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Comparative Study Of 2-Dimensional And 3-Dimensional Static Analysis On Piston Of IC Engine Using Finite Elements

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Abstract: *Piston is one of the main components composing an internal combustion engine and a lot of empirical knowledge and advanced technologies are fully used for the piston design. The piston primary motion is an important phenomenon in IC engine. It occurs due to piston transverse and rotational motion during piston reciprocating motion. The piston primary motion results in engine friction and engine noise .Recent studies are aimed at reducing the engine friction as well as the noise generated due to piston secondary motion. In this study an emphasis is given to study the 2D and 3D finite elements used for developing axi-symmetric and solid finite element model respectively of the piston model. The results of the both analyses are compared to arrive for the most reasonable but near to exact solution based on the theoretical values.i.e Stress and displacement values.* ***Keywords:*** *Axi-symmetric element, Finite element model, solid finite element.*

I. Introduction

Piston is one of the main component composing an engine and lot of empirical knowledge and advanced technologies are fully used for the piston design. Because the weight reduction of the piston and its high durability under severe operating conditions must be realized especially for small high performance engine, if the piston motion and dynamic load at its high speed operating conditions could be examined.

Inside the engine cylinder, side forces on the piston cause lateral translation and rotational motion of the piston and impact on the cylinder liner . the impact is cushioned by a thin oil film,and the piston is supported on the cylinder liner mainly on the piston skirt. These secondary piston motions are of great importance because they affect the skirt to liner impact force, skirt lubrication, friction andhow this impact excitation energies is damped, transmitted and eventually radiated as noise namely engine structure.details of skirt liner intraction depends on various piston design parameters, oil film behaviour,on engine operating conditions.piston secondary motion have been under intense investigation in recent years,both experimentally and analylitically, in efforts to design new light weight,low friction pistons with low noise and vibration characteristics.

The piston secondary motion is an important phenomenon in IC engine. It occurs due to piston transverse and rotational motion during piston reciprocating motion. The piston secondary motion results in engine friction and engine noise .There has been lot of research activities going on in piston secondary motion using both analytical models and experimental studies. These studies are aimed at reducing the engine friction as well as the noise generated due to piston secondary motion.[1]

In addition to manufacturing tolerances that can cause the liner to deviat from this ideal condition, the liner will deviate from the ideal geometry as a result of the thermal and mechanical loads during engine operation. The load acting on the liner come from a variety of conditions, e.g.

- Assembly of the cylinder head and cylinder head gasket.
- Thermal expansion variations between the cylinder block and cylinder head.
- Gas pressure during fired operation.

Dr.S.N.Kurbet and Mr.Vinay.V.Kuppast et al, presented the results of a finite element study of a piston ring under assembly load in terms of induced stress and ring gap. The study included the stress analysis at the interface between the coating and substrate of ring for various lay design. The information from the analysis would serve to reduce the design performance testing cycle time and be useful in the development of coating techniques.[2]

1.1 Plane42 Element Description for 2D Axisymetric structural Solid

PLANE42 is used for 2-D modeling of solid structures. The element can be used either as a plane element (plane stress or plane strain) or as an axisymmetric element. The element is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

