

# Design and Study State Dynamic Analysis of High Pressure Fuel Pump

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**ABSTRACT:** Modal analysis could be a powerful tool to spot the dynamic characteristics of structures. Each and every structure vibrates with high amplitude of vibration at its resonant frequency. It's imperative to understand the modal parameters- resonant frequency, mode shape and damping characteristics of the structure at its varying operating conditions for improving its strength and reliability at the planning stage. During this work study and analysis of dynamic characteristics of mechanical system internal gear pump with the assistance of Finite element Method. supported the obtained results with help of shape optimization improving the dynamic characteristic behaviour. During this study for pre-processing Hypermesh is employed together with Abaqus solver for post processing Hyper view software has used.

**KEYWORDS:** FEA, Fuel injection internal gear pump, Hypermesh, Modal analysis

## I. INTRODUCTION

Internal gear pump Model "FIG" (i.e. Fuel injection Internal Gear Pump) is a high precision and fuel pressuring type positive displacement internal gear pump which prepared by graded material of cast-iron. These nitrated gear, shafted rotor give better performance with closed tolerance to relinquish long life. Model "FIG" is flange mounted. These pumps produce maximum vacuum determined by the cavity between the gear teeth. These pumps modified profile teeth cutting to produce accurate capacity within the pressure range. These pumps are capable to run liquid up to 500 CST viscosity and up to a temperature of 200°C. The sealing is finished with mechanical seal to make sure zero leakage. The suction and delivery connections which are available in 3/8", 1/2", 3/4" and 1" size. Model "FIG" pumps are available during a capacity range of 60 LPH to 6000 LPH with operating pressure up to 35 kg/cm<sup>2</sup>, yet for continuous duty maximum recommended pressure is 30 kg/cm<sup>2</sup>. These pumps can even be used at 2800 RPM. The capacity will have approximately double of normal duty condition. These pumps can run clockwise and anti-clockwise direction as per requirement.

## II. MODELING AND ANALYSIS

The early CAD systems use geometry construction and editing techniques to create the model. These techniques created the models of wire frame and surfaces that could be edited by a geometric editing, however, these systems had no capabilities to understand the relations between the geometry. Later parametric modeling systems were introduced, which could be used to build relationships between geometric entities. These constant techniques relied on constraints and parametric expressions defined by the user to build the model. These approaches built a more intelligent model, but could become restrictive; the constraints would sometimes stop a user from carrying out a modification, which had not been originally foreseen. These systems also relied heavily on bodies created from swept sketches, profiles and did not have a wide variety of construction and editing techniques. Modeling of the fuel pump is done using CATIA.

CATIA is a powerful modeling software package which is one of the most effective parametric modeling and surface feature based modeling software. Solid modeling is done in CATIA which has a rich set of features to create and modify the designs. In this paper 3-D solid fuel pump is considered for the analysis. The procedure followed in CATIA for modeling of the solid bar is, first getting the 2-D sketch which is the profile of the web, then the web profile is projected by using "project 3D element" option and then the "rotate" option is used to rotate the projected profile. Care

should be taken to convert the projected profile into construction lines. After modeling the Fuel pump, it is saved as CATIA file and IGES file format for meshing purpose. IGES means Initial Graphic Exchange Specification; this file can be easily imported to any software package. The CATIA part file can also be saved as STEP file.

In this study, first step we have ran the finite element analysis of design 1, based on obtained results we did design changes to base model. Two designs are created to identify the best design in terms of dynamic characteristics.

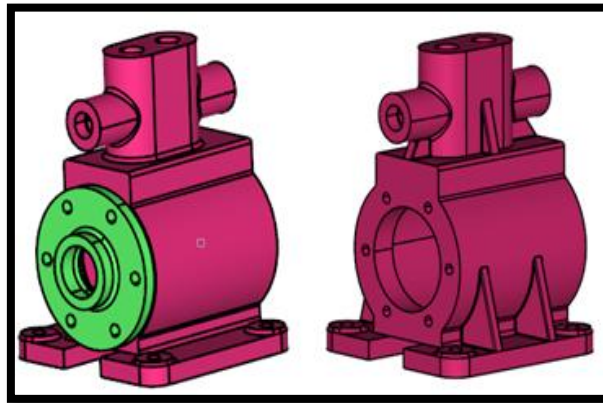


Figure 1: CAD models of FIG pumps

**A.MESHING**

Meshing is a process of converting infinite number of degrees of freedom into finite number of degrees of freedom for analysis. The meshing of the stabilizer bar is carried out using the commercially available software HYPERMESH. Hypermesh is a very effective tool of meshing which can deal with both shell and solid models where quality characteristics of mesh as required for different types of analysis can be maintained and controlled. For meshing of surfaces Hypermesh has many options and capabilities including meshing across multiple surface boundaries and choosing between quad or triangle-dominated meshes. Model editing features include combining, detaching, and translating elements. Hypermesh can check meshes for duplicate elements, facet warpage, aspect ratio, skewness, and can display and modify element normals.

In this work, tetramesh is done for the fuel pump. Firstly, a collector is created named as “shell” and the surfaces of the component are meshed using triangular elements. Then, another collector is created and the “Tetramesh” option is used to produce tetramesh for the whole component. The element used in this work is the first order tetrahedral element. HYPERMESH is a very effective package to maintain various mesh qualities like warpage angle, jacobian, minimum and maximum angle, minimum and maximum length.

