TEST Engineering & Management

*November - December 2019*
*ISSN:0193-4120 Page No. 6806 - 6813*

# Seismic Analysis of Horizontal Split-casing water Pump

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***Article Info***
***Page Number: 6806 - 6813***
***Publication Issue:***
***November - December 2019***

***Article History***
***Article Received:*** *5 March 2019*
***Revised:*** *18 May 2019*
***Accepted:*** *24 September 2019*
***Publication:*** *31 December 2019*

**Abstract**

The massive transformation in manufacturing sector, creates new challenging environment to pump manufactures. The Seismic Analysis of Splitcase Water Pump is introduced in this research work. Earthquake is a Natural calamity with massive accelerations that could lead to severe damages of Splitcase Water Pump. As the occurrence of this instance is not in control of anybody, it is better to ensure that the products that are installed in such zones are designed to withstand these massive loading. There are two approaches used to ensure the mechanical integrity of the products installed. The first is experimental approach wherein the shake table tests are conducted with a view to find the natural frequencies and relative deflections with specified accelerations. This work presents an alternative approach to ensure mechanical integrity of the product when installed in earthquake prone area. The approach is demonstrated by considering a Split Case double suction pump. The natural frequencies are estimated using commercially available FEA packages.

**Key Words:** Radial deflection, efficiency, mechanical integrity, natural frequency.

## INTRODUCTION:

Kirloskar Brothers Limited, Pune are manufacturer of pumps valves and turbines. The pump is described as a machine that increases the compression capacity of a liquid with the help of Pump. The pulse movement is transferred to the liquid using a blade embedded in a disk known as an impeller. The operating principle depends on the fact that rotating

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the incense with properly formed particles, sets the liquid particles in the incense field moving, from the suction side toward the delivery side. The pumps are used for variety of applications and special care is to be taken when installing these pumps in Earthquake prone zones. To ensure safer operation under seismic condition, the mechanical behavior of the pump motor assembly was studied from the viewpoint of structural integrity of the system.

Bin Cheng et al. [1] The purpose of this study was to analyze the flow characteristics of the inlet at side diversion stations and pumping stations to enter and access the flow adjustment of the guide separator by quantitative simulation, according to the chaotic model and SIMPLEC algorithm. The main conclusion was that, the flow flow pattern is more complex than a single lateral separation or lateral pump station and the flow pattern in the lateral deviation section is similar to the curvature flow. Honggeng et al. [2] investigated the internal flow patterns of the volume-discharge corridor, with a mixed flow-based system based on computational fluid dynamics (CFD). analysis shows that the internal flow pattern of the flow of the volute-type discharge is very complex; there is a separation of vortex and flow in normal cross-sections. Marscher et.al. [3] discussed various causes of centrifugal pump failure. He introduced the major equipment reliability issues facing modern pump users as well as design features, installation issues and repair methods that proved to be helpful in reducing repair costs and downtime. Veness et al. [4] has been introduced in the form of a small spray Seal, used to treat toxic, hazardous & environmentally friendly chemicals. Sub-magnetic seals for small pumps appear as the first option. With the successful installation and operation of the required seal under the pump to provide all the necessary information about the pumping fluid. Pierecy et al. [5] explained the problems with mechanical shaft accounts that make up most of the maintenance costs of the pump. When pumping critical or hazardous liquids, users may use special markers such as double-cartridge markers. However there are still some problems that occur with special symptoms. This requirement leads to the development of a waterless pump. The new suspension uses an axial field, a permanent magnet motor connected directly to the impeller & pump casing. Brennan et al. [6] discussed the many designs of the Sealless centrifugal pump that has been well developed over the years. When handling transparent fluids, shear critical fluids or flow / pressure requirements other than centrifugal pumps, rotary, good transmission pumps provide reliable, efficient, and economical solutions. Waterless circulation pumps are available in a growing range of configurations. The need for waterless pumps ranging from cosmetic storage issues and maintenance costs to hitting a toxic, destructive, glittering liquid or other hazardous or hard to stop liquid.

