"Comparative investigation of vibration analysis of VCR diesel engine for different types of grey cast iron"

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Abstract- The main purpose of this work is to analyze the vibration in diesel engine cylinder liner considering combustion gas forces and cylinder liner temperature using finite element software ANSYS. Also different materials are being tested in the software for this purpose. The output results were quite satisfactory to predict the behavior of deflection under different pressures. The combustion gas forces calculated for varying compression pressures. Results are presented the displacement vs frequency shows the amplitude of vibration. By comparing the analytical results, the validity of the proposed analysis has been confirmed. Furthermore, this analysis is applied to evaluate the vibration of different materials along with increase in thickness, and revealing the closer response according to the material and vibration.

***Index Terms*-** VCR [14] (Variable Compression Ratio) Diesel engine, Cylinder liner, Combustion gas force, Harmonic analysis (ANSYS 10)

I. Introduction

Most of the researchers have found for the mechanical noise i.e. piston slap. The noise due to combustion gas force is the major source for the occurrence of noise in the engine cylinder. Very few efforts are devoted for combustion gas force analysis. Little attention was paid on noise and vibration due to combustion gas force. This work focuses on this issue. For this modeling was done at the cross section of engine cylinder liner including 2-dimensional and 3-dimensional analysis. Beam and 3-dimensional liner are consisting of thickness of cylinder and stroke length of cylinder. The results are considered for calculating the combustion forces for the certain ranges of compression pressure (between 45-75bar). Further, the effect of cylinder liner temperature was also analyzed.

Piston slap is a collision phenomenon between the piston and the cylinder liner when the lateral force acting on the reciprocating piston. As a result piston slap was identified and the instants of slap were determined. These were compared with the instants of slap calculated from a theoretical analysis of the dynamics of the moving parts of the engine [1]. Another investigation presented the various methods for estimating the pistons slap. This phenomenon of piston slap has been investigated by oscillographic and simulation technique to determine its relative magnitude, compared with the other noise sources of the engine. It has been found that this source of noise is important and its significance will become greater as other sources, such as combustion are reduced [2]. The finite element method (FEM) is employed to simulate the vibration response of the hull due to the excitations of diesel piston-slap and vertical inertia force of reciprocating masses. The numerical results show that, piston-slap imposed rolling moment on the diesel frame may cause a higher level vibration [3, 4, 5].

Fig 1 Schematic Diagram Generation of engine noise / vibration related to piston slap

The work focuses on vibration issue and the main causes of mechanical noise are the "piston slap" phenomenon [3-5, 7]. The Problem is formulated as under study of the cross section of engine cylinder liner as 2-dimensional and 3-dimensional model with the help of ANSYS Version 10. Beam and 3-dimensional liner are consisting of thickness of cylinder and stroke length of cylinder. In this analysis, application of combustion gas forces and cylinder liner temperature on the piston cylinder components to investigate the vibration. The problem is described in a two dimensional beam and three dimensional model along with model meshing as shown in figure 2.1 and figure 2.2. Calculating combustion gas forces for the certain peal ranges of compression pressure (between 45-75 bar), considering cylinder liner temperature [8].

In order to simulate the model, prerequisites are as follows,

- Geometry:- Cross section of engine cylinder as a 2-D and 3-D model with the help of ANSYS.
- Boundary Conditions:- By fixing left side of model as all DOF zero and fixing the right side of model as UX as zero.
- Mesh:- Mapped (3-4 sided).
- Force Analysis:- Combustion gas forces applied at TDC position only.
- Parameters:- Analysis was done from nodal solution and graph.
- Analysis Method:- Harmonic Analysis

For the geometry analysis the work includes single cylinder, four stroke, and VCR (Variable Compression Ratio) Diesel engine.

II. METHODOLOGY.

1) An overview is given based on a literature survey of general theory for the vibration phenomenon.
2) The system is modelled using ANSYS Version 10 software to create needed geometry, and carry out simulations.
3) The problem is described in a two dimensional beam and three dimensional model.
4) Calculating combustion gas forces for the certain peal ranges of compression pressure (between 45-75 bar).
5) Considering cylinder liner temperature [11.]

