Vibration Analysis of Distributor Pipe System and Base Structure

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***Abstract*— This paper is emphasis to avoid the bursting of outlet pipe of distributor and base structure by using analysis. Initially the total load acting on the distributor and base structure is calculated. The stress analysis is carried out by applying total load to find the structural stability. The resonance frequency in system due to fluid fluctuations with high rate of fluid passing through the pipes is find out by modal analysis. Vibrations analysis is carried out with pre-stress effects. The result of stress analysis shows maximum stress of distributor is much smaller than the allowable stress of the material. The first frequency of modal analysis is sufficiently high as compared to the design frequency of the problem. So structure is safe for the given loading conditions. Also the Vibrations analysis, results shows drop in 2nd natural frequency which indicates Vibrations will take place in this range.**

***Keywords*— Component; Formatting; Style; Styling; Insert**

I. INTRODUCTION

Engineering Design Process

A design process is the set of technical activities within a product development process that work to meet the marketing and business case vision. This includes refinement of the product vision into technical specifications, new concept development, and embodiment engineering of the new product.

Problem Definition

Stress analysis plays important role in the structural safety. Engineering problems are becoming complex with the improvement in the technology and requirements of the industry. Flow induced vibrations are becoming critical in failure of the components. Since flow study and vibration study are the mix of branches of engineering, these studies are complex and are made possible by advances in finite element based software's using coupled field algorithms.

In the present work, a distributor is facing problem of failure due to unexpected vibration. So cause of vibration need to be explored. In the present study, main concentration is given to flow induced vibration. At the distributor, a gas and fluid are mixing. So a multiphase study is required using fluent software. Later the resulting pressure loads need to be considered for prestressed modal analysis to explore possibility of failure of the distributor by Vibrations. Vibrations analysis is a complicated iterative study which needs coupling of fluid structural interface loads. The computational fluid dynamics software gives the advantage of proper estimation of a pressure in the thermal environment. In the present work, 3 accumulators are mixing through common pipe line and exiting to the next system. But here due to sudden opening of the outer pipe line, the resulting burst pressure need to be estimated to find the structural stability of the supporting structure. So a CFD analysis is required to find the flow and existing pressure to find the correct design parameters for the base supporting structure.

II. PROPOSED WORK AND METHODOLOGY

A. Proposed Work

During sudden opening of the distributor main outlet, there is possibility of sudden vibration at the end. This may create a problem for overall structural behaviour of the distributor. This may lead to resonance in the system. So finding the resonant frequency which is linked to flow velocity is important by which dynamic nature of the system can be estimated.

B. Geometrical Model of The Problem.

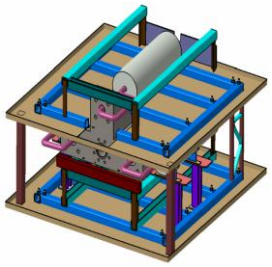

Figure 1. Geometrical representation of the problem

The figure shows three dimensional model of the problem along with distributor mounting. Distributor is mounted using support plates. The structure is built with box and channel sections to provide strength to the structure. CATIA software is used for modelling of the assembly.

Methodology:

- Modelling and meshing of the structure for the required dimensions
- Extraction of fluid mesh for analysis through Fluent.
- Application of inlet, outlet and wall boundary conditions to solve the problem
- Extraction of results for velocity and pressure plots.

- Calculation of exit pressure and resulting reaction forces
- Static structural analysis of the distributor.
- Structural strength analysis of the base structure
- Vibrations analysis of the distributor

Modal analysis to find the resonant conditions.

