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# Shaft deflection Analysis of Multistage centrifugal Pump by Finite element Method

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***Abstract*— The base frame of multistage centrifugal pump is designed by conventional design Practices. The factor of safety of this design frame is more than required. After optimizing weight of the base frame of multistage centrifugal pump the factor of safety is reduces to drop down drastically. The different method & technique are given in text books for finding the shaft deflection. In this project work after optimizing the base frame of pump its need to check the shaft deflection of pump as per API standard.**

**The forces & moments acting on the suction & discharge nozzle of the pump create fluctuation. The shaft deflection of the pump getting from the vibration analysis is 9.1 micron for Exiting base frame. The allowable shaft deflection for shaft is 50 micron when frame is not intended grouting as per API 610.pump base frame weight is reduced by near about 30%after optimizing the base frame .In static analysis of the new updated base frame stress and deformation getting approximately about same. The base frame of centrifugal pump have good stiffness after reducing the weight so the objective of this project checking deflection of pump for optimizing frame within range of API standard**

***Index Terms*—Shaft deflection analysis of centrifugal pump**

## I. Introduction

A multistage centrifugal pump is a machinery or device for raising, compressing or transferring fluid. Pumps are used industries for transferring fluid from one place to another. The pumps are working on high speed & various reaction occur by flowing fluid due to which chances failure of various parts e.g. bearings failure shaft misalignments in shafts. Many times due to the excessive load the chances of failure of bearings and seals. It is very important to employ a good design procedure. The pump Shaft design consists of determining shaft diameter to provide strength and rigidity. Shafts are generally subjected fluctuating loads of bending and torsion with various degrees of stress concentration. In today's world computer playing good role to design of shafts & machine element this is essentially an analysis problem which determine how safe a shaft is for the proposed loading conditions. The other thing to be considering material properties, support locations positions of geometry changes, constraints on deflection and factor of safety. It's important to verify the pump shaft deflection due to the forces & moments acting on the suction and discharge nozzles. The loads on the inlet & outlet of the pump create more forces & moments which is very important to design the pumps. The pump manufacturer has used the standard for piping as per API Norms. The API standard provide the standard for allowable forces & and moments for various different sizes of flange.

## II. Objectives of the Work

1. To optimization of the base frame of multistage centrifugal pump and maintain the deflection of shaft as per API norms.
2. To study the shaft deflection of the existing base frame of multi-stage centrifugal pump.

## III. Methodology of Work

Optimization of frame will be carried out analytically and also by using CAD / CAE software's like CATIA / ANSYS. Then this configuration is simulated in ANYSYS. Stress Analysis is done by using ANSYS software. We will obtain optimum results with the help of FEA. Then this configuration is validated with the help of experimental results.

## IV. API 610 Stiffness Test Acceptance Criteria for Pumps

**Table1. Stiffness test acceptance criteria**

| 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. $M_{yc}= (M_y)_{suction} + (M_y)_{discharge}$; $M_{zc}= (M_z)_{suction} + (M_z)_{discharge}$ | | |

The table 1 shows the stiffness test acceptance criteria for rigidity of frame. as per API 610 standard consider two loads cases $M_{yc}$ & $M_{zc}$ in both load cases used for different loading $M_{yc}$ is loading is used on suction & discharge nozzle to create moment about y axis and deflection along z direction in $M_{zc}$ loading condition loads are applied on suction and discharge to create moment about z axis and defection of shaft is