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RESEARCH ARTICLE

OPTIMIZATION AND ANALYSIS OF AUTOMOTIVE TWO WHEELER ENGIN PISTON THROUGH THERMO- MECHANICAL COUPLING USING PRO E AND ANSYS

*Abraham Eben Andrews, A. and Selvaganapathy, P.M.

Mechanical Engineering, Hindustan Institute of Technology and Science, Chennai, India

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ABSTRACT

Engine Pistons are one of the most complex components among all the automotive. In this article 3D model of engine piston is established by means PRO-E software and the finite element model for the same was established by means of the ANSYS software. The cynosure of the project is to rectify the disadvantages found in the existing piston models. The same can be achieved by modeling and analysis of the new piston. The three different piston models of same capacity engines are taken and the respective modeling and analysis are carried out and the results are tabulated. The structural, thermal, thermo- mechanical and dynamic analyses are carried out to determine the results. Using the analysis, stress distribution, temperature distribution, and deformation length are found and tabulated. With aid of the tabulated information, the modeling of new piston is made and the analysis for the respective is carried out. Calculating results indicates that the maximum stress concentration occurs at the upper end of the piston boss inner hole due to peak pressure of fuel.

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INTRODUCTION

Due the development of automobile technology, the reliability, efficiency, durability, low exhaust gas and noise and operating performance of automobile engines is wished to be carried to a higher level. It is well known that almost all these properties of an internal combustion engine are closely associated with its mechanical behaviors. Thus, it is necessary to reveal these mechanical characteristics of an engine in order to improve its general property and quality, and it is far more important in piston system.

Problem Ststement

In engineering field, the result of failure must be exactly true. Finite element analysis will be able to analysis the created design as well when all the specification is known, then, that can show the better result. From the review, there are several problems should be highlighted in this project. These include Failure of piston engine may cause damage to automobile as well as an accident and It is a need to study the failure of piston to prevent any harm injury to human.

Objective

- They are three main objective that must be achieved
- To develop the geometry of the piston using Pro- E software
- To investigate maximum stress using stress analysis
- To investigate maximum temperature using thermal analysis

Corresponding author: Abraham Eben Andrews, A
Mechanical Engineering, Hindustan Institute of Technology and Science, Chennai, India

Modelling and Analysis

Modeling of Piston

Pro E, PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. The models consist of 2D and 3D solid model data, which can also be used downstream, in finite element analysis, rapid prototyping, tooling design, and CNC manufacturing. All data is associative and interchangeable between the CAD, CAE and CAM modules without conversion. A product and its entire bill of materials can be modeled accurately with fully associative engineering drawings, and revision control information. The associatively functionality in Pro/E enables users to make changes in the design at any time during the product development process and automatically update downstream deliverables. This capability enables concurrent engineering design, analysis and manufacturing engineers working in parallel and streamlines product development processes.

Specifying Geometry: This can be done either by entering the geometric information in the finite element package through the keyboard or mouse, or by importing the model from a solid modeler like Pro/ E.

Specify Element type & material properties: In an elastic analysis of an isotropic solid, these consist of the Young's modulus and the Poisson's ratio of the material.

Mesh the Object: Then, the structure is broken into small elements. This involves defining the types of elements into which the structure will be broken, as well as specifying how the structure will be subdivided into elements.

Apply Boundary Conditions & External Loads: Next, the boundary conditions and the external loads are specified.

Generate solution: Then the solution is generated based on the previously input parameters.

Post-Processing: Based on the initial conditions and applied loads, data is returned after a solution is processed. This data can be viewed in a variety of graphs and displays.

Refine the mesh: FEM are approximation increases with the number of elements used. The number of elements needed for an accurate model depends on the problem and the specific results from a single finite element run, you need to increase the number of elements in the object and see if or how the results change.

Interpreting Result: This step is perhaps the most critical step in the entire analysis because it requires that the modeler use his or her fundamental knowledge of mechanics to interpret and understand the output of the model. This is critical for applying correct to solve real engineering problems and in identifying when modeling mistakes have to be been made.

Model 1

We choose a Indian bike engine with a four-stroke, 149.1cc engine. It has 15.06ps of peak power at 9000 rpm and a maximum torque of 12.5Nm at 6000 rpm.

Table 1. Specification of model 1 automotive engine

Engine type	Air-Cooled
Stroke	4 Stroke
No. of cylinders	Single Cylinder
Bore x Stroke	57mm x 56.4mm
Displacement	149cc
Power	15.06ps @ 9000rpm
Torque	12.5N-m @ 6000rpm

Table 2. Aluminum alloy4032 Properties

Chemical composition of model 1 engine piston: Si=12.2%, Mg=1.05%, Cu=0.9%, Ni=0.9%, Al=84.95%		
PROPERTY	VALUES	UNITS
Density	2.68×10^3	Kg/m^3
Modulus of elasticity	79	Gpa
Thermal expansion	19.4×10^{-6}	$◦C^{-1}$
Specific heat capacity	850	J/(Kg×K)
Thermal conductivity	154	W/(m×K)
Tensile strength	379	Mpa
Yield strength	317	Mpa
Shear strength	262	Mpa
Fatigue strength	110	Mpa
Hardness	120	HB
Annealing temperature	413	◦C
Solidus temperature	532	◦C
Liquidus temperature	571	◦C
Solution temperature	510	◦C

Its torque unfolds offers the bike a high level of low-speed tolerance and obviates the want for frequent shifting into a lower gear. The low-end torque additionally aids in achieving high mileage. This engine delivers a fuel economy exceeding 45 km/l in city conditions while highway driving may give you an additional mileage of 10-15 km/l.