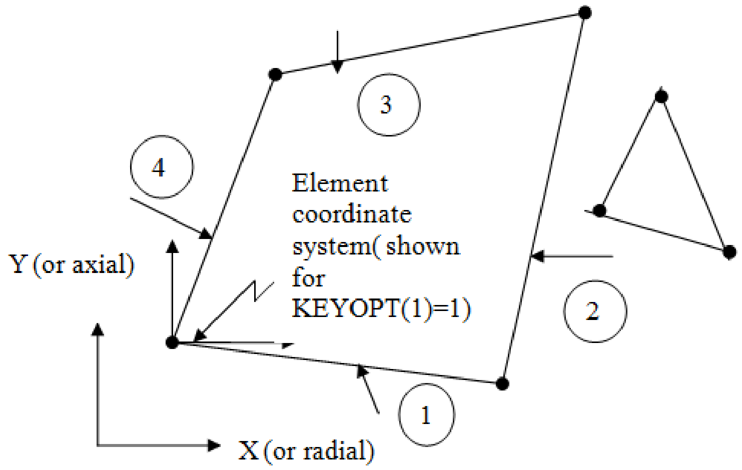


Fig 1: plane 42 geometry

1.2 Solid45 Element Description of 3D structural Solid

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. A reduced integration option with hourglass control is available. See SOLID45 in the ANSYS, Inc. Theory Reference for more details about this element. A similar element with anisotropic properties is SOLID64. A higher-order version of the SOLID45 element is SOLID95.

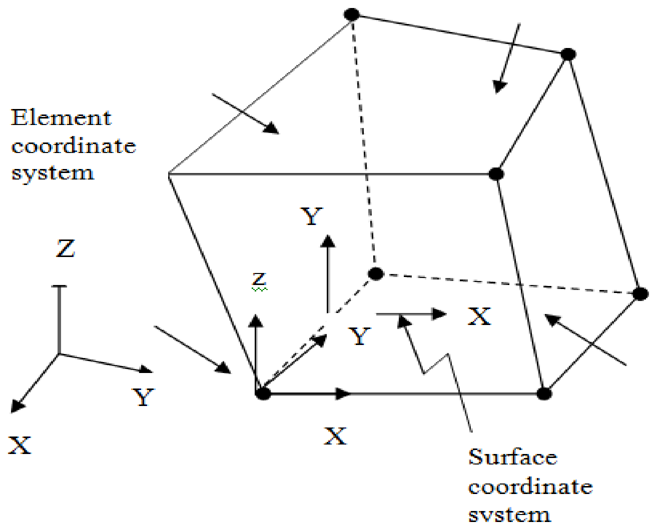


Fig 2. Solid 45 geometry

II. Objectives

1. To study of 2D and 3D elements for structural behaviour of IC diesel engine piston.
2. To compare stress and deformation for 2D and 3D elements.
3. To find out the most desirable FE analysis for piston problems by comparing the results of 2D and 3D finite elements analysis.

III. Method

An overview is given based on a literature survey of general theory for IC engine. The system is modeled using CAD software to create needed geometry and finite element software to implement physics and carry out simulations.The simulation aspects of the Finite element Method is carried out by applying the boundary conditions. Then the FE solution results are tabulated. The conclusion is made by comparing the stress and displacement values that are obtained from the 2D and 3D solutions, using a commercial software ANSYS.

IV. Design Parameters Of Piston

Dimensions in mm
Diesel piston designed for 3000rpm
Assuming Diameter (D)=100mm
Height (H) =1.31×D=1.31×100=131mm
Height of top land (h) =0.17D=0.17×100=17mm
Crown thickness (h_{cr}) for cast piston=0.20×D= 0.20×100=20mm
Height of the first hand (h_1) =0.058×D=0.058×100=5.8mm
Distance between piston lower edge and pin axis (H_1) =0.44×H = 0.44×131 = 57.64mm
Height of skirt (H_2) = 0.66×H =0.66× 131= 86.46mm
Pin external diameter (d_{ex}) = 0.36×D = 0.36×100 = 36mm
Design of piston rings
Thickness (t) =D/25 = 100/25 =4mm
wide of the rings (b) =5.3mm
max diameter (D)=110mm

