Optimization of Base Frame of Multistage Centrifugal Pump maintaining the Shaft Deflection as per API Standards

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Abstract: ***Base Frame are the traditional and most common means for reducing weight of pump. The factor of safety of existing base frame is more than the required. In this project work, after optimizing weight of base frame of multistage centrifugal pump the factor of safety reduces and it becomes as per required. For weight reduction we considered the forces and moments acting on the suction and discharge nozzle of the pump. Shaft deflection analysis is carried out by using ANSYS software. Also the shaft deflection of pump is checked after optimization which is within API 610 standard.***

Keywords: Multistage Centrifugal Pump, Base Frame, Motor, Shaft Deflection, API Standards

1. Introduction

Pumps are widely used in various industries like petrochemical, textile, natural gas, chemical based on application. So, it is very much essential for the manufacturers to produce parts of pump assembly having highest possible reliability. Over past many years, changes had to be made to pumps and pump assembly to improve performance. In these industries, base Frame are the traditional and most common means for reducing weight of pump assembly. Hence, optimization of base frame of pump has become the area of interest. However, for petrochemical industry compliance of API 610 standard is mandatory.

In this work, optimization of base frame of multistage pump can be done maintaining the shaft defection as per API standard. The standard stipulates that pressure casings are to be designed to twice the maximum allowable values, and limits the allowable coupling end shaft displacement under specified test conditions as per API 610 standard (Table 13).

Generally, the piping systems carrying gases, liquids etc. is subjected to excessive piping reactions in pumps, thus causing higher vibrations, coupling failures, and pump shaft misalignments. In severe cases there are flanged joint leaks and the occasional occurrence of impeller rub or casing distortion. Excessive shaft misalignment in turn leads to premature seal and bearing failures. These difficulties are a costly maintenance item that can also result in plant shutdowns, and in severe cases, fires and extensive damage. Recognizing the critical importance of managing piping loads on rotating equipment, engineers have established standards for allowable forces and moments for rotating machinery. These standards become design criteria for the equipment manufacturer and establish allowable limits for the piping system designer. The American Petroleum Institute standard for centrifugal pumps provides a table for the maximum allowable forces and moments for various flange sizes.

Table1: Stiffness Test Acceptance Criteria For Pump

Base plate not intended for grouting		
Loading condition	Pump shaft displacement (μ)	Direction
M_{yc}	125 (0.005)	+Z
M_{zc}	50 (0.002)	-Y
M_{yc} and M_{zc} equal the sum of the allowable suction and discharge Nozzle moments from table 1. $M_{yc}= (M_y)_{suction} + (M_y)_{discharge}$; $M_{zc}= (M_z)_{suction} + (M_z)_{discharge}$		

2. Objective of Work

To optimize base frame of multistage centrifugal pump and check the shaft deflection as per API std.

3. Relevance

Base Frame, Shaft, bearing are the key components of any single stage or multistage pump. Therefore to obtain better performance of multistage pump, different theoretical cases have been studied by changing length of I-section, by changing size of supporting channel etc. Then these cases have been analyzed for the stresses coming on the components of base frame, shaft etc. of pump by using design formulae / data book and CAD /CAE software's like HYPERWORKS /ANSYS .The vibrations can be controlled and also life of pump can be increased by base frame optimization and shaft deflection analysis.

4. Experimental Set-up

Fig. shows the block diagram of centrifugal pump assembly.

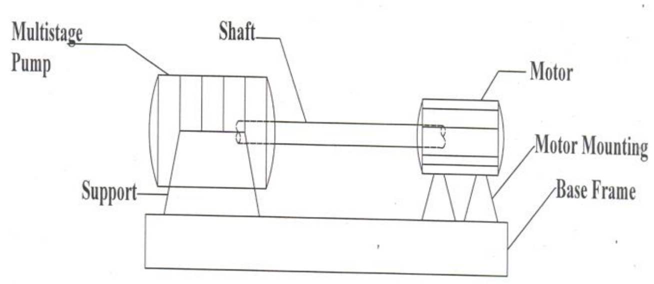

Figure 1: Assembly of Multistage Centrifugal Pump

It consists of Multistage Centrifugal Pump, Base Frame, Electric Motor, Shaft, motor mounting and pump mounting on the base frame.

Multistage centrifugal pump having 16 stages. It consists of discharge casing, stage casing and suction casing. The weight of pump is 1300 kg. Squirrel cage motors are generally used to drive multistage pumps. Motor having capacity 650 KW and running at speed 2986 rpm. Running torque is 2079 Nm. Torque is transferred to pump by means of rotating shaft. Base frames are used to mount pump & motor specially designed and engineered to support mechanical equipment requiring a supplemental mounting base frame. The Extra supports are provided for mounting the pump & motor. The weight of base frame is 1381 kg.

