International Journal of Advance Research in Science and Engineering
Vol. No.5, Special Issue No. 01, March 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

PREDICTION OF PISTON SLAP OF IC ENGINE USING FEA BY VARYING GAS PRESSURE

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ABSTRACT

The automotive industries in recent years are growing with a faster rate with an emphasis on the development of quieter engines to minimize noise and vibration. Hence by improving performance, contribution can be done to minimize the noise pollution. In present work the study of engine part, viz. piston is considered as main source of vibration and noise due to slap. The motion of piston in cylinder from TDC to BDC is of two types, primary motion and secondary motion. The secondary motion gives the lateral motion of piston perpendicular to the axis of the motion of the piston. Hence, the lateral displacement of the piston is studied considering the different gas pressure on the piston for different crank angle position. The gas pressure curve is obtained from the actual engine performance data of Kirloskar make. In this work the finite element model of the piston is developed and structural analysis is done in ANSYS11 software. The stress and displacement curves are used to predict the presence of piston slap. The piston slap is considered as one of the chief sources of vibration during secondary motion.

Keywords: Engines, piston, noise, vibration, secondary motion

I. INTRODUCTION

The effort to achieve greater efficiency is witnessed in many researches in IC engines. The emphasis on the IC engine vibration and noise given rise to wide scope for the methods of predicting and controlling the engine noise and vibration. The noise from the engine comprises of mechanical and combustion noise. The mechanical noise which is generated by the vibration of engine parts is produced by its movements. The combustion noise is produced because of primary and secondary motion of the piston movement. The primary motion of the piston produces noise due to combustion. The primary motion of piston is nothing but the movement of piston from TDC to BDC and TDC to BDC because of applied pressure without twist. The secondary motion of piston is the motion of piston in transverse direction due to twist of piston due to the impact of load (combustion). In both cases the pressure rise resulting from combustion approximates an exponential function. The early theoretical analysis showed that the form of cylinder pressure development determines the dynamic stress in the engine parts. Subsequent studies indicated that the level of certain mechanical sources of noise such as timing gear impacts and piston slap could increases with the increase of combustion induced mechanical noise. They operate at high peak pressure giving rise to noise and vibration. The secondary motion produces piston slap which is the result of piston side thrust on cylinder liner as it moves to and fro from TDC to BDC. Hence it is necessary to study the effect of secondary motion on engine parts.

II. LITERATURE SURVEY

There are many technical contribution published in IC engines field and mainly the piston and piston ring dynamics in IC engines. The modeling of primary and secondary motion of piston and piston ring dynamics in IC engines. The modeling of primary and secondary motion of piston and piston ring especially FE models with 3D approach have been used to study the secondary motion with regards to predict the frictional losses and methods to reduce the friction were emphasized. Toshiaki Kobayashi *et al.* developed a new method of predicting the pistons slap noise [1]. The distortion of the cylinder liner at low temperature, the dynamic stiffness of the Piston and the cylinder block and oil film model enhancement was taken into consideration. It proved that relative change of cylinder linear vibration and subjective evaluation had high correlation with the measurement results of a real engine. The motion of the piston and rings are strongly influences lubrication and blow by in reciprocating engine [2]. The 3D finite element models of a single cylinder and four cylinders IC engines are developed to analyze the piston the piston and ring motions, the ring motion in radial and axial direction and ring twist, along with the end gap size variation are studied in details. Results are compared with those obtained by neglecting piston secondary motions. Comparative analysis of piston and ring motions between single and four cylinder engines has also been performed; it has been found that the predicted ring motion of a single cylinder engine is different from that of a multi cylinder engine [3]. The conclusion is that the piston tilt has a profound effect on the end gap variation, the ring twist and the ring lift. The piston slap is an important phenomenon in the engine, which governs the vibration, noise and the wear of the linear surfaces. It occurs due to transverse and rotational motion of the piston, which depends upon clearance between and linear is governed by geometry, mass and inertia properties of reciprocating parts and gaseous loads. The finite element method and piston transverse movement calculation technique is satisfactorily used to predict engine vibrations and noise due to piston slap [4]. S.N. Kurbet *et al.* presented the results of a finite element study of 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. Information from the analysis would serve to reduce the design performance testing cycle time and be useful in the development in the coating techniques [5].

III. FINITE ELEMENT MODELING AND PROCEDURE

The finite element model of the piston is developed using ANSYS 11 software. The meshing is done with axi-symmetric PLANE 42 elements. The material model is created using the Kirloskar engine data and is shown in the Table 1.

Table 1: Material Properties of the Kirloskar Diesel Engine.