III. DESIGN AND ANALYSIS

- Should be within the allowable stress limits
- Maximum operation frequency : 10Hz

Mesh Details:

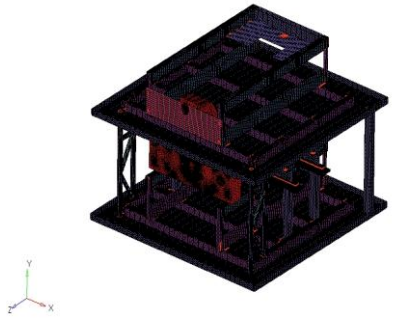

Figure 2.Meshed Model

CFD Mesh :

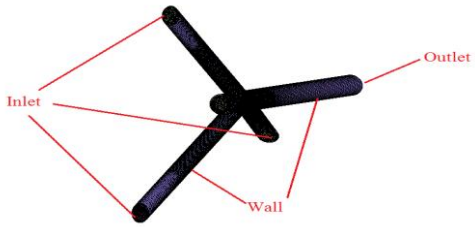

Figure 3. CFD Mesh

The figure shows CFD mesh of the inlet and outlet pipes. A finer tetrahedral mesh is used for getting better results. Total of 414634 elements with 170270 nodes are used for meshing the structure. Inlet, outlet and wall collectors are made along with fluid collector to assign properties for executing into fluent software. HYPERMESH face option is very much useful in separating the surface elements from solid mesh. The boundary conditions can be applied in the HYPERMESH itself and later imported to Fluent in '.mesh' file format. Gambit also can be used for meshing and exporting to FLUENT software for solving the fluid problems.

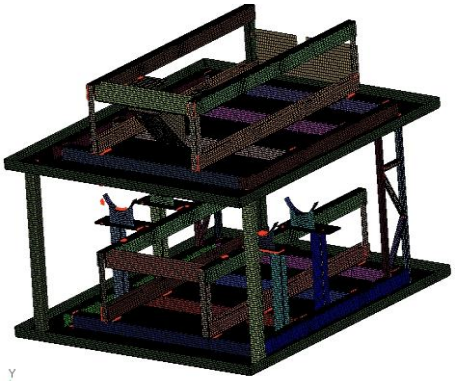

Figure 4. mesh view 2(Without Distributor)

The figure shows meshed view of the overall system. Total of 603141 elements along with 287210nodes are used for structural mesh. 4 noded tetrahedral mesh is used for meshing the distributor. Shell63 element is used for the shell structure. Beam188 element is used for bolts. Different collectors are used for meshing the geometry. The mesh is done using HYPERMESH software.

Boundary Conditions:

- Bottom region is fixed
- The accumulator supporting plates are applied with 5907N (Accumulator weight) load + 316 kg (3160N) of fluid load .So each accumulator is applying a total load of 9067N at the supporting plates.
- Self-weight effect is considered.

Figure 5. Boundary Conditions on the distributor for structural Conditions

The figure shows applied boundary conditions on the problem. Here along with thermal loads, structural loads are applied to find the structural safety of the problem. A pressure load application on the inner faces of distributor is shown in the figure.

CFD Results

Initially Computational Fluid analysis is carried out to find the pressure at the exit to find reaction force developed on the base structure. CFD analysis requires inlet, outlet and wall boundary conditions. Mass flow rate condition is specified at the inlet of the openings and wall boundary conditions are applied across the manifold inner edges. The

CFD results are as follows. Since all the openings are inclined, at a time, flow in two openings can be displayed.

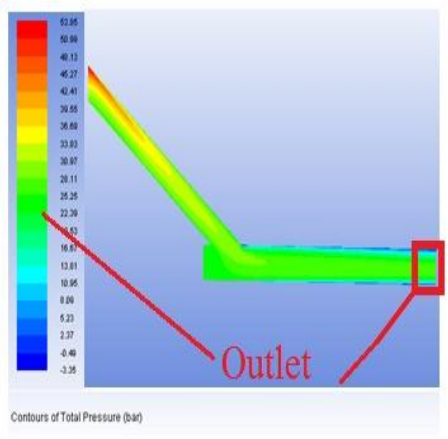

Figure 6. Pressure Plot along the third manifold opening

The figure shows pressure flow across the bottom manifold. A maximum pressure of 53.85bar can observe in the flow. Maximum pressure is observed at the wall boundary where velocity is almost zero. The status bar at the left shows variation of pressure from lowest value to the highest value. Generally the minimum pressure is observed at highest velocity regions. The fluent software is very much helpful in changing the properties of fluid any time along with minimum input data. Also in the figure outlet pressure is shown with red arrow marks. The outlet pressure value can be observed from the left status bar colour code representation.