Fig. 1. Solid Model Of The Piston 1

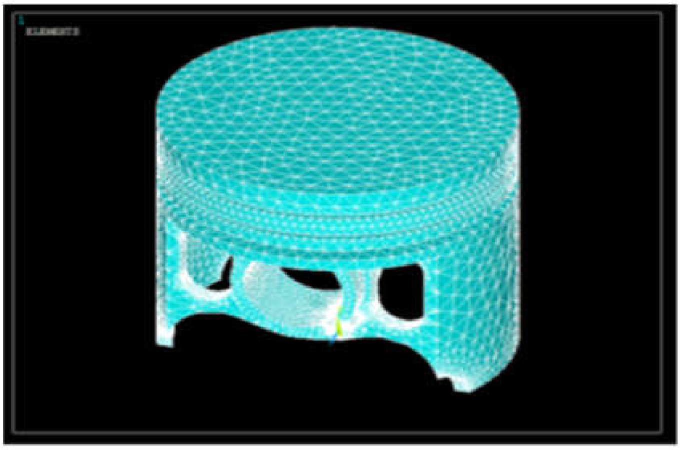

Fig. 2. Meshed View

Table 3. Boundary Conditions

Pressure applied on the piston head	65Bar
Constraint for pressure applied	On piston pin boss upper half
Temperature applied on piston head	540◦C
Temperature applied on piston	100◦C