Sr. No.	Part Name	Material Name	Density	Young's Modulus		Poison Ratio
			In Kg/m3	In GPA	In N/mm^2	
1	Piston	Al alloy	2630	72.4	72400	0.31

For defining boundary conditions, the pressure curve of the Kirloskar engine at running speed of 1500 rpm is considered and the variation of the pressure with different crank angles is shown in the Figure 1. The bottom skirt of the piston is constrained in all degrees of freedom. The analysis is carried out for one engine cycle. The effect of gas pressure on the stress induced in the piston body is observed [6, 7].

IV. RESULTS AND DISCUSSIONS

The stress values are observed for different crank positions (APPENDIX). The result data have been tabulated to plot the respective graphs. The displacement curves are plotted to study the piston slap (displacement in x-direction). From Figure 1, it is evident that the maximum pressure of 56 bar is observed near TDC. Hence, the structural analysis of the piston is taken from TDC to BDC travel during power stroke i.e., after combustion of fuel in the chamber. The stress developed in the piston for different crank angle position and the lateral displacement of the piston in x-axis is tabulated in the Table 2.

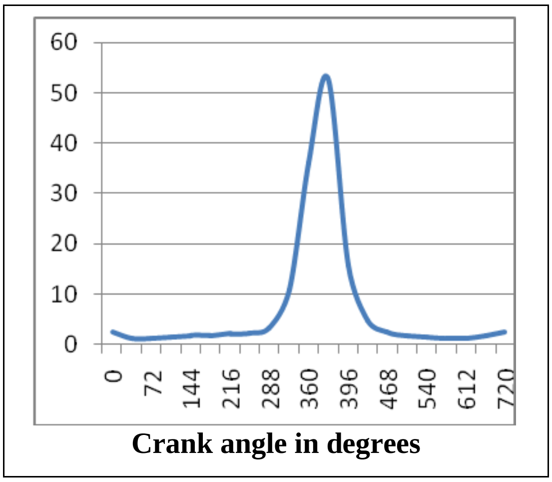

Fig. 1: The Pressure v/s Crank Angle Graph.

Table 2: The Gas Pressure, Von Mises Stress and X-Displacement of Piston.

Crank Angle	Gas Pressure in N/mm^2	Von mises Stress in N/mm^2	x-displacement in mm
360	3.600	60.835	0.277
396	5.280	89.227	0.406
432	1.560	26.361	1.200
468	0.480	08.109	0.369
504	0.240	04.055	0.185
540	0.180	03.039	0.138
576	0.144	02.431	0.111
612	0.120	02.027	0.923
684	0.180	03.042	0.189
720	0.240	04.055	0.185

From the Figure 2, it is observed that the stress in the piston is maximum near the 90 N/mm2 stress region and causes the piston to deform more at this region. Hence, the gap between piston and cylinder reduces compared to the other region. This phenomenon causes the piston to tilt about the gudgeon pin axis and causes the piston

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ISSN 2319 - 8354

to slap. The graph of x-displacement v/s crank angle is shown in the Figure 3, which clearly indicates the change in the gap between cylinder and piston travel from TDC to BDC. This behavior of the piston tilt repeats for regular interval of the crank angle between 0^0 to 720^0 of the complete cycle. The Figure 4 shows the graph of piston-cylinder gap in microns versus different crank positions in degrees for the data logged during actual running of the engine. The finite element analysis results closely agree with the experimental results as the trend matches for the gap between cylinder and piston between 380^0–650^0.

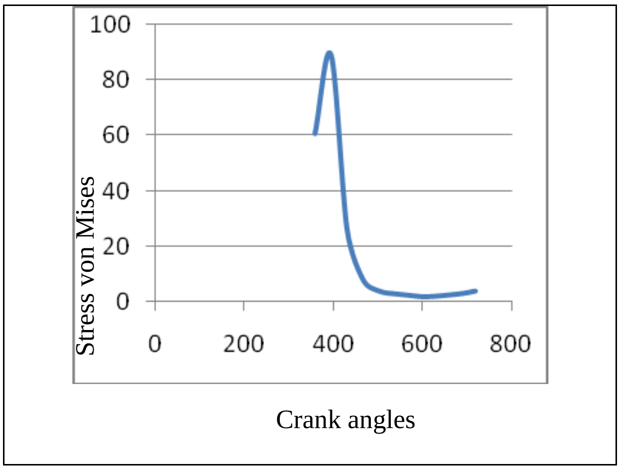

Fig. 2: Variation of Von Mises Stress for Different Crank Angles.