Velocity Vectors:

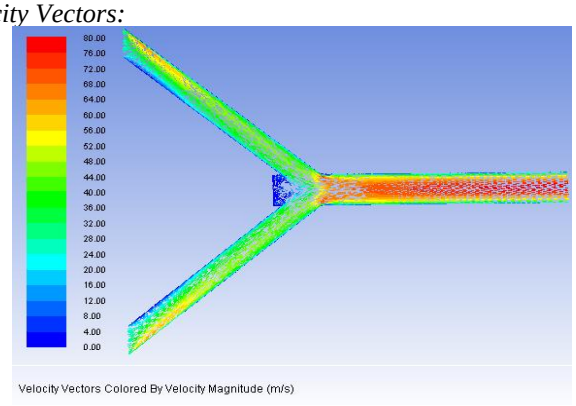

Figure 7. Velocity Vector plot at manifold openings

The figure shows vector plot of the velocity. Vector plots helps in identifying exactly the location of maximum velocity with bigger sized arrows. In the figure maximum velocity is shown in the outlet pipe corner regions. This condition has been done for unplugged condition due to which maximum velocity at the exit can be observed, Velocity is almost minimum along the wall boundaries. Also as per the hydrodynamic theory velocity along the wall boundaries is zero and is applied as boundary condition for any Computational Fluid Dynamics problems.

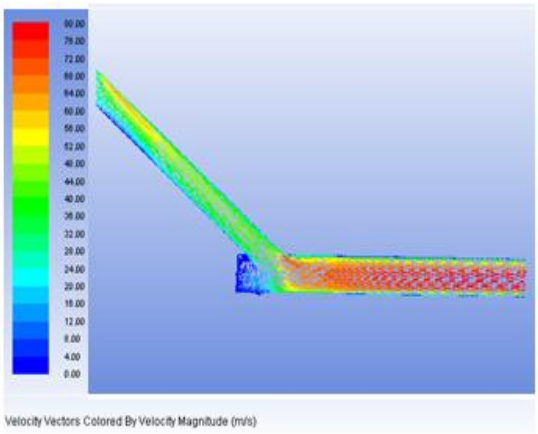

Figure 8. Vector velocity plot at the third section

The figure shows velocity at the third section. Here maximum velocity is taking place at the junction of third inlet with main outlet pipe.

Table 1: Load Calculation from the CFD analysis

Pressure	Pascal	Force (N)
Static Pressure	791180.69	6602.338
Total Pressure	2242653.8	18714.76

So a total load of 18714.76N acts at the exit, in case of sudden opening in the structure. Total pressure is the sum all the pressure including static and dynamic pressure. These values are directly available with the software. This reaction force calculation is used to check the structural stability of the system in the case of sudden opening. This load is almost equal to 1.87 tons which is a considerable load on the structure. Also the structure is subjected to pressure load internal to the body which will try to open up the base structure. The distributor structure is clamped to the base structure by 6 bolts. So these bolts also subjected to shear due to these burst load and other traction loads.