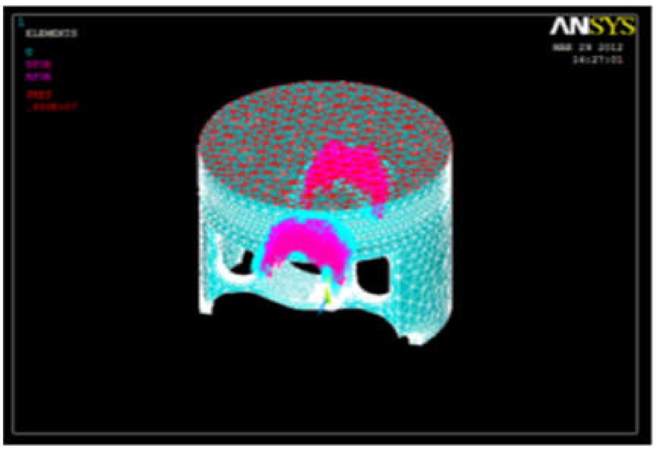

Fig. 3. Mechanical Load Applied

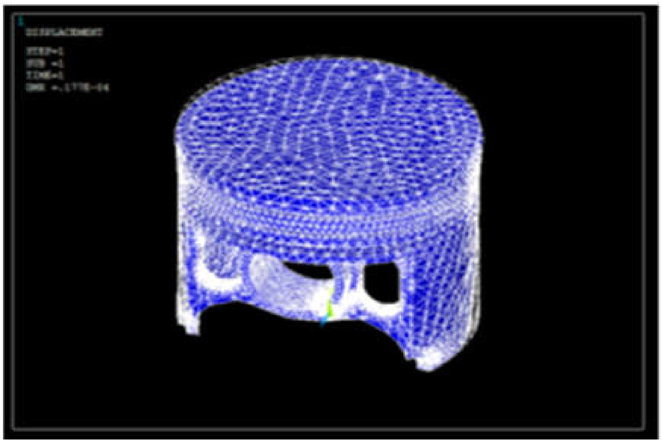

Fig. 4. Displacement View

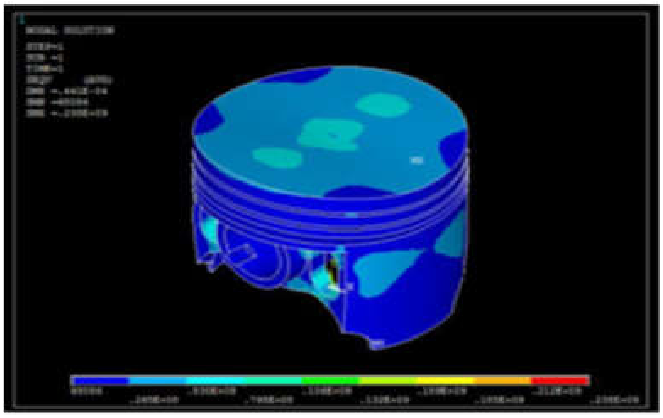

Fig. 5. Stress Deformation

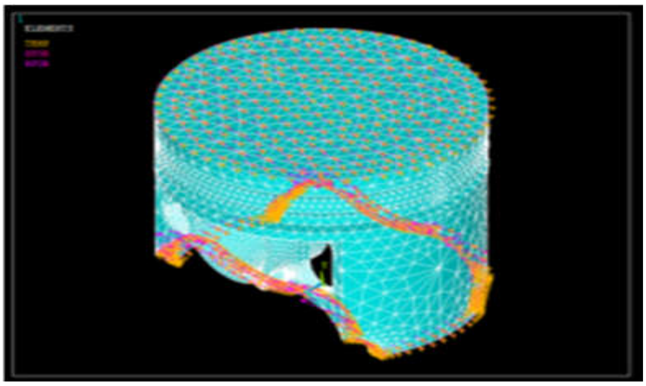

Fig. 6. Thermal Load Applied

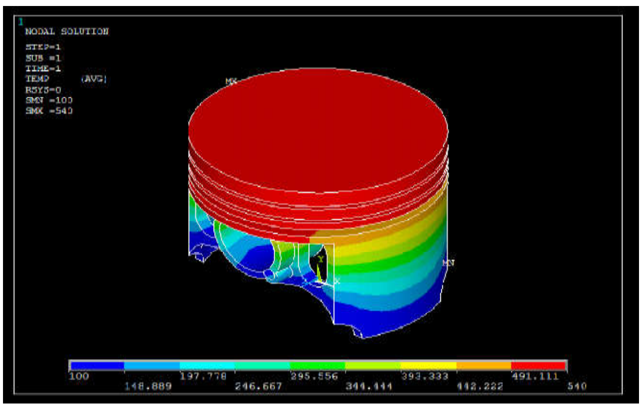

Fig. 7. Temperature Distribution

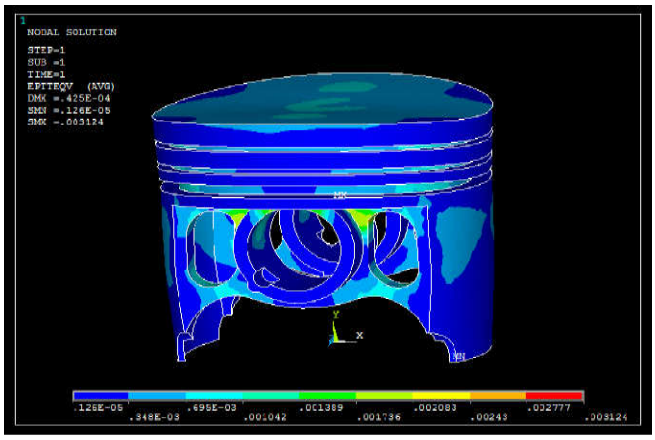

Fig. 8. Coupled Field Analysis

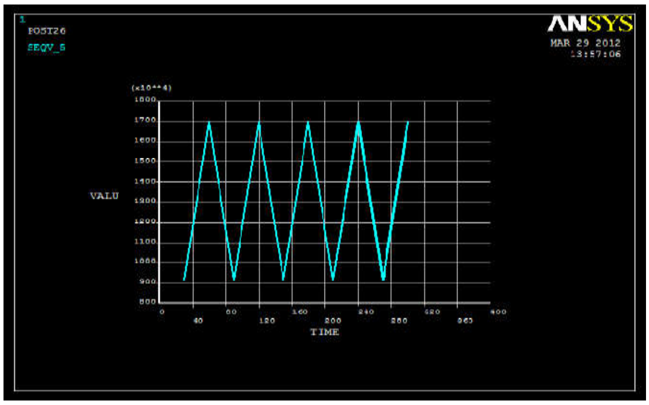

Fig. 9. Dynamic analyis

Table 4. Engine specification of model 2

Engine type	Air-Cooled
Stroke	4 Stroke
No.of cylinders	Single Cylinder
Bore x Stroke	58mm x 57.9mm
Displacement	153cc
Power	14ps @ 7500rpm
Torque	14N-m @ 6000rpm

MODEL-2

We choose a second model having VT-I engine depends on three parameters: friction reduction, complete combustion of fuel, and controlling the amount of fuel to exactly meet the driver's needs. Lower friction and complete combustion of fuel ensure lower emissions. The microprocessor senses the engine requirement, based on sensors which feed it information, like engine temperature and rpm level, and adjusts the ignition timing accordingly. The engine thus offers high fuel efficiency and wide torque band. We are using same model 1 material Table 2.

Fig. 10. Model 2 Piston

When the mechanical load in terms of gas pressure, which is produced during combustion of the engine, is 65 Bar, in which piston pin boss is constrained Piston is meshed through Solid 45 where node is formed. After applying pressure on piston head the each element tends to displacement.