5. Finite Element Analysis of Old Base Frame

The solid model of base frame was imported into ANSYS 14 for meshing and analysis. The complete assembly consists of shell elements, solid elements, beam elements, rigid elements. Geometry is meshed by keeping relevance center as medium. Element size has been set to 6. Total element and node count for old base frame
Node population count = 8, 21,434.
Element population count = 4,54,685.

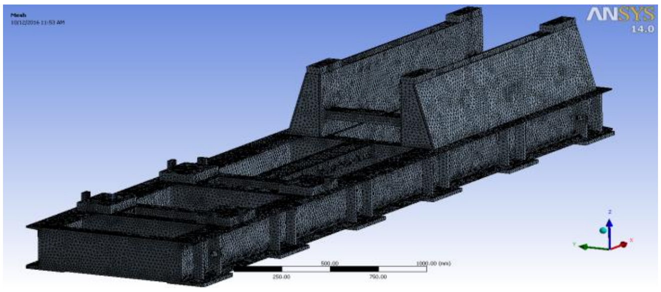

Figure 2: Isometric mesh assembly of old base frame

Table 2: Material Properties of Base Frame

Density of material	7850 kg/mm3
Young's modulus	21000 kg/mm3
Poisons ratio	0.3
Ultimate tensile strength	410 MPa
Yield strength	250MPa

The bottom plate of frame surfaces provided the fixed support, the moment & forces considered from API standard. Figure 3 and Figure 4 shows forces and moments acting on old base frame respectively.

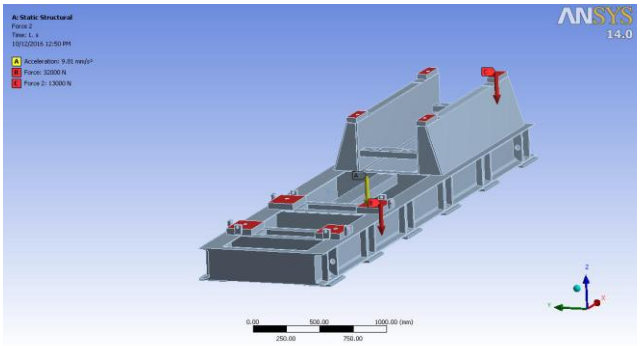

Figure 3: Static forces due to self-weight of frame, motor and pump

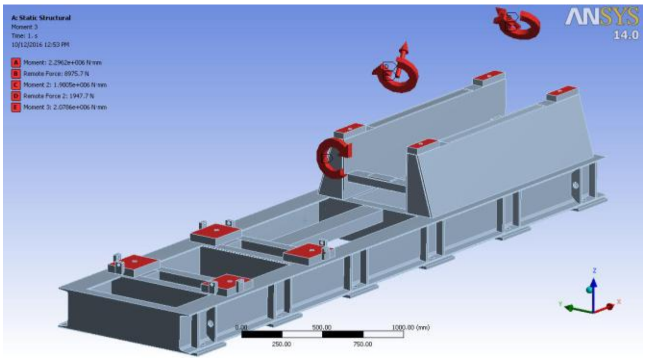

Figure 4: Resultant Moments & Forces from Motor and pump

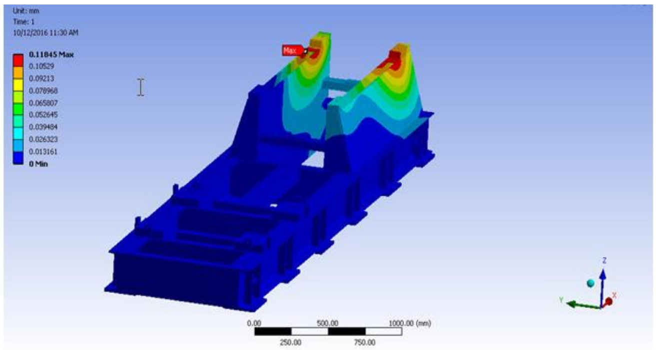

Figure 5: Total Deformation plot of Old Base Frame

Table 3: Forces and Boundary Conditions For Shaft Deflection Analysis

Forces	Suction nozzle	Discharge nozzle
My	930	470
Mz	1380	720

Moment due to rotation of motor shaft
Torque (T) = (Power (p)*60)/(2*3.14* N(rpm))
T = 2078.61 Nm

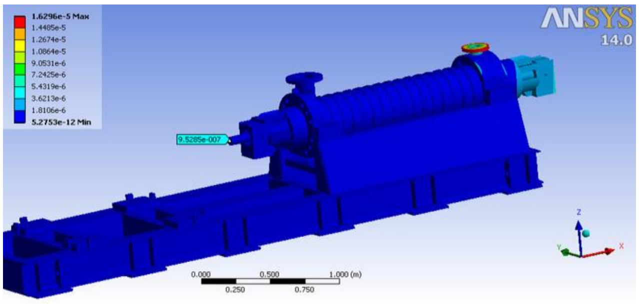

Figure 6: Deflection at shaft end due to M_Z

6. Modification in Old Base Frame of Pump

The Base frame modified as shown in fig.7 and 8.