Analysis

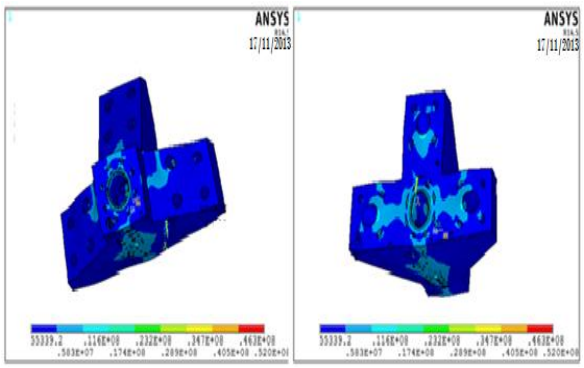

Figure 9. Resulting Von-mises Stress

The figure shows resulting thermo-mechanical stresses in the distributor, for the given loads. Maximum stress of 52Mpa can be observed in the problem. Stresses are maximum at the inner hole region due to stress concentration effect. But this stress is much smaller than the allowable stress of the distributor material. So structure is safe for the given loading

IV. RESULTS AND DISCUSSION

After the manifold is analyzed, the overall structure is analyzed for the given loads. The shell structure is applied with various thickness values for optimization. So the following problem is applied with self-weight, along with reaction load at the manifold exit.

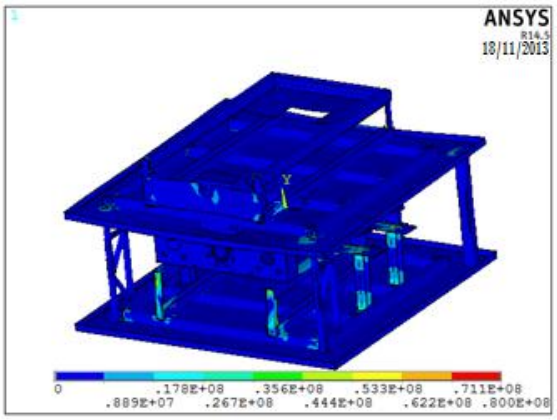

Figure 10. Overall Stress in the structure

The figure shows overall stress in the problem. Maximum stress of 80Mpa can be observed in the problem indicating the overweight of the structure as the allowable stress of the structure is more than the developed stress.

Modal Analysis

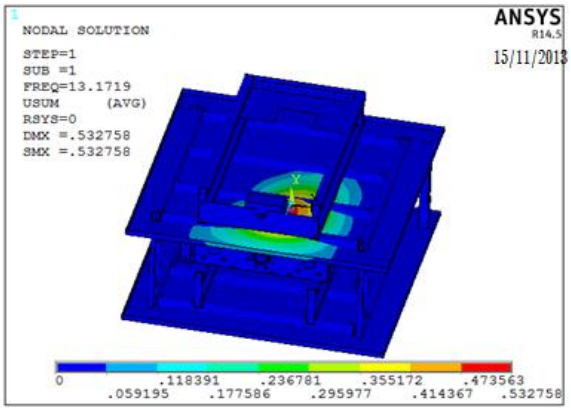

Figure 11. Modal Frequency results

The results show first frequency of 13.172 Hz. This frequency is sufficiently high compared to the design frequency of the problem. So structure is safe for the given loading conditions.

V. CONCLUSION

The structural analysis is carried out on Distributor and supporting system for structural safety and optimization. The results summary is as follows.

- Initially the geometry is built using CATIA modelling software to accommodate three accumulators. The box and channel sections are considered for the base structure.
- The CFD analysis is carried out for the distributor to find reaction force on the structure in case of sudden opening which creates reaction force on the structure.
- CFD analysis is carried out using FLUENT software using inlet, outlet and wall boundary conditions. Mass flow rate is considered for inlet boundary condition.
- From CFD analysis, pressure, velocity plots are obtained. Reaction force is calculated for the obtained pressure values adding the static pressure.
- Further structural analysis is carried out using ANSYS software. The mesh excepting the distributor is done with shell mesh.
- Initial thermal analysis is carried out to find the effect of temperature on stress distribution and further force development at the support regions. These loads are further used for structural optimization of the problem.
- Finally modal analysis is carried out to find resonant frequency. The very first fundamental frequency is much higher than the operational frequency of the system. So structure is stable for dynamic modal conditions.
- The Vibrations analysis is carried out and results are obtained for different preloading conditions. The results shows drop of 2nd natural frequency.

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