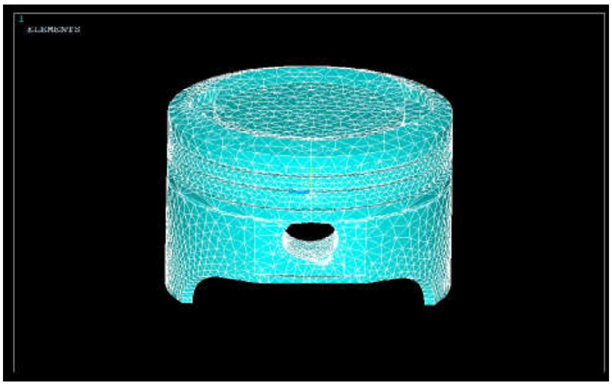

Fig. 11. Meshed View

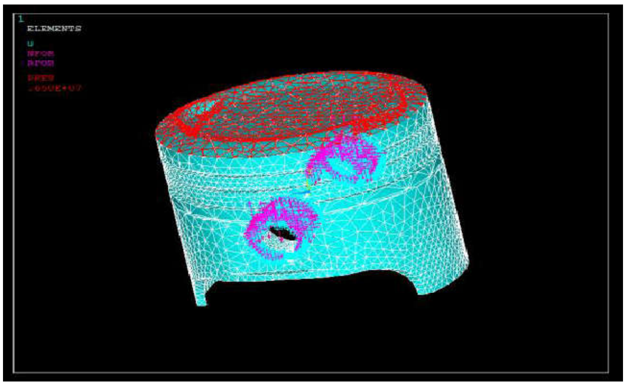

Fig. 12. Mechanical Load Applied

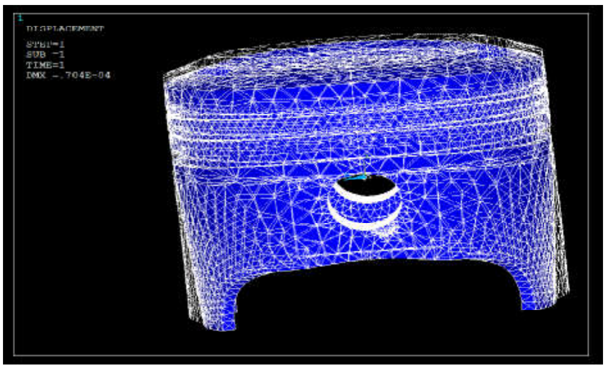

Fig. 13. Displacement View

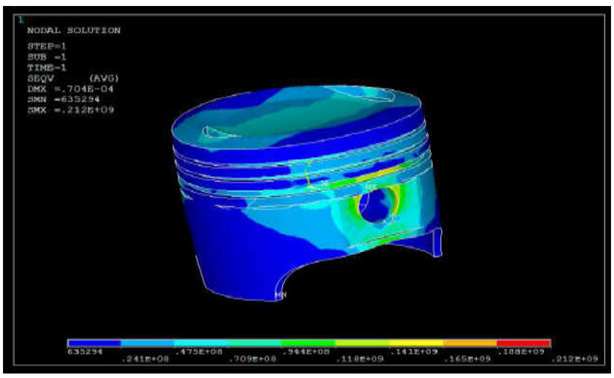

Fig. 14. Stress Deformation

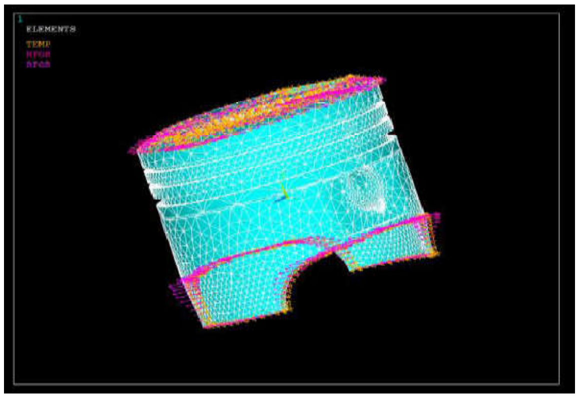

Fig. 15. Thermal Load Applied

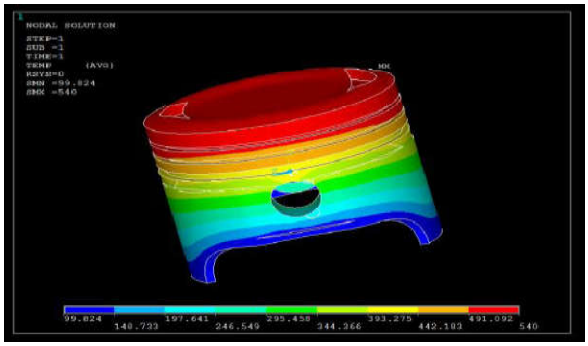

Fig. 16. Temperature Distribution

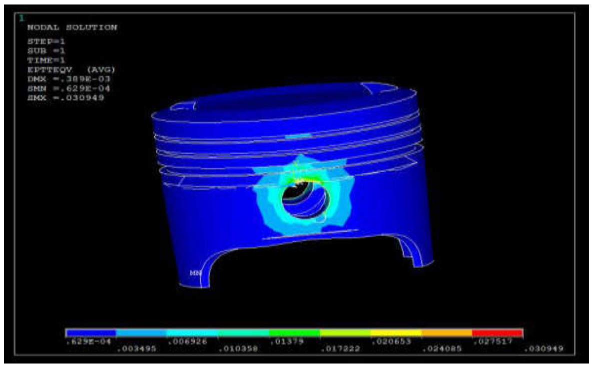

Fig. 17. Coupled Field Analysis

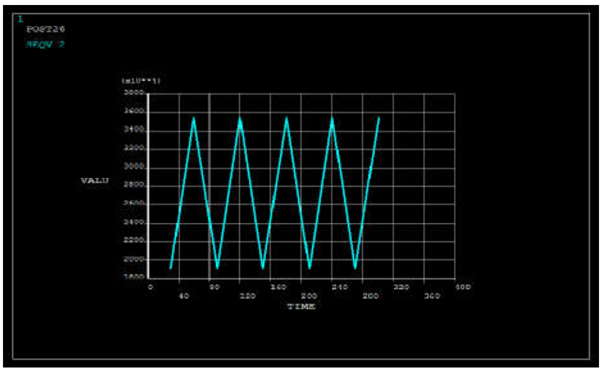

Fig. 18. Dynamic analyis

Model 3

Its 149.1 cc 4 stroke air-cooled single cylinder OHC engine churns out maximum power of 13.30 ps @ 8000 rpm and maximum torque of 13 Nm @ 5500 rpm. It has 4 speed constant mesh gear box. This low-end bike scores high on the mileage front too.