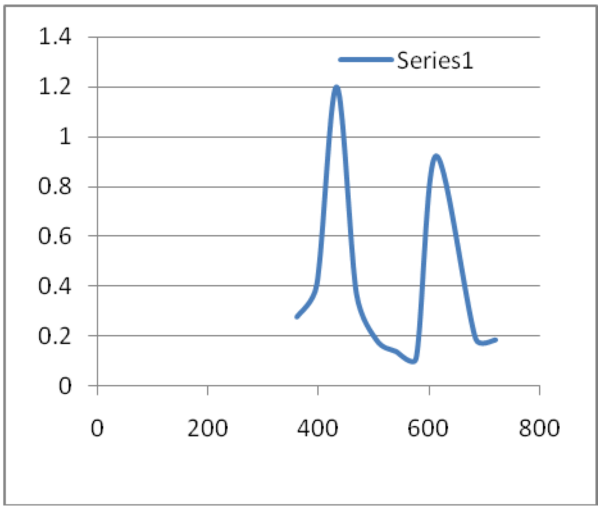

Fig. 3: Variation of Piston-Cylinder Gap for Different Crank Angles.

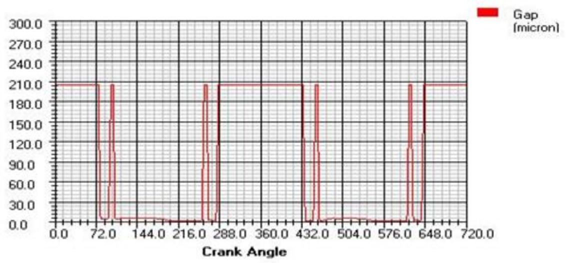

Fig. 4: Repetition of Variation of Piston-Cylinder Gap for Different Crank Angles.

Figures 5 and 6 show the maximum stress and displacement in the piston respectively

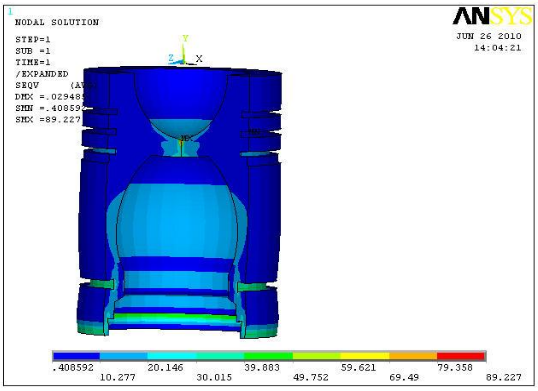

Fig. 5: Von Mises Stress.

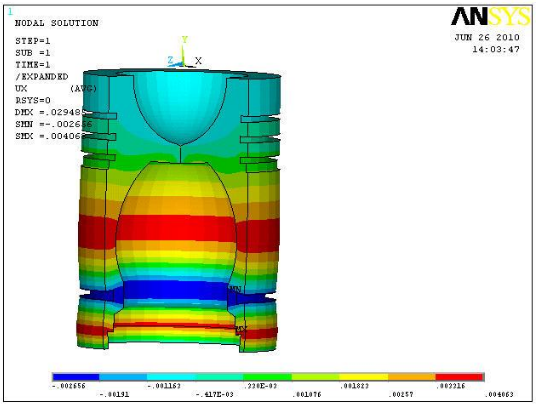

Fig. 6: Displacement.

V. CONCLUSION

The structural analysis of the piston for the various pressures on the piston for different position of the piston in the cylinder moving between TDC to BDC has been studied. The piston experiences maximum stress in the region where it directly comes in contact with combustion i.e., at the piston head and skirt. This high stress region in the piston deforms more than the other region of the piston. The deformation in the piston causes it to displace more in this region and this cycle repeats even for the reduction in combustion pressure. This is because of the piston-tilt about the gudgeon-pin axis. This behavior of the piston motion inside the cylinder with varying gap is prediction of the presence of piston-slap for secondary motion.