1) Rectangular pocket added in pump base mounting of 215 * 1140 mm
2) I channel section replaced by c channel section
3) All four sides of two rectangular pockets (215 * 1140 mm) are covered by 2mm thick plate.
4) Rectangular 4 holes of 50 * 50 mm on the opposite inner sides of both pockets (215 * 1140 mm)

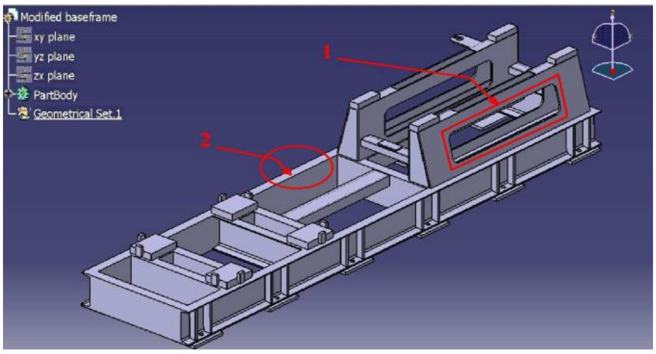

Figure 7: Modified Solid Model of Base Frame using CATIA V5

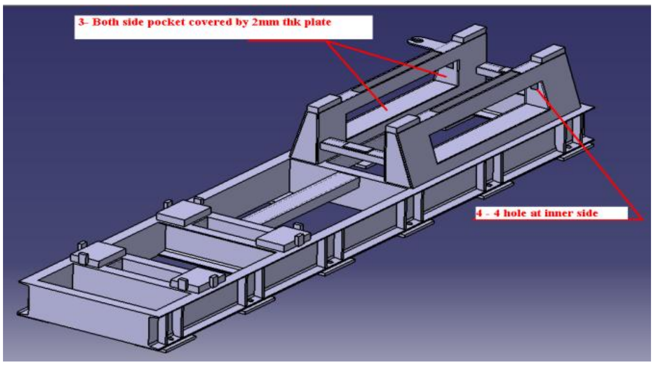

Figure 8: Modified Solid Model of Base Frame using CATIA V5

7. Finite Element Analysis of Modified Base Frame

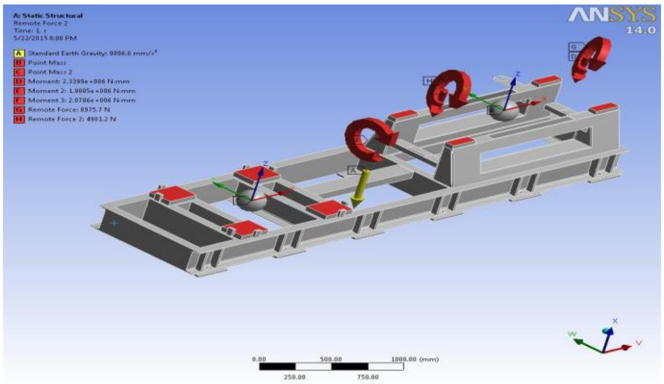

Figure 9: Resultant Moments & Forces from Motor and pump acting on modified base frame