Table 5. Engine specification of model 3

Engine type	Air-Cooled
Stroke	4 Stroke
No.of cylinders	Single Cylinder
Bore x Stroke	57.3mm x 57.8mm
Displacement	149.1cc
Power	13.30ps @ 8000rpm
Torque	13N-m @ 5500rpm

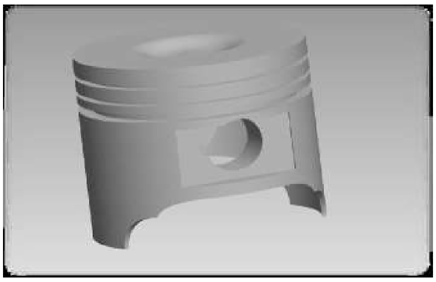

Fig. 19. Model 3 Piston

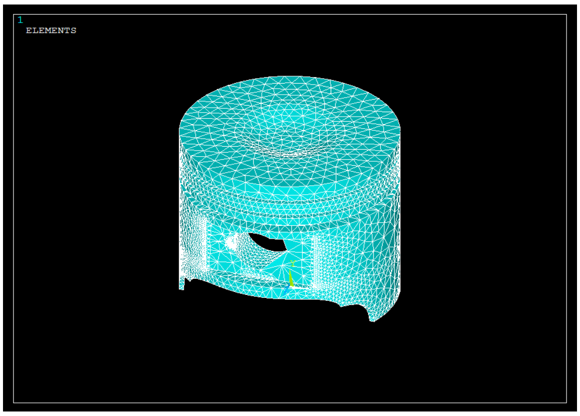

Fig. 20. Meshed View

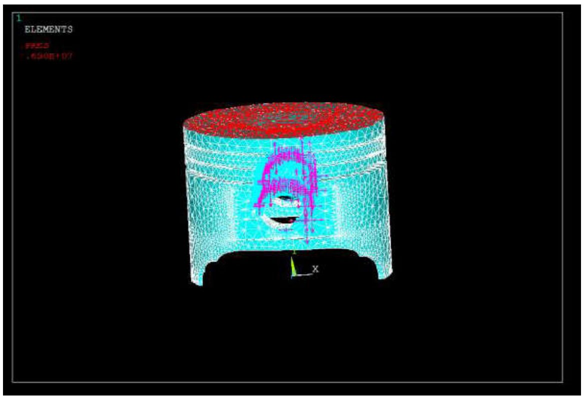

Fig. 21. Mechanical Load Applied

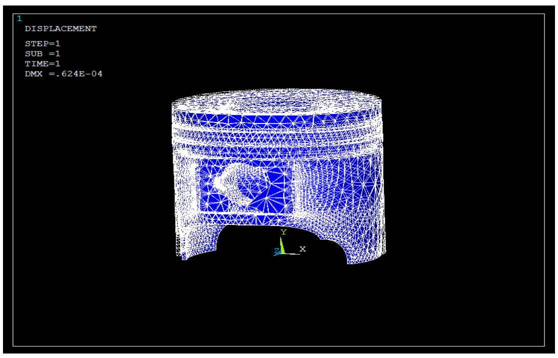

Fig. 22. Displacement View

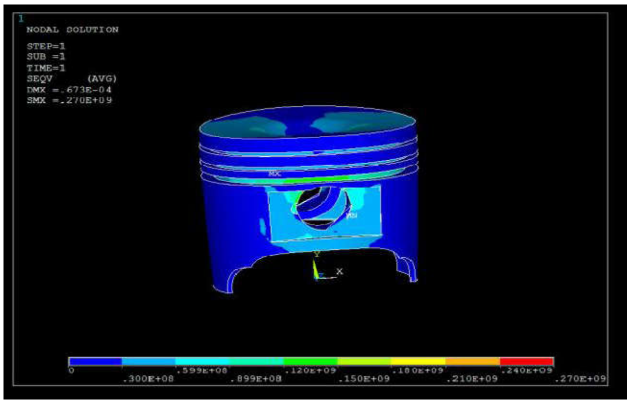

Fig. 23. Stress Deformation

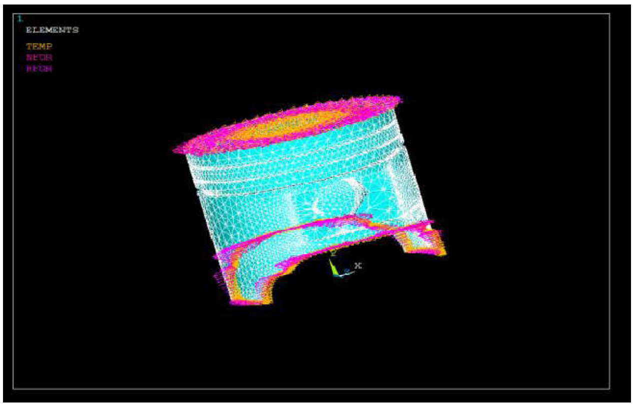

Fig. 24. Thermal Load Applied

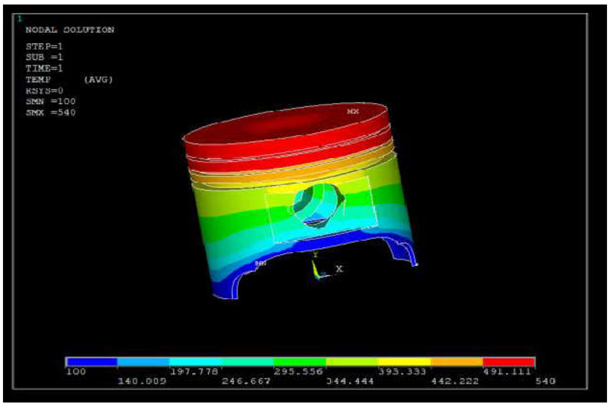

Fig. 25. Temperature Distribution

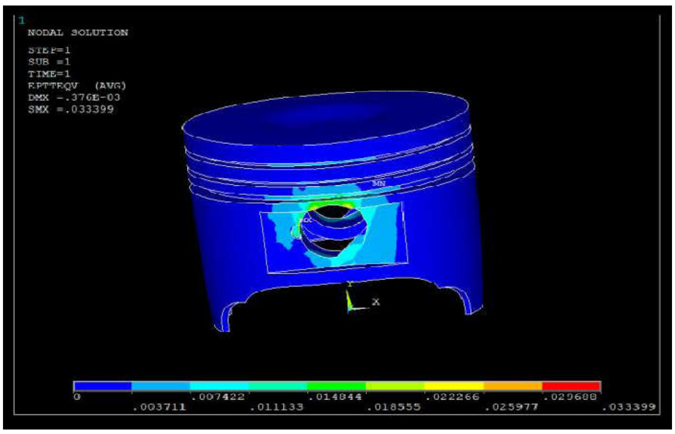

Fig. 26. Coupled Field Analysis

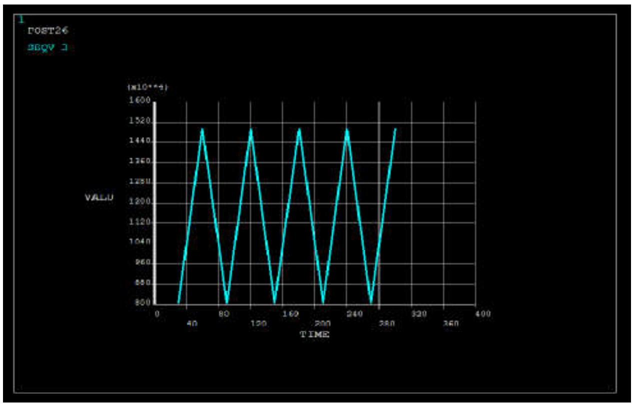

Fig. 27. Dynamic Analysis

New Piston Model

Ideology for design of new piston