The scope of the study was to carry out the natural frequency analysis, find out the fundamental natural frequency of the structure and to study if the natural frequency is matching with any of the excitation frequency e.g. rotational speed of the pump. The stresses developed under various loads and the translations are to be estimated. The stress levels and the relative deflections are to be estimated under specified forces, moments, operating pressure and seismic accelerations. The general requirements of design were specified in ASME Section III, Division-I, Subsection-NB. The support requirement is taken from ASME Section III, Division-I, and Subsection-Nf. [10]

The paper describes Computational approach used in the analysis and presents results in the form of natural frequencies, stresses developed, bearing clearances compared with relative deflection at respective locations.

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**DETAILS OF MODEL:**

The module consists of following major components.

i) Stationary Unit
ii) Rotating Unit
iii) Bearings

The stationary unit consists of Pump Casing, Glands, Oil ring, bearing housing, bearing cover, bearing bracket, support foot, stator of the motor & base plate. The rotating unit consists of shaft, impeller, coupling and rotor of the motor. Figure.1 shows Pump Motor Unit. The entire assembly is modeled as three-dimensional model consisting of beam and plate elements. The computational model is shown in Figure.2

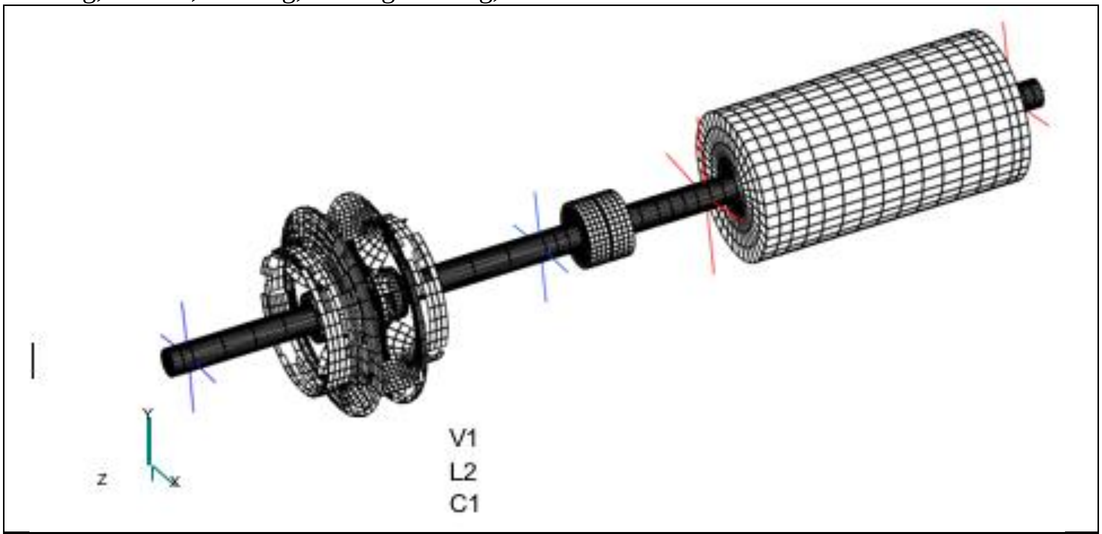


**Figure:1-Rotating Components and Bearing Location**

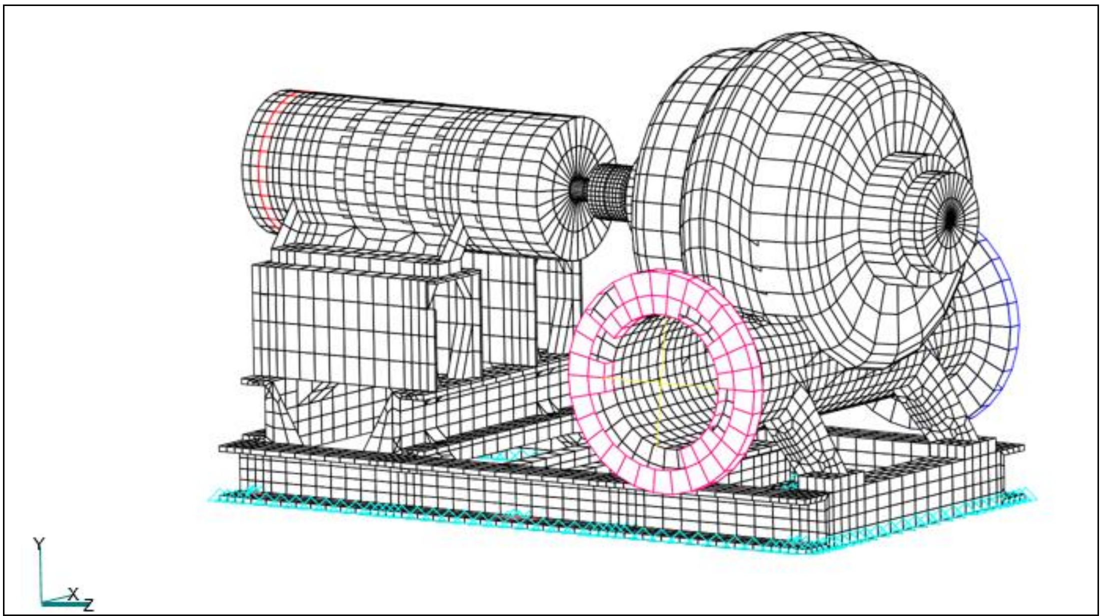


**Figure 2:-Computational Model with Constraints**

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## Stiffness

As the bearings are modeled as spring elements appropriate stiffness was estimated as specified in [8]. The stiffness calculated is as follows.

Radial Stiffness – 2.745 x $10^7$ N/m Pump (N.D.E) Radial Stiffness – 1.945 x $10^7$ N/m Pump (D.E) Radial Stiffness – 1.280 x $10^8$ N/m Motor (D.E) Radial Stiffness – 1.280 x $10^8$ N/m Motor (N.D.E)Axial Stiffness – 2.0 x $10^{10}$ N/m

## Natural Frequency Analysis:

The natural frequency of the assembly was estimated to judge the stiffness of the unit and explore the possibility of resonance. The pump rotates at 1450-rpm i.e. 24.16 Hz. Table 1 gives the frequencies for all the modes. The Table shows that the first mode of vibration is with frequency of 94.78 Hz, of the pump motor assembly, which is considerably higher than the operating frequency of 24.16 Hz. indicating that there is no possibility of resonance occurrence. The mode shapes for first four natural frequencies are presented in Figure.4a, 4b, & 4c

Table – 1

**Natural Frequencies**

| Mode No. | Frequency in Hz |
|---|---|
| 1 | 94.78 |
| 2 | 98.93 |
| 3 | 117.01 |
| 4 | 131.14 |
| 5 | 133.02 |
| 6 | 146.47 |
| 7 | 154.44 |
| 8 | 171.95 |
| 9 | 211.82 |

