Design and Analysis of Boiler Feed Pump Casing Working at High Temperature by using Ansys

Pravin D. Bhawar¹, M. B. Patwardhan²

¹P.G. Research Scholar, Mechanical Engineering Department, Walchand College of Engineering, Sangli, Vishrambag-416415, Maharashtra, India

²Associate Professor, Mechanical Engineering Department, Walchand College of Engineering, Sangli, Vishrambag-416415, Maharashtra, India

Abstract: Casing of Centrifugal pump is key factors for satisfactory performance of centrifugal pump. In this paper the Casing is designed in such a way that it should be operating without leakage and internal contact to rotating and stationary members. While engaged in maximum allowable working pressure (M.A.W.P.) and maximum operating temperature. This report presents the generation of model, structural and seismic analysis, and necessary geometrical modifications performed for pump casing. Possibility of failure would be examined under structural and seismic analysis. For theoretical investigation of problem Finite Element Method is used. To control possibility of failure and its failure phenomenon are examined and necessary geometrical modifications are applied to the initial model, Such that geometrical modifications should not increase the manufacturing costs.

Keywords: Centrifugal pump casing, Structural analysis, Seismic analysis.

1. Introduction

Pumps have continued to grow in size, speed and energy level, revealing new problems that are being addressed by innovative materials and mechanical and hydraulic design approaches. Pump and its components must have reliable performance without any leakage. Centrifugal pumps are used in a wide range of applications and they can handle a variety of liquids like boiler feed water at relatively high pressures and/or temperatures. The present work focuses on high energy, double volute pump, it should be operating without leakage while subjected simultaneously maximum allowable working pressure (M.A.W.P.) and maximum operating temperature. However, due to the high energies involved these pumps tend to suffer more pressure pulsations than single stage pumps. Hence for satisfactory performance it is intended to do the various analyses like structural analysis, Seismic analysis. So that the important part of pump shall be designed and possibility of failure would be examined and necessary geometric modification will be applied to the model.

2. Design of casing and description of pump

The centrifugal-pump is designed with single stage and double suction impeller. The requirements for the centrifugal pump are it should develop the 475 m of head with 2135 m³/h flow rate while running at 4200 rpm. The schematic view of the centrifugal pump casing with impeller is shown in Fig.1. The casing has trapezoidal section for volute shaped segment [6]. The volute is developed by distributing its cross-sectional area on base circle beginning from its tongue. For designing the casing the double suction impeller are used with 445 mm outside diameter, 21° vane discharge angle, 96.96 (m/s) impeller peripheral speeds [1].



Figure 1: Pump Casing with impeller

Fig. 2 shows the exploded view of centrifugal pump casing (Hydraulic of Casing).



Figure 2: Casing section (Hydraulic of Casing)

The material used for casing is ASTM A743- CA6NM. The casing volute thickness (40 mm) is calculated as per

International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Impact Factor (2012): 3.358

American Society of Mechanical Engineer (A.S.M.E.) [3]. The Main casing body is fitted to the casing cover with suction and discharge pipes are connected to casing through bolted connection. The centrifugal pump casing is fixed on base plate in two points. The schematic arrangement of centrifugal pump casing is as shown in Fig.3.



Figure 3: Pump Casing

3. Structural Analysis of casing

Structural analysis is the determination of the effects of the loads on the physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, pressures, torques and moments. Mechanical capabilities and reliability of casing are examined by using finite element analysis techniques. Here the capability means the maximum amount of stress generated in the casing while subjected to maximum allowable working pressure and temperature. So the maximum stress developed in casing is considered as optimum criterion to measure the capability of the casing. The maximum allowable working pressure in the casing for combination of required head and maximum temperature (103 bar.) is chosen according to the American Society of Mechanical Engineer (A.S.M.E.) and according to American Petroleum Institute-610 (A.P.I.) [2], [3]. The casing volute thickness (40 mm) is fixed. Finite elements analysis is used considering 3D stress analysis. The required material properties are listed in Table 1.

Table 1: Mechanical properties of Casing material (ASTMA743- CA6NM) [5].

Material	Ultimate Tensile Strength	Yield Strength
CA6NM	814 ((N/mm ²)	676 (N/mm ²)

Static structural analysis was performed to find out the maximum equivalent stresses developed in the casing due to maximum allowable working pressure. The developed pump casing model for Finite Element Analysis with meshes as shown in Fig. 4.



Figure 4: Meshed Pump casing model

The model meshed with patch independent meshing having 10-node tetrahedral elements. To obtain mesh independent analysis result model were sufficiently refined. For analysis some simplification were made in non-critical sections like bolt holes.

3.1 Finite Element analyses

In the suction side of nozzle suction pressure (16 bar) are applied, and in discharge side the maximum developed pressure (103 bar) are applied. These are as shown in Fig. 5 and 6 respectively.



Figure 5: Pressure at suction side



Figure 6: Pressure at discharge side According to API 610, the effect due to Gravity was due to very high pressure [2].

3.2 Result of analysis

As the equivalent stresses are considered for analyzing the capability and strength of casing. The obtained equivalent stresses are shown in the following Fig. 7



Figure 7: Equivalent stresses

It is observed that the maximum equivalent stress developed in casing is 540.94 N/mm^2 . The maximum stress is developed near the tongue.