V. Geometric Models From Ansys

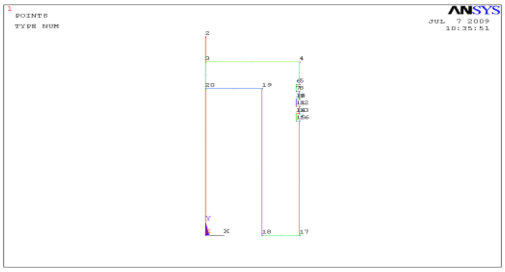


Fig 3. Line geometry for 2D and 3D piston

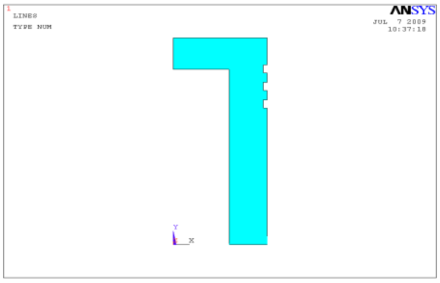


Fig 4. Area modeling for 2D and 3D piston

Fig 5. ¼ solid model of piston

Table 1: Element Types

SL NO	TYPE OF ANALYSIS	ELEMENT TYPE	ANSYS LIBRARY
1	2-DIMENSIONAL	2D AXISYMMETRIC OF PISTON	PLANE 42
2	3-DIMENSIONAL	3D SOLID ELEMENT	SOLID 45

Table 2: Material Properties

TYPE OF MATERIAL	YOUNG'S MODULUS	POISSON'S RATIO
CAST IRON	1.7*E5	0.23

Table 3: Boundary Conditions

CONSTRAINTS	LOADS
ALL DEGREES OF FREEDOM AT BOTTOM OF PISTON	UNIFORM COMBUSTION PRESSURE OF 5 N/MM² ON THE TOP OF THE CROWN

The meshing and boundary conditions applied to the piston 2D model in ANSYS are shown in Figure 6 and Figure 7 respectively.

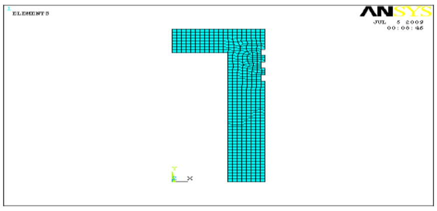
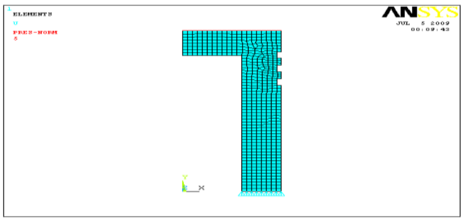



Fig 6: Meshing of 2- dimensional piston model Fig 7: Boundary conditions of 2-dimensional piston model

The meshing and boundary conditions applied to the piston 3D model in ANSYS are shown in Figure 8 and 9 respectively.

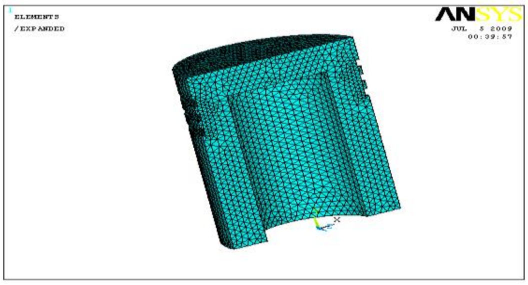
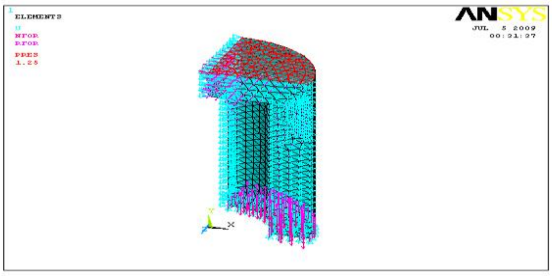
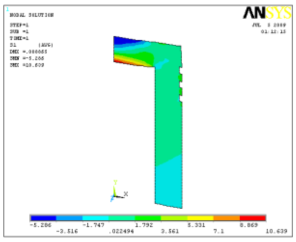



Fig 8: Meshing of 3-dimensional piston model Fig9: Boundary conditions of 3-dimensional piston model

VI. Result And Discussion

The ANSYS simulation post processor outputs are considered for the analysis of results and are listed as follows:

1. Stress distribution in piston crown and at piston grooves for 2-dimensional model as well as 3-dimensional model.
2. Displacement of piston and the plots of displacements considered at crown center to edge and another at piston ring grooves for 2-dimensional and 3-dimensional analysis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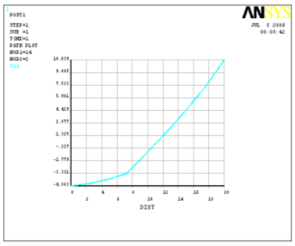
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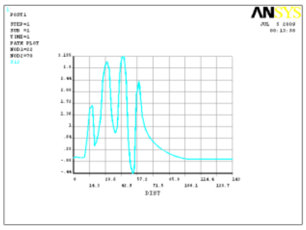
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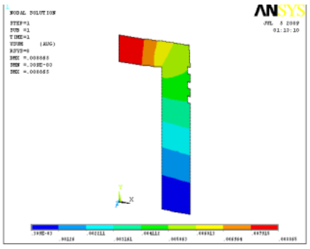
Fig 10: a. Stress contours in piston crown b. Stress between top center of crown and bottom center of crown c. Stress at piston grooves of 2- dimensional model.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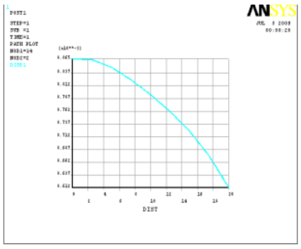
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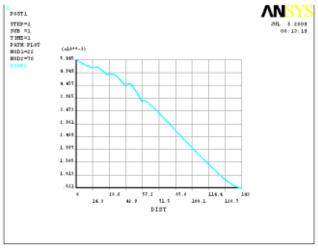
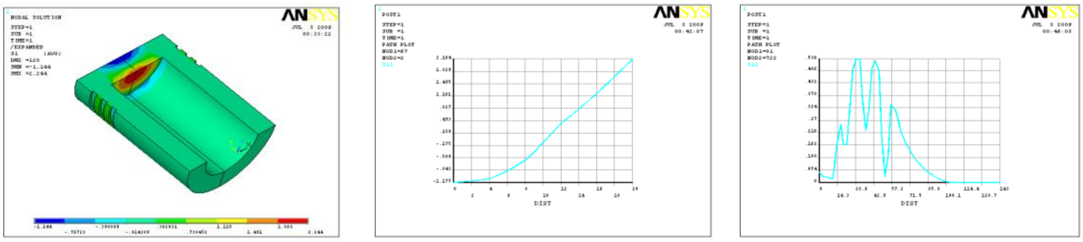
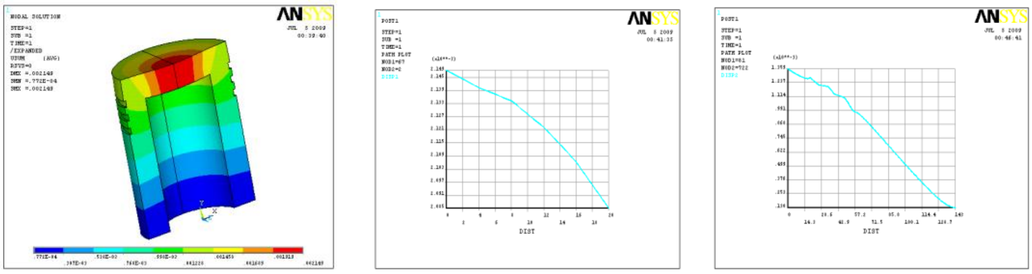

c

Fig 11: a. Displacement contours b. Displacement plot at the crown c. Displacement at piston grooves for 2-dimensional axi-symmetric model.



a b c

Fig 12: a. Stress contours in piston crown b. Stress between top center of crown and bottom center of crown c. Stress at piston ring grooves of 3- dimensional model.



a b c

Fig 13: a. Displacement contours b. Displacement plot at the crown c. Displacement at piston grooves for 3-dimensional axi-symmetric model

The above stress distribution plots and displacement plots for 2-dimensional analysis and 3-dimensional analysis closely match with each other showing the nature of the curve is just similar .This trend shows that the analysis above 2-dimensional anlysis is having the same result that of 3-dimensional analysis. However the values obtained for 2-dimensional and 3- dimensional analysis different values shown in table.