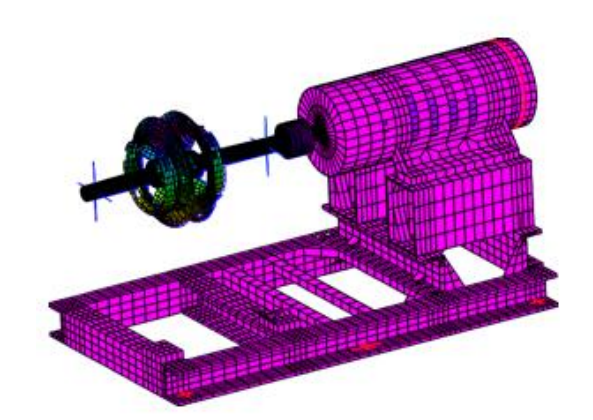

**Figure 4a:-Mode 1 Frequency 94.78 Hz**

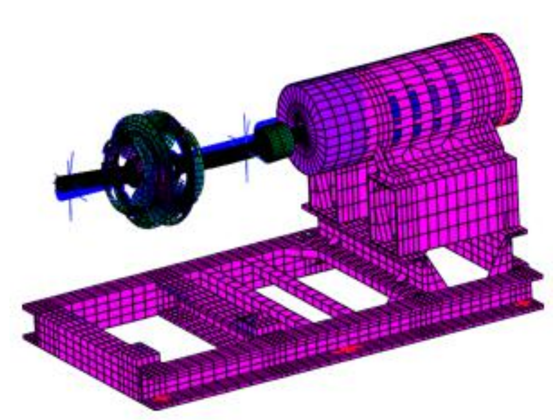

**Figure 4b:-Mode 3 Frequency 117.01 Hz**

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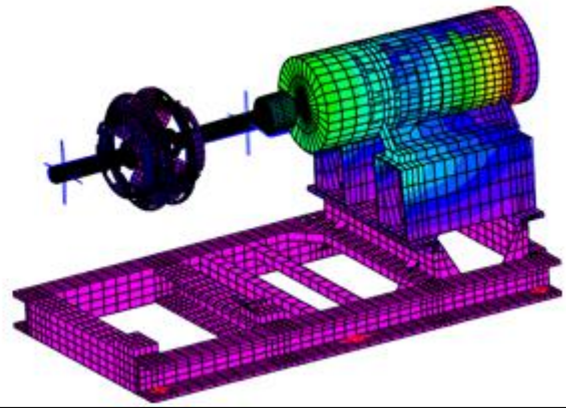

**Figure 4c:-Mode 6 Frequency 146.47 Hz**

## Equivalent Static Analysis:

The first natural frequency is considerably higher than the threshold frequency of 33 Hz, the system is considered to be relatively stiff and instead of performing dynamic analysis for specified spectra, an equivalent static analysis was carried out. The Seismic accelerations for Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) conditions were specified and applied to the model as a body force. The forces and moments on suction anddelivery flanges were applied appropriately. The pressure force corresponding to shut off head was applied on all wetted surfaces of the pump. Figure 3. Shows the computational model with all forces, moments and constraints.

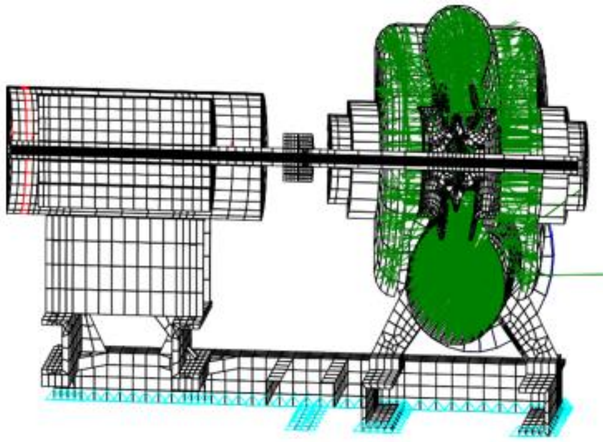

**Figure 3:- Cut Model with Loads (Pressure)**

The results are in the form of Von-Misses stresses. The stress levels are maximum on casing i.e. Suction & Delivery portion. The maximum stress level is seen to be 124.17 Mpa in OBE condition and 129.23 Mpa in SSE condition as shown in Figure.5 & Figure 6. The stress levels were seen to be well within the allowable stress limits for the material. [7]