The main ideology for the design of new piston is to compare the results obtained from the above said three pistons and rectify the cause for the problem in proper Stress Distribution. From the above results it is seen that in Model 2 piston stress was not evenly distributed when compared to the other two due to its complex shape and model 1 piston was having moderate stress distribution. Then we decided to change the piston crown shape of model 1 piston to achieve more Stress Distribution. So we had made several design models changing the crown shape of the piston. Those models are as follows.

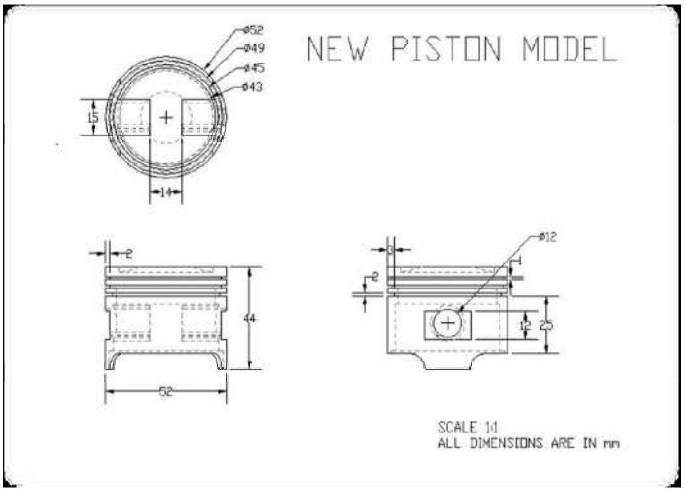

Fig. 28. Drafted View

Fig. 29. Model of New piston

we were not able to attain even Stress Distribution. Then after making several changes to the shapes finally we are able to achieve an even Stress Distribution with the following model. For this new model we have done the 2-0 design, analysis & design calculation as follows.