Table 4. 2D, 3D Stress and displacement values

TYPE OF ANALYSIS	TYPE OF ELEMENT	STRESS VALUES		DISPLACEMENT VALUES	
		MAX	MIN	MAX	MIN
2-DIMENSIONAL ANALYSIS	2-D PLANE42	0.105N/MM2	0.5N/MM2	0.85	0.5
3-DIMENSIONAL ANALYSIS	3D SOLID45	0.1N/MM2	0.5N/MM2	0.13	0.32

VII. Variation Of The Theoretical Results Is Shown In Figure

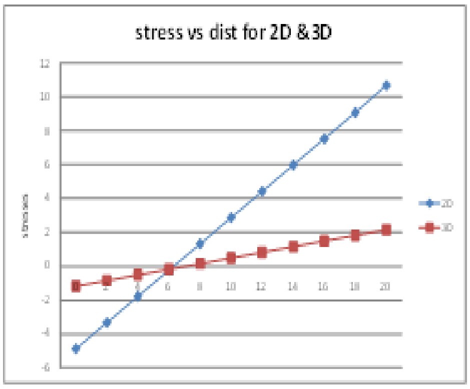


Fig14: 2D &3D Stress distribution near piston crown

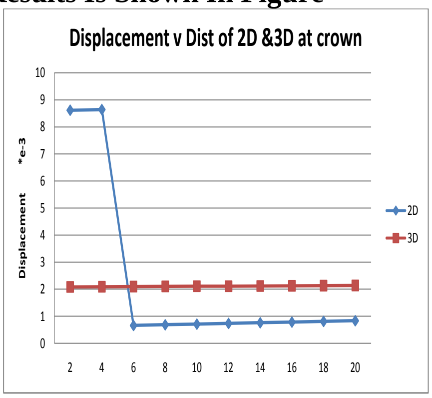


Fig15: 2D &3D displacement plot near piston crown

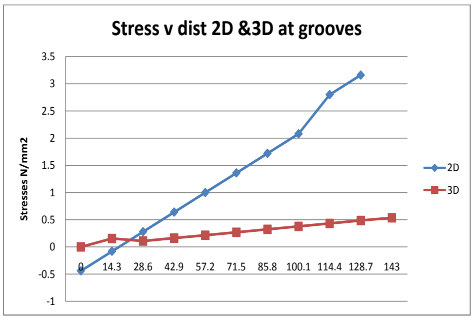


Fig 16: 2D &3D Stress distribution near piston ring grooves

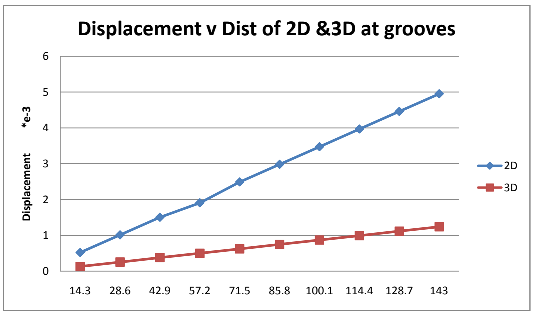


Fig 17:2D &3D displacement plot near piston ring groove

VIII. Conclusions

The conclusions are made from this study, the choice between 2-D and 3-D depends on the complexity (intrinsic or extrinsic) of the problem. The comparison of 2-D and 3-D analysis of Piston reveals that,3-D analysis stress distribution and deformation are much nearer to the experimental values compared to 2-D analysis. The structural behavior is easily understood in 3-D as compared to 2-D analysis. The elements types, mesh qualities would be considered by experience in determining the type of analysis.

Future Scope

2-D and 3D non-linear analysis proposed by considering dynamic forces for entire piston-cylinder – crankshaft assembly and the result may be compare to arrive to the choice of type of analysis which leads to the optimization of the design process.

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