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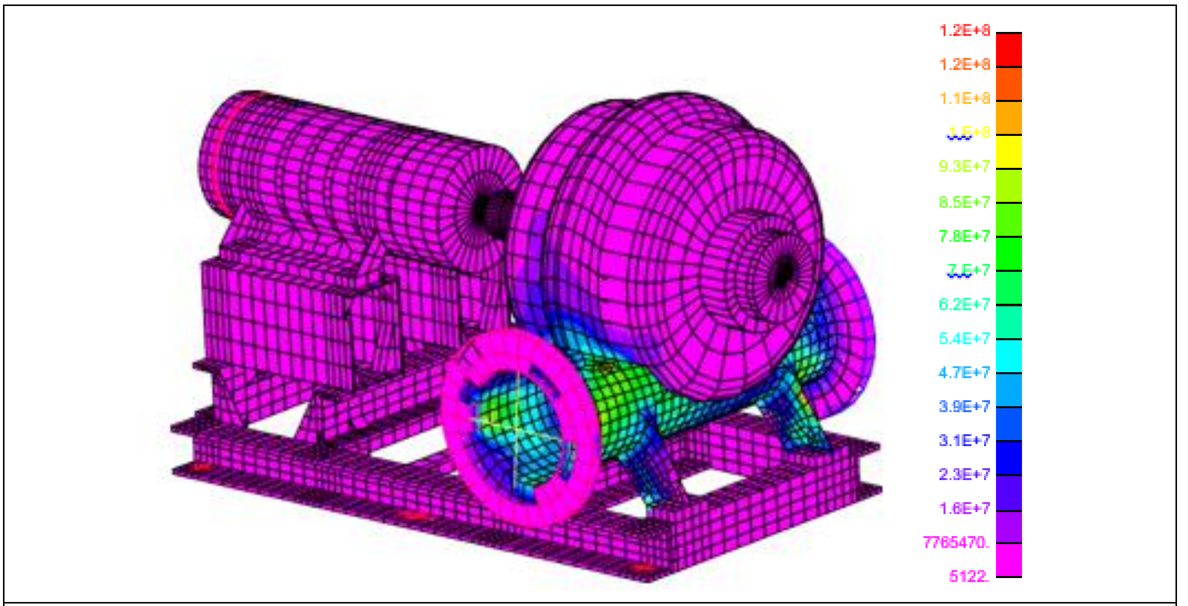