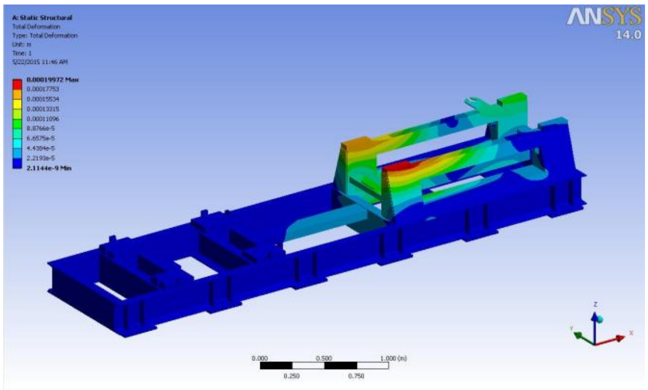

Figure 10: Total deformation of modified base frame

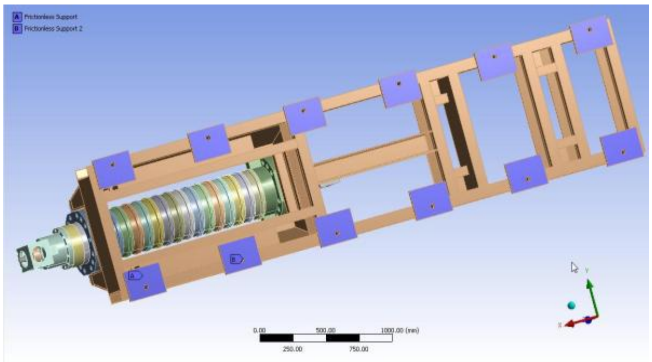

Figure 11: Frictionless support applied to modified base frame and pump assembly

Following figure 12 & 13 shows shaft deflection after modifying the base frame of centrifugal frame at suction and discharge nozzle due to moment acting My and Mz.

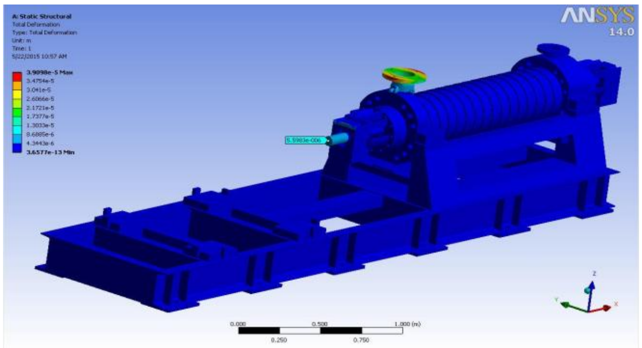

Figure 12: Deflection at shaft end due to My

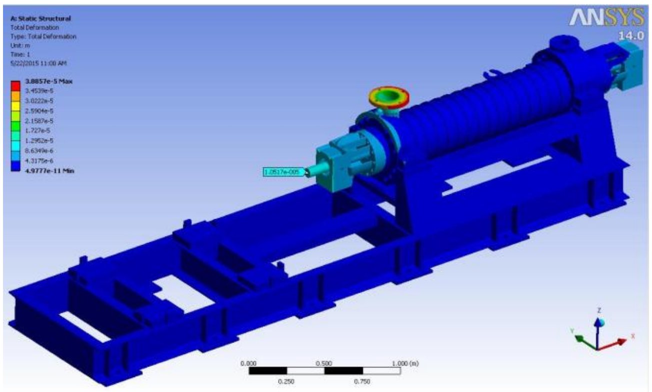

Figure 13: Deflection at shaft end due to Mz

8. Results and Discussion

Table 4: Shaft Deflection Due to the Suction and Discharge Nozzle

Deformation of old base frame (mm)	Shaft deflection at old base frame (μ)	Deformation of modified base frame (mm)	Shaft deflection at modified base frame (μ)
0.11845	9	0.19972	11

9. Conclusion

From above discussion it is seen that the shaft deflection of old base frame is 9 micron and after modifying the base frame of pump, the maximum deflection is 11 micron which is within API standard.

Also, the weight of base frame reduced from 1331 to 958 kg. Modified base frame has 373 kg less mass as compared to old base frame. It states new base frame is cost effective than old base frame.

10. Acknowledgment

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References

[1] Naveena M and Dr. Suresh P, "Lateral critical speed analysis of multistage centrifugal pump rotor using FEA," International journal Of Innovative research in Science, Engineering and Technology (ISO 3297: 2007 Certified Organization) Vol. 2, Issue 8, August 2013.
[2] Amit V. Chavan and S.S. Gawade, "Experimental and finite element analysis of base frame for rigidity," International Journal of Engineering Science and Technology (IJEST) ISSN : 0975-5462, Vol. 3 No. 10 October 2011.
[3] Kishor D. Jadhav and Maneet.R.Dhanvijay "Design and standardisation of base frame & ant vibration mounts for balanced opposed piston air compressor," International Journal of Applied Research in Mechanical Engineering (IJARME) ISSN: 2231 –5950, Vol-2, Iss-2, 2012.
[4] Joshi A. M. and Jadhav T. A. "Analysis and testing of skid of frame of compressor", International Journal of Applied Research and Studies (iJARS) ISSN: 2278-9480 Volume 2, Issue 9 (Sep - 2013).
[5] James E Staiger —Lead design engineer API 610 Base plate and Nozzle loading criteria‖ Design engineer, united centrifugal pumps, San Jose, California.
[6] API STANDARD 610 ELEVENTH EDITION, Centrifugal pumps for petroleum, petrochemical and Natural gas industries.