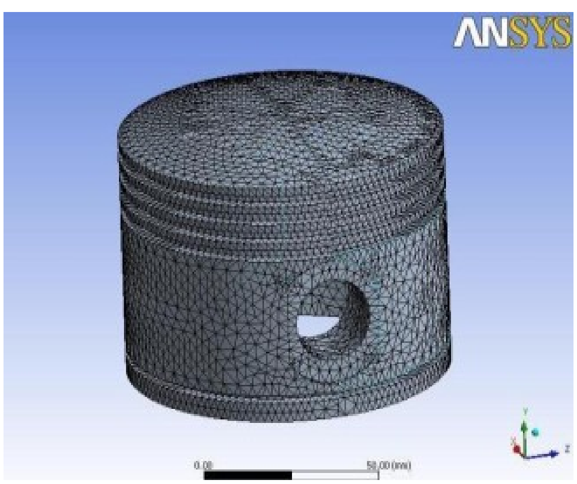

Fig.3 Meshed model of piston

F. Loading & boundary conditions: Figure.4 show the loading and boundary conditionsconsidered for the analysis. The uniform pressure of 18MPa isapplied on crown of piston (red color) and the model isconstrained on upper a moiety of piston pin aperture as shownby violet color.

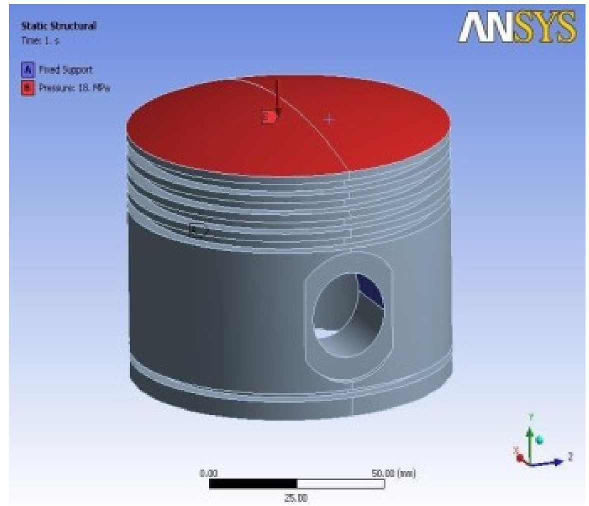

Fig.4 Loading and boundary conditions on piston

IV. RESULT ANALYSIS

A. Total deflection

Figure.5 show the maximum deflection in the pistongeometry due to the application of gas pressure which is0.29669 mm observed at the central portion of the pistoncrown

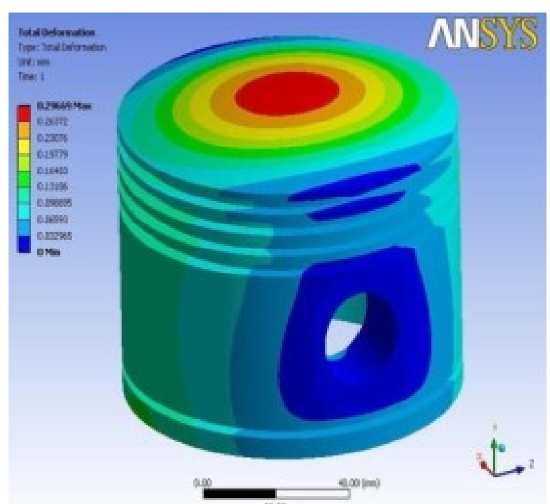

Fig.5 Total deflections on the piston head

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B. Maximum principal stress: Figure.6 show the distribution of localized and observedat inner side of piston pin boss. The overall maximum stressesin the piston body are of value 231.25 N/mm^2 at the inner sideof piston crown as well as piston boss.

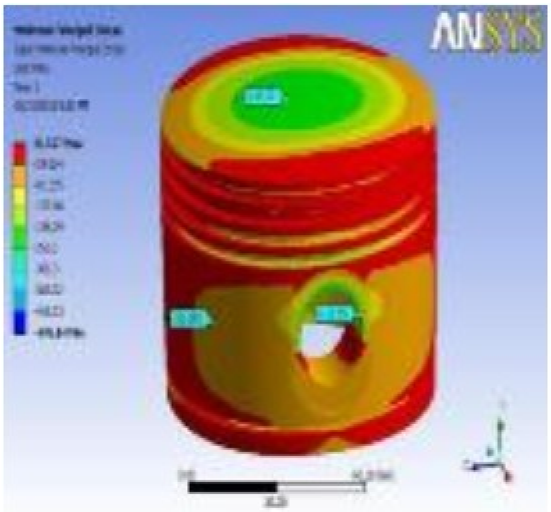

Fig.6 Maximum principal stress on piston

C. Minimum principal stress

Figure.7 show the distribution of the minimumprinciple stresses induced within the piston body. The mostmaximum values of equivalent stresses are goes up to - 376.74N/mm^2, which are highly localized and observed at inner sideof piston crown & skirt junction. The overall maximumstresses in the piston body is -250.5 N/mm^2 at the top of pistoncrown

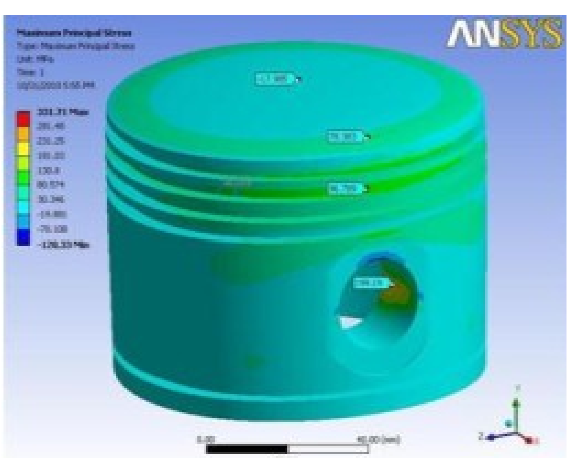

Fig.7 minimum principal stress on piston

V. CONCLUSION

Due to the deformation, the greatest stress concentration is caused on the upper end of piston, the situation becomes more serious when the stiffness of the piston is not enough, and the crack generally appeared at the point A which may gradually extend and even cause splitting along the piston vertical. 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 to reduce the deformation.

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