**Figure 5:-Von Misses Stress (N/m^2) OBE Condition**

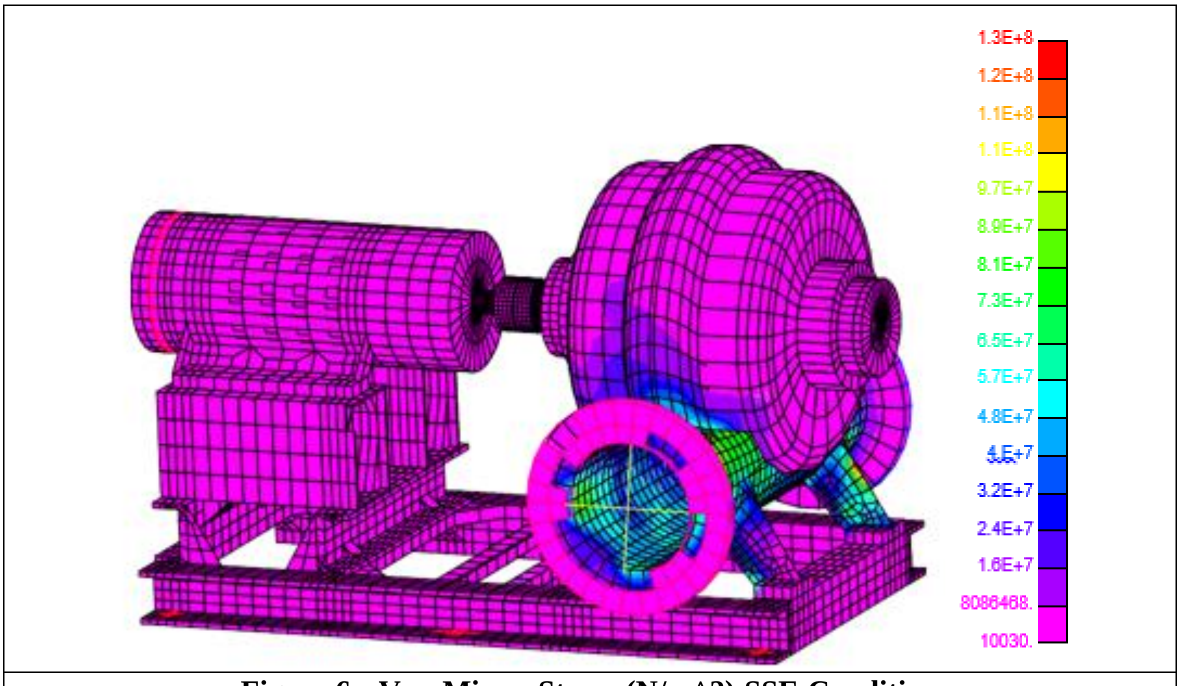


**Figure 6:- Von Misses Stress (N/m^2) SSE Condition**

The relative deflections at various bearing locations & corresponding design clearances in bearings [8] are presented in Table 2. It is clearly seen that the minimum clearance available is more than that of the max relative deflection between stationary and rotating component at bearing.

**TABLE – 2**
**RELATIVE DEFLECTIONS AT BEARING PORTIONS AND IMPELLER AND CASING (EQUIVALENT STATIC ANALYSIS)**

| Sr.No | Bearing Type | | Max.Relative Radial deflection (microns) | Design Clearance (microns) Min | Max |
|---|---|---|---|---|---|
| 1 | Pump NDE | 6309 | 2.015 | 19 | 35 |
| 2 | DE | 6309 | 7.024 | 19 | 35 |
| 3 | Motor NDE | 6313 | 9.081 | 26 | 52 |
| 4 | DE | 6313 | 15.089 | 26 | 52 |

## Qualification of Foundation Bolts:

The static analysis was carried out with flange loads and seismic loads to arrive reactions at the foundation bolts. The reactions at six bolt locations were used for estimating stresses developed in bolts for OBE and SSE condition.
The bolt with maximum reactions is checked for strength. Other bolts with lower loading automatically get qualified.

The foundation bolts used (M30 bolts 6 nos) are checked for tension and shear considering actual reactions at all 6 bolt locations to meet requirements of ASME III section NF 3324.
The maximum tensile stress was estimated to be ft=28.48 Mpa and shear stress fv= 24.04 Mpa for bolt no.6.

Principal Stress = ft /2 + $\sqrt{(f_t/2)^2 + f_v^2}$ (For M 30 bolt) = 939.00 Kg/cm$^2$

Material for Foundation Bolt IS: 1570 40 C 8

Su = 42 Kg/mm$^2$

**As per NF 3324.6**

For combined tensile & shear loads

$$\frac{F_t^2}{F_{tb}^2} + \frac{f_v^2}{F_{vb}^2} < 1$$

Where,

$f_t$: Computed $_{\text{tensile}}$ Stress For M 30 bolt $f_t$ = 621.72 Kg/cm$^2$

$f_v$ : Computed Shear Stress For M 30 bolt $f_v$ = 545.82 Kg/cm$^2$

$F_{tb}$ : Allowable tensile Stress Su/2 = 4200/2 = 2100 Kg/cm$^2$

$F_{vb}$ : Allowable Shear Stress = 0.62 * Su / 3 = 868 Kg/cm$^2$

Substituting, For M 30 bolt

$$\frac{(621.72)^2}{(2100)^2} + \frac{(545.82)^2}{(868)^2}$$

$$= 0.4830 < 1$$

As seen in M 30 foundation bolts are qualifying ASME Subsection Nf requirements.

## Conclusion

- The pump motor assembly of Splitcase Water Pump was investigated thoroughly for it mechanical integrity with specified loads and constraints using a computational approach.

- The first mode of natural frequency was estimated to be 94.78 Hz and was much higher than the operating speed of the pump.
- The maximum stresses are well within the acceptable limits of material, as per guidelines specified in ASME Section-III Division I - ND. Table ND 3416-1.
- The deflections at bearing portions are less than the available design clearances.
- The analysis suggests that the pump motor assembly and foundation bolts integrity is safe under the specified seismic conditions prevailing at site.

**Acknowledgement:**

Authors take this opportunity to thank the management of Kirloskar Brothers Limited, Pune, INDIA for their encouraging attitude towards research and engineering activities, which led to this paper. Authors would like to acknowledge the support provided by Research and Engineering Staff for their cooperation

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