Materials used for the analysis are listed below table:

Components	Material	Young’s Modulus (MPa)	Poisson’s Ratio	Density (tonnes/mm3)
Housing	Steel BSK46	2.1E5 MPa	0.3	7.8E-9
Gear	ANESIS15	2.1E5 MPa	0.3	7.8E-9
Cam shaft	A3003-O	7.2E4 MPa	0.28	2.8E-9
Bearings	Stainless Steel 440C	200E3 MPa	0.3	7.8E-9

Table 1: Material properties

**B.BOUNDARY AND LOADING CONDITIONS**

In general fuel pumps are fixed to the engines with tight bolted connections. In this study instead of modelling the

bolts we are used the Coup kin elements. Coup kin elements are used in bolt locations and fixed in all degrees of freedom.

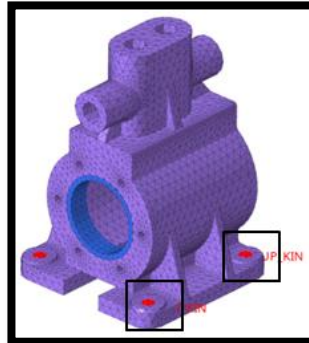


Figure 2: Mesh model and BC condition.

For loading conditions in Abaqus solver we are used the lanczos eigen solver. For the Lanczos method we need to provide the maximum frequency of interest or the number of eigenvalues required; Abaqus/Standard will determine a suitable block size (although we can override this choice, if needed). If we specify both the maximum frequency of interest and the number of eigenvalues required and the actual number of eigenvalues Abaqus/Standard will issue a corresponding warning frequency extraction.

We can also specify the minimum frequencies of interest; Abaqus/Standard will pull out eigen values until either the requested number of eigenvalues has been extracted within the given range or all the frequencies within the given range are extracted. In this study we extracted the first 10 natural eigen modes and eigen vectors.

### III.RESULTS

First 10 natural frequencies of two designs are listed below:

Mode no	Frequency(Hz) Design@ 1	Frequency(Hz) Design@ 2
1	134.66	148.1
2	136.64	168.96
3	289.09	316.3
4	317.66	327.5
5	435.05	443.29
6	495.63	501.94
7	579.24	594.22
8	592.92	606.56
9	616.57	668.54
10	842.13	897.89

Table 2: Natural frequencies of Design 1,2



Mass participation factor of Design1 listed in below table:

Mode no	Frequency (Hz)	X-Direction	Y-Direction	Z-direction
1	134.66	0.01	0.01	56.84
2	136.64	49.34	5.30	0.01
3	289.09	6.91	84.70	0.01
4	317.66	0.01	0.01	3.91
5	435.05	7.51	5.14	0.01
6	495.63	0.01	0.01	1.46
7	579.24	0.01	0.01	12.61
8	592.92	0.03	0.01	1.94
9	616.57	21.52	0.06	0.01
10	842.13	0.01	0.01	2.37

Table 3: Mass participation factor table of Design@1

From the above table, 50% of mass is acting in X- direction @ 136 Hz . 84% of mass is acting in Y- direction @ 289 Hz From the above table, 56% of mass is acting in Z- direction @ 134 Hz, Mode 1, 2 and 3 are critical modes.

Mass participation factor of Design@2 listed in below table:

Modeno	Frequency (Hz)	X-Direction	Y-Direction	Z-direction
1	148.1	50.13	3.76	0.01
2	168.96	0.01	0.01	58.15
3	316.3	6.84	82.37	0.01
4	327.5	0.00	0.02	2.82
5	443.29	6.76	10.32	0.01
6	501.94	0.01	0.01	1.43
7	594.22	0.01	0.01	14.59
8	606.56	0.02	0.01	0.59
9	668.54	24.95	0.08	0.01
10	897.89	0.01	0.01	9.84

Table 4: Mass participation factor table of Design 2

From the above table, 50% of mass is acting in X- direction @ 148 Hz ,82% of mass is acting in Y- direction @ 316 Hz From the above table, 58% of mass is acting in Z- direction @ 168 Hz .From the above table, Mode 1,2 and 3 are critical modes

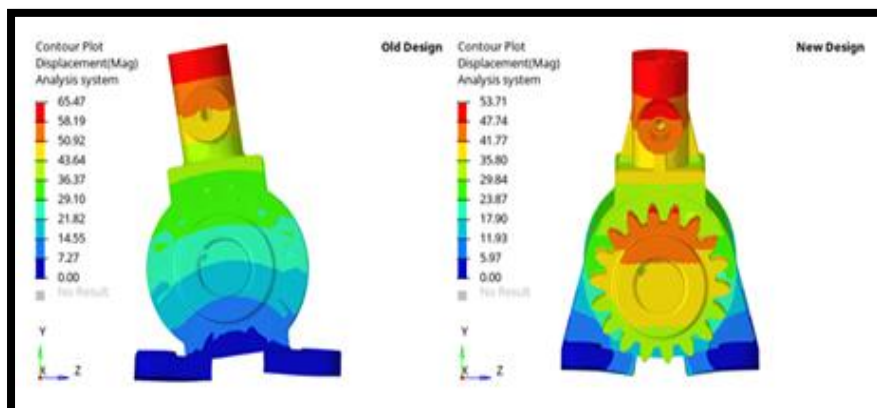


Figure 3: 1st Mode shapes of Old and new design

#### IV.CONCLUSION

In this work we carried out the analysis of dynamic characteristics of Fuel injection pump with the help of Finite element Method. Based on the obtained results with help of shape optimization improve the dynamic characteristic of base design. With adding ribs we had increased the first natural frequency from 134Hz to 148Hz with minimal weight increment. With adding ribs, the structure got enough strength to change the mode behavior that we can clearly observe from slide no 41 to 43. And we also plot the mass participation factors to know which co ordinate directions our structure will displace more. There is further more scope to improve the structure with topography that is optimization of thickness.

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