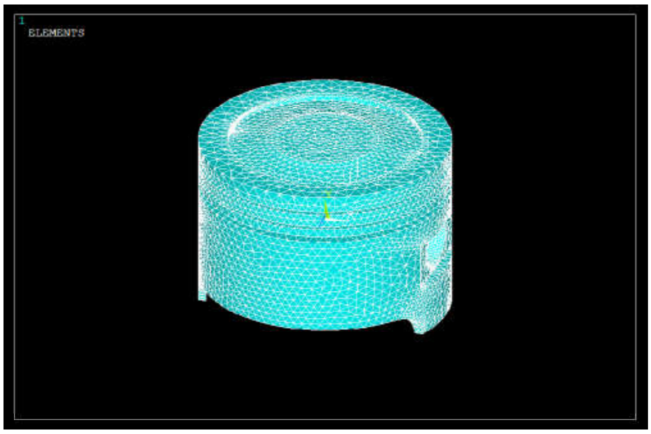

Fig. 30. Meshed View

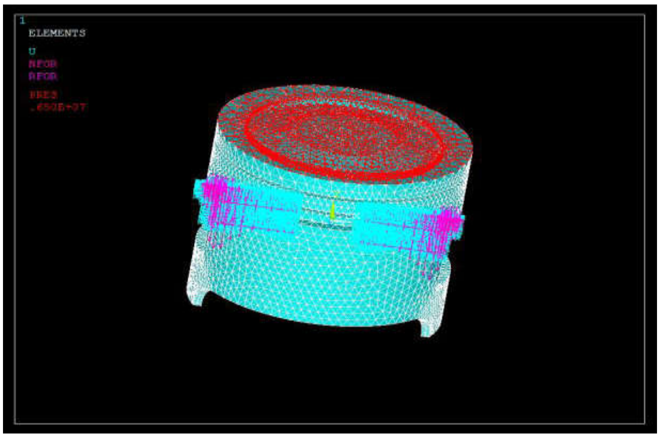

Fig. 31. Mechanical Load Applied

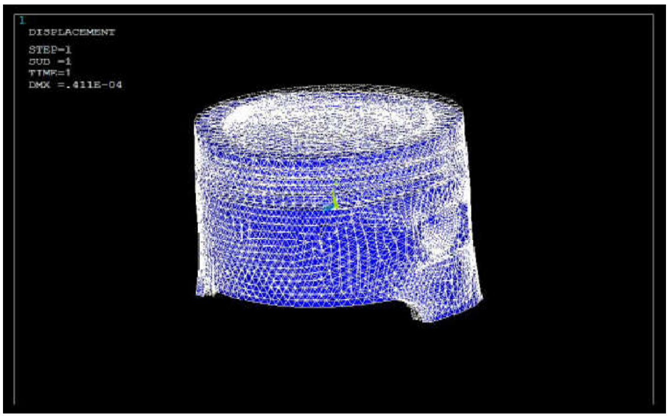

Fig. 32. Displacement View

Aluminum 4032 alloy material is used as the element for piston. After then the piston pin boss is constrained and applying the gas pressure produced by combustion is 65 Bar (1000 Psi). To view the material deformation the Vonmises stress is viewed and it is a standard stress. Vonmises stress is considering all stress acting on the piston 198N/MM2and the material deformation is 0.041 mm.

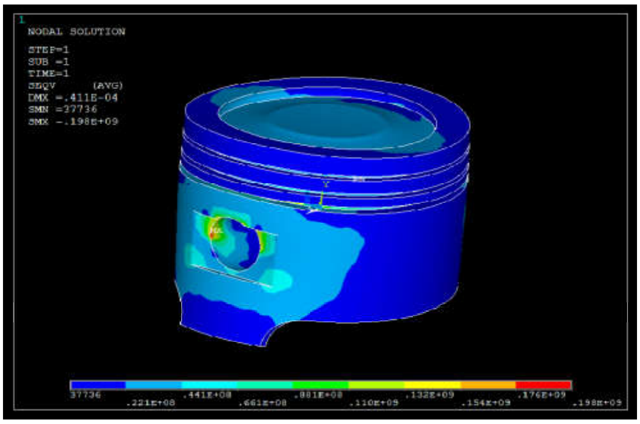

Fig. 33. Stress Deformation

Thermal load is applied on the piston head and Solid 70 is used as the element for thermal load. SOLID70 has a 3-D thermal conduction capability. Piston lumen is constrained and thermal load applied on the piston head of 540□. Temperature applied on piston lumen is lOO□. Temperature distribution was clearly seen ranging from 540□ to 1OO□.

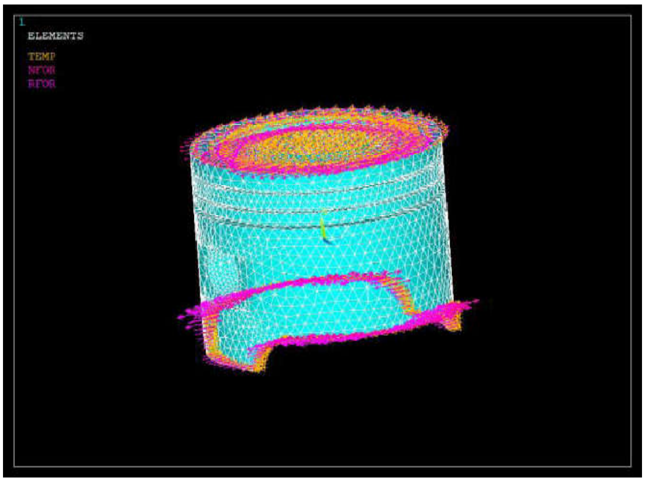

Fig. 34. Thermal Load Applied

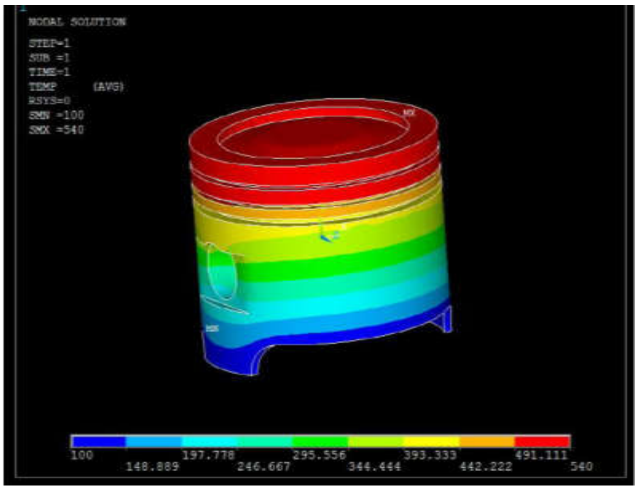

Fig. 35. Temperature Distribution

In general piston is subjected to both the structural and thermal loads. So, it is necessary to carry out couple field analysis to determine the occurrence of stress caused by effect of both structural and thermal loads. Temperature change will cause thermal load and the deformation, but these kinds of deformation affect the quantity of heat transmission within the piston.