4. Seismic analysis of casing

The seismic analysis is one of the important and crucial designing steps considered in designing of the various machineries. Those are used in nuclear power plants such that they should operate and withstand at the desired earthquake loading conditions. In seismic analysis the modal analysis are performed and then evaluated Required Response Spectrum (RRS) from the given Floor Response Spectrum (FRS) are obtained [4]. Finite element model are established and the natural frequencies are find out from modal analysis. After these obtained natural frequencies and the structural safety can be verified and its validity can be confirmed. The developed F.E.A. model with mesh shown in the following Fig.8



Figure 8: Meshed F.E.A. model

The model meshed with patch independent meshing having 10-node tetrahedral elements.

4.1 Modal analysis

For seismic condition the data for modal analysis, such as effective mass were used to determine natural frequencies of the model. In the modal analysis the natural frequencies for the developed model are calculated up to six modes. As most of earthquake wave having the frequencies less than 33 Hz [4]. As per the requirements the pump are rotating at 4200 rpm. This gives the natural frequency as 70 Hz. As the impeller having 5 numbers of blades so its blade passing frequency is 350Hz.

4.2 Results from modal analysis

The following fig. 9 gives the natural frequencies for the developed model.



Figure 9: Natural frequencies (For 6 Modes)

As the natural frequencies are calculated for six modes, so here six natural frequencies' are obtained from the modal analysis and these are shown as following Fig. 10

International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Impact Factor (2012): 3.358

	Mode	Frequency [Hz]
1	1.	592.99
2	2.	625.03
3	3.	851.01
4	4.	1069.3
5	5.	1075.1
6	6.	1176.8
		40.37 4.0

Figure 10: Natural frequencies

5. Conclusion

In this paper the centrifugal pump casing was designed and modeled for specific requirements as per the American petroleum Institute (A.P.I.) and American Society of Mechanical Engineers (A.S.M.E.) standards and undergone as structural and seismic analysis in ANSYS. By considering the results obtained from structural analysis, as maximum Equivalent stress developed (540.94 Mpa) is less than yield strength (676 Mpa) of casing material, it is predicted that the designed casing is reliable and safe for maximum allowable working pressure and temperature. For seismic condition the data for modal analysis, such as effective mass were used to determine natural frequencies of the model. As the obtained minimum natural frequency (592.99 Hz) is far away from the standard Earthquakes wave frequency (33 Hz) and blade passing frequency (350 Hz), the casing is safe for seismic condition as per American petroleum Institute (A.P.I.) standards. As the maximum equivalent stresses are developed near the tongue. So by considering more safety of casing the required geometrical modification should be done at the tongue.

6. Future Scope

The topic of this work is design and analysis of centrifugal pump casing. In this paper the Centrifugal pump which is used as boiler feed pump in Nuclear power stations. So this report gives further future scope to those companies that are interested in the world market for manufacturing of centrifugal pumps with detailed design and analysis information on its present status and future development for hazardous area applications like nuclear power stations. Emphasis has been placed on providing to the reader with the latest available information on how the maximum allowable working pressure and temperature affect on the pump casing in the nuclear station and what are the possible geometrical modification would be applied on initial model by considering seismic conditions. This report is ideal for analyzing the centrifugal pump casings reliability and capability and predicting its life.

References

- Igor J. Karassik, Joseph P. Messina, Paul Cooper, Charles C. Heald "Pump Hand Book," TATA McGraw-Hill, 3rd Edition 2001, pp. xviii,2.1-2.30,5.28,5.29.
- [2] "American Petroleum Institute Standards-610," (Pump Hand book), Eleventh Edition, September 2010, pp.19,24-26.

- [3] American Society of Mechanical Engineers, "Boiler & pressure vessel code" Section VIII, division 2.
- [4] Jintai Chung ,Hyung-Bin Im , Sewan Kim, "Seismic Analysis of an Axial Blower using ANSYS," published on June 2009, pp. 1-9.
- [5] Kubota metal corporation, "Mechanical properties and composition of material and alloy", pp. 1, 2, [online]. Available:http://www.kubotametal.com/alloys/corrosion _resistant/CA6NM.pdf.
- [6] Austin H. Church,"Centrifugal pumps and Blowers", Metropolitan book company pvt. Ltd. Delhi-6, pp. 142-148.

Author Profile



Pravin D. Bhawar received B.E. in Mechanical Engineering degree in 2011 from Shri Tulja Bhavani College of Engineering, Tuljapur and Pursuing Master of Technology in Mechanical Design Engineering degree for year 2014 from Walchand college of Sangli

Engineering, Sangli.



Prof. M. B. Patwardhan received B.E. in Mechanical Engineering degree in 1979 from Walchand college of Engineering, sangli. And Master of Technology in Mechanical Design Engineering degree in year 1981

from Indian Institute of Technology Bombay. Also he is having 10 years of experience in Indian Institute of Packaging (I.I.P.). Now he is working as Associate professor in Walchand college of Engineering, sangli since 1997.