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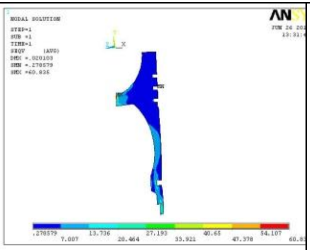
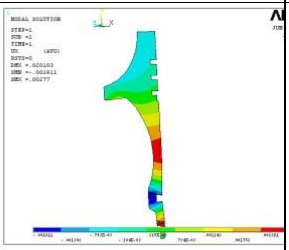
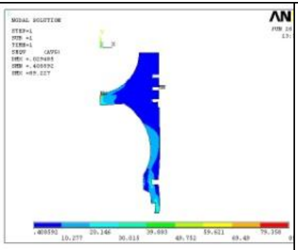
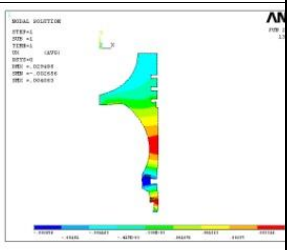
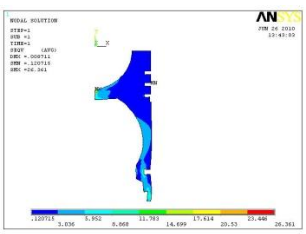
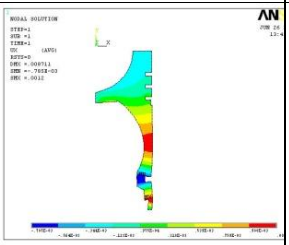
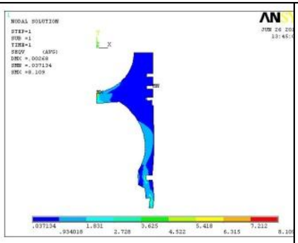
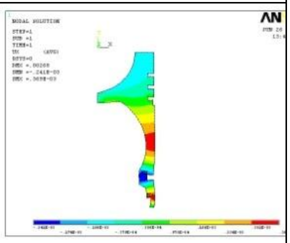
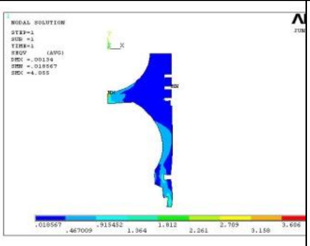
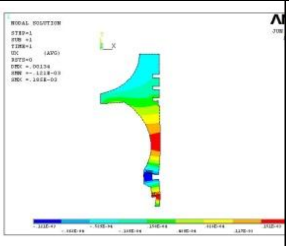
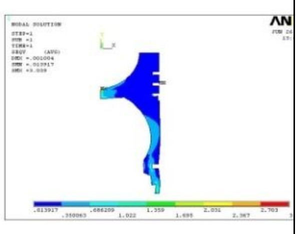
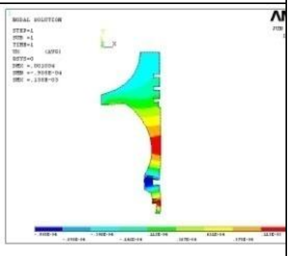
APPENDIX

Von Mises Stress Distribution (Axisymmetric Model)	**x-displacement in mm (Axisymmetric Model)**	**Von Mises Stress Distribution (Axisymmetric Model)**	**x-displacement in mm (Axisymmetric Model)**
Case 1: The Piston Position at 360 Angle of Crank Rotation		**Case 2:** The Piston Position at 367 Angle of Crank Rotation	
			
Case 3: The Piston Position at 432 Angle of Crank Rotation		**Case 4:** The Piston Position at 468 Angle of Crank Rotation	
			
Case 5: The Piston Position at 504 Angle of Crank Rotation		**Case 6:** The Piston Position at 540 Angle of Crank Rotation	
			
Case 7: The Piston Position at 576 Angle of Crank Rotation		**Case 8:** The Piston Position at 612 Angle of Crank Rotation	

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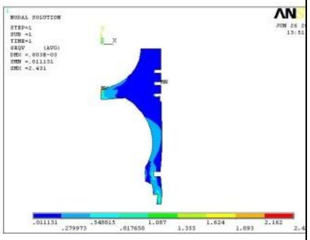	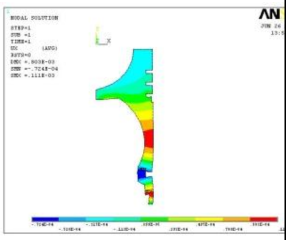	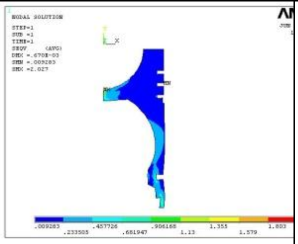	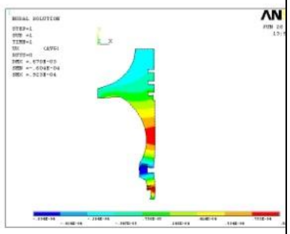
Case 9: The Piston Position at 684 Angle of Crank Rotation		**Case 10:** The Piston Position at 720 Angle of Crank Rotation