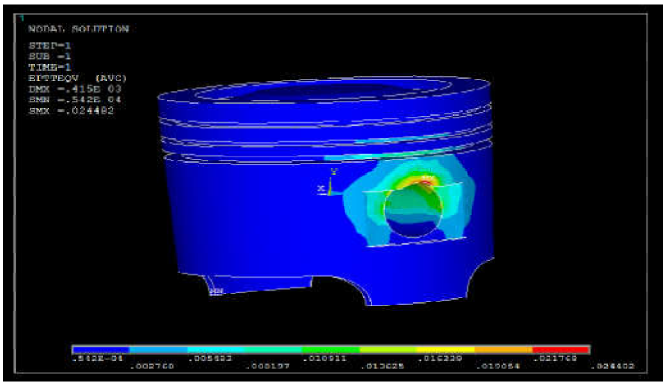

Fig. 36. Coupled Field Analysis

In mechanical dynamic analysis the pressure applied is varied for different time intervals and the result is obtained in the form of graph. Pressure is varied for every 30 seconds and the same is repeated for 10 time periods.

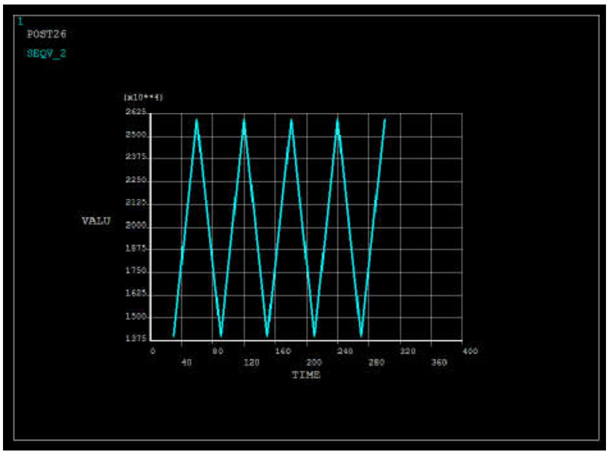

Fig. 37. Dynamic Analysis

Model	Maximux coupled stress N/m2	Displacement Mm	Maximum stress N/mm2
Model 1	0.0312	0.04	238
Model 2	0.033	0.06	270
Model 3	0.0309	0.07	212
New Model	0.024	0.04	198

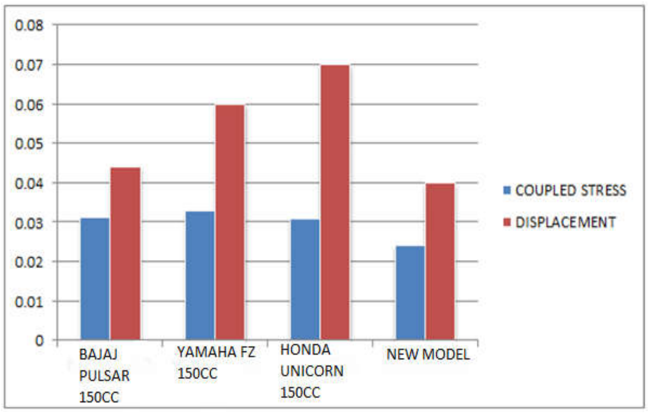

Fig. 38. Comparison graph for coupled stress & displacement

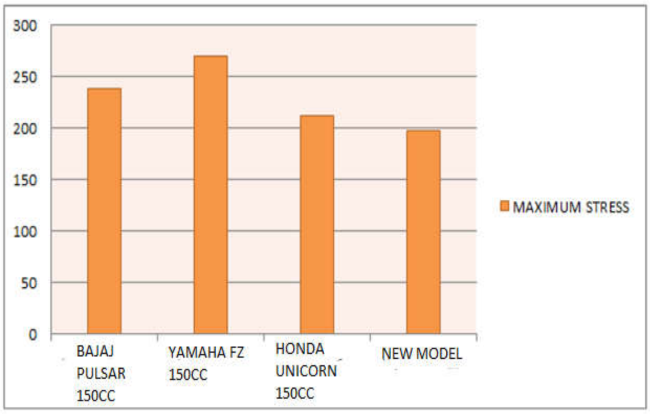

Fig. 39. Comparison of maximum stress

Conclusion

The results obtained by the means of structural and thermo mechanical loads are tabulated.

Result Comparison

The above table clearly lists the displacement and maximum stress obtained by means of both the structural and thermo mechanical analysis of all the four pistons. The following graph enables easy comparison of the tabulated values. With the aid of the graph, one can clearly have a view about the stress distribution and deformation. The graph ensures one to understand the results attained by the different types of piston.

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