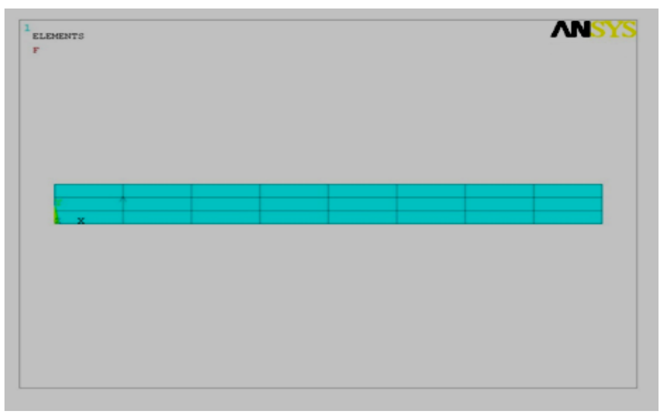

Fig. 2: Figure showing the application Combustion Gas Forces in 2-Dimensional Beam after Meshing

III. PISTON FORCE CALCULATION FOR GASES.

Calculation of gas forces were carried out to define the compression pressure during combustion in an engine. Following are the calculations performed for featured analysis of vibration due to combustion gas force.

Force acting due to gas pressure on piston

Force = P * π / 4 * dp2 [12]

Where, P = Compression Pressure

dp = Piston Diameter.

Sr. No.	Pressures	Force acting due to gas pressure on piston
1.	45 bar	27022.32 N
2.	50 bar	30024.8 N
3.	55 bar	33027.28 N
4.	60 bar	36029.77 N
5.	65 bar	39032.25 N

6.	70 bar	42034.73 N
7.	75 bar	45037.20 N

Table 1: Calculated combustion gas forces for different compression pressure.

IV. MODELING AND SIMULATION.

Simulation technique can never be complete replacement for an experimental testing. But they can provide a useful service in that the effect of parameter changes may readily be expressed without resource cutting metal, leaving experiment to confirmatory role. Experiment must also provide the evidence needed to validate the mathematical model in first instance. Since, vibration characteristic can be found with empirical relations it is also helpful to get the point load that impact on the side of the cylinder, data was taken from books, which were used to run the program.

The studied system representing an I.C. combustion engine is modeled as a cylinder liner which is consisting of cylinder thickness and stroke length. Simulation with the finite element software ANSYS lends to the integration to the piston and cylinder liner.

Material name		**Modulus of elasticity**	**Poison's ratio**	**Density**
Grey cast iron	FG 150	100800	0.26	7050
	FG 400	146100	0.26	7300

Table 2 Properties of Material [13]

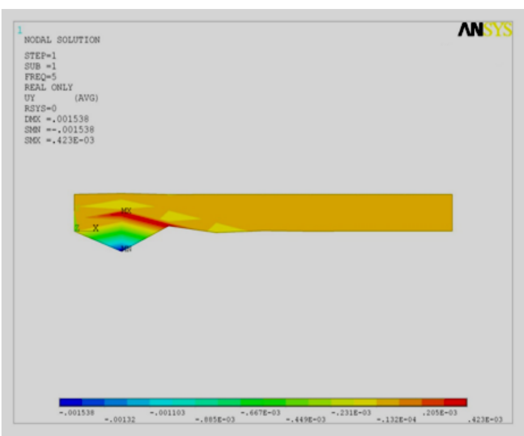

Fig3: Nodal solution for 75 bar compression pressure (FG 400)

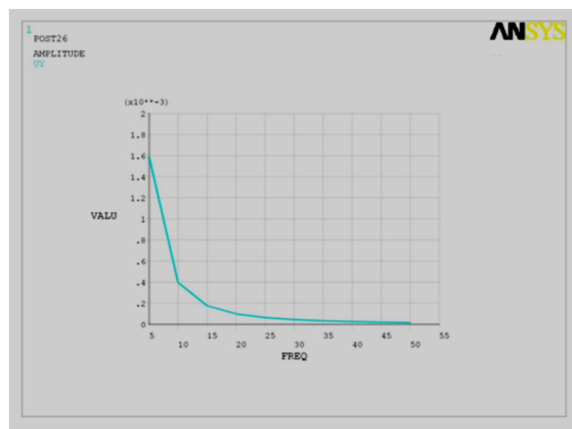

Fig4: Graph for 75bar pressure (FG 400)

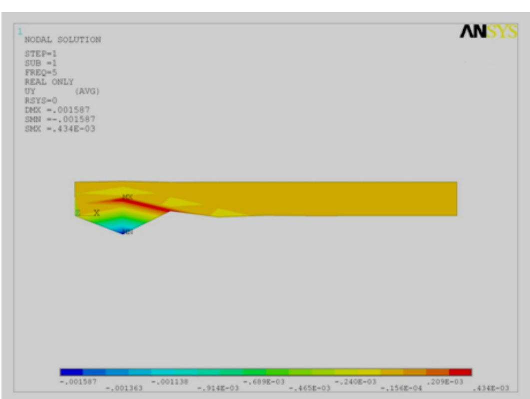

Fig5: Nodal solution for 75 bar compression pressure(FG 150)

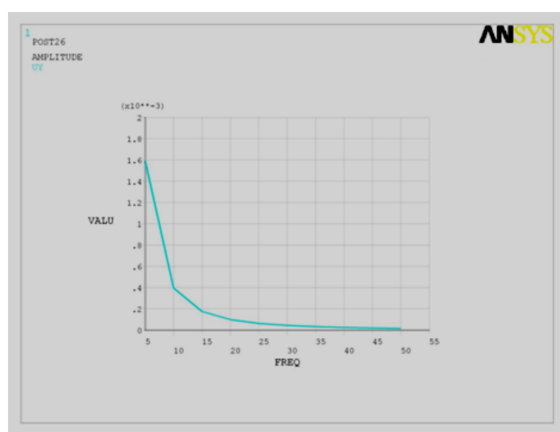

Fig6:Graph for 75bar pressure (FG 150)

V. RESULT AND DISCUSSION.

This elaborates the results obtained after the analysis which includes different materials along with the directions. After applying gas forces to 2-dimensional and 3-dimensional cylinder liner, we get some results. In this chapter we discuss the node number at which we get the deflection due to each compression pressure for each material.

In following table, at node 22, the 2-dimensional beam deflects in Y direction due to combustion gas force.

Compression pressure / Property	**FG 150 (Grey cast iron)**	**FG 400 (Grey cast iron)**
45bar	0.95242E-03	0.92293E-03
50bar	0.10583E-02	0.10255E-02
55bar	0.11641E-02	0.11280E-02
60bar	0.12699E-02	0.12306E-02
65bar	0.13757E-02	0.13331E-02
70bar	0.14815E-02	0.14357E-02
75bar	0.15874E-02	0.15382E-02

Table 3: Nodes at which 2-Dimensional beam Deflects in Y direction

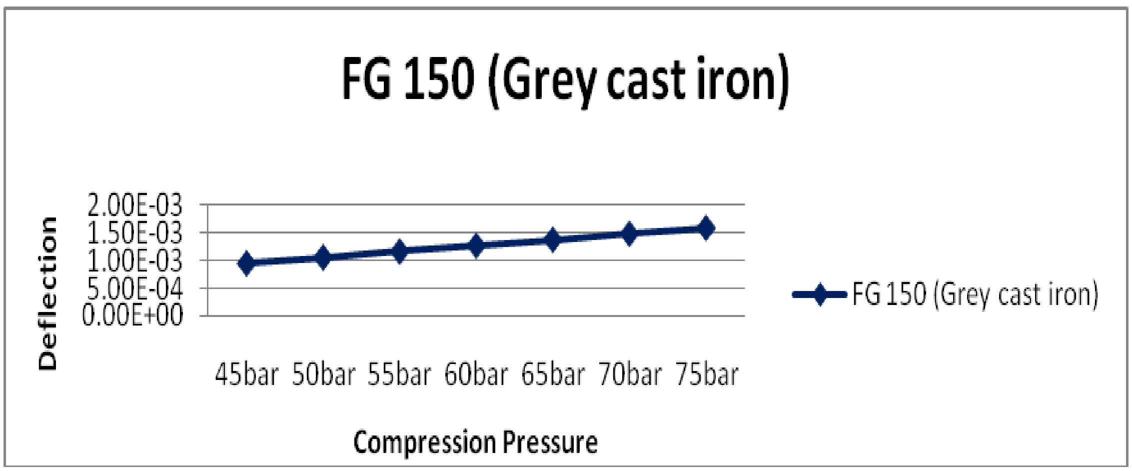

Fig.7: Graph showing the deflection of FG 150 (Grey Cast Iron) material (for 2-D)

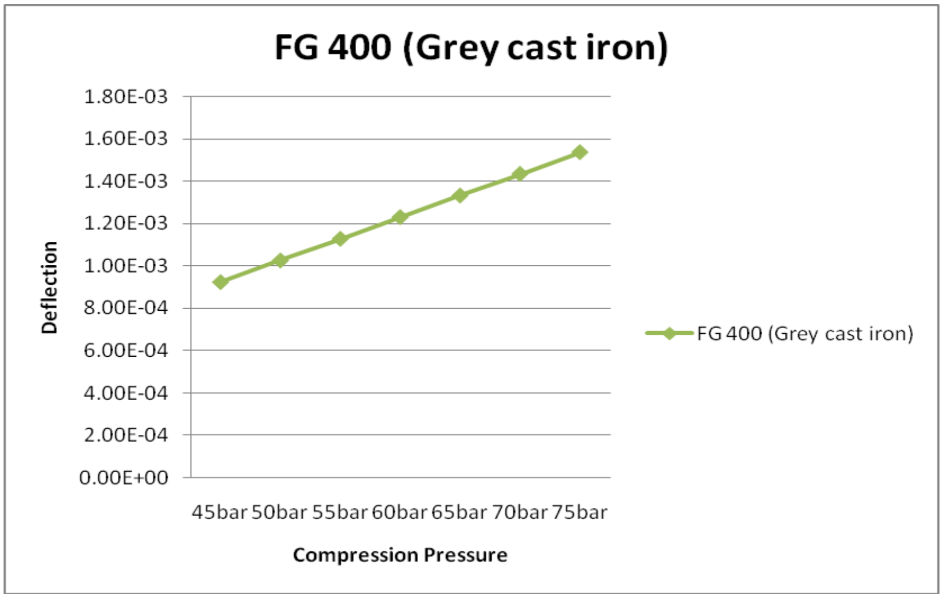

Fig.8: Graph showing the deflection of FG 400 (Grey Cast Iron) material (for 2-D)

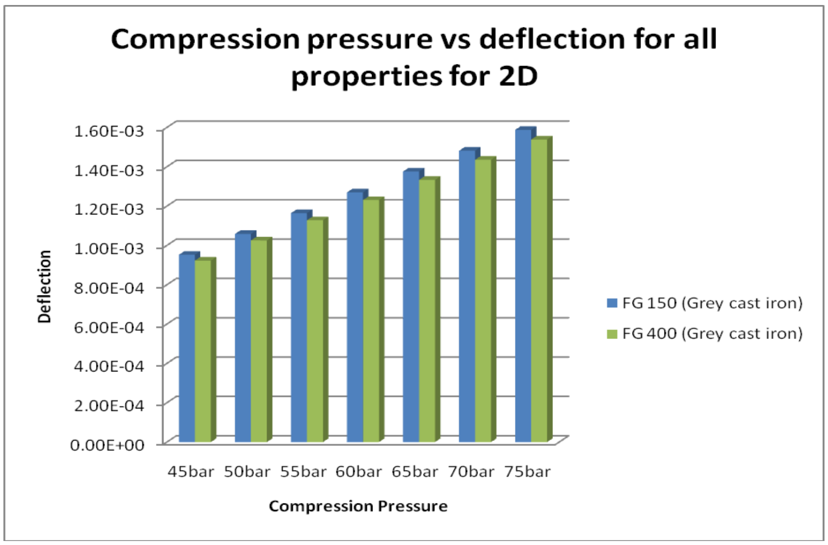

Fig.9: Compression Pressure vs. Deflection for all properties of materials for 2D

From above Graph (Fig 9) deflection of FG 150 is little more than that of FG 400 for 2D.

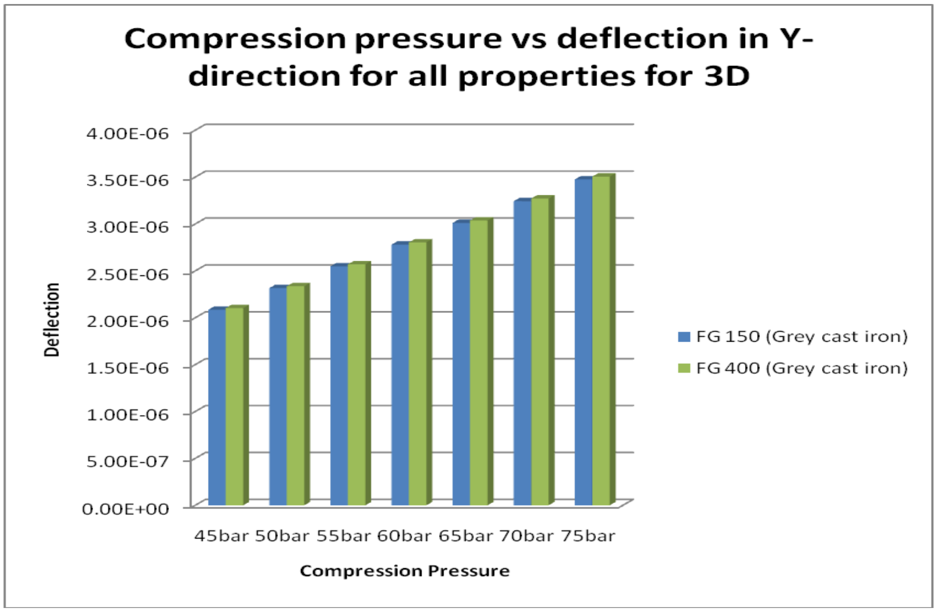

Fig.10: Compression Pressure vs. Deflection in Y-direction for all properties of materials for 3D.

3D

From above graph it is seen that, for grey cast iron material, at 45bar pressure the minimum value of deflection for the material FG 260. And the maximum values of deflection at 75 bar pressure for the material FG 400..

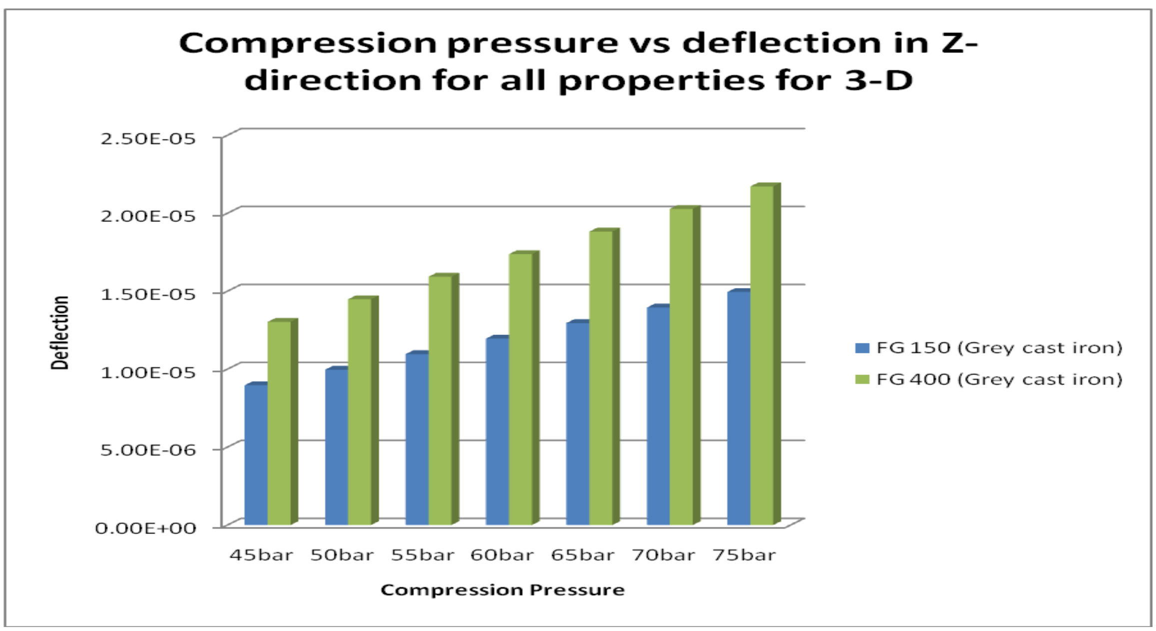

Fig.11: Compression pressure vs. Deflection for all properties of materials in Z-direction for 3D.

From above graph it is seen that, the minimum value of deflection at 45 bar pressure for the FG 150 material

VI. CONCLUSION

In this paper, vibration analysis was carried out for 2-D and 3-D model along with different direction for different materials and nodes. In the analysis it is observed that 2-dimensional beam deflects least for FG 400 in Y-direction.

In 3-dimensional model it is observed that, FG 400 behaves similar to FG 150 and the difference in deflection between these two is negligible.

Further in order to reduce vibration level, thickness of outer periphery of cylinder increased by 1mm. Better results were obtained i.e. the level vibration is found to be less for FG 150 & FG 400 materials. Therefore it is observed that we can predict and understand vibration levels in a better way during engine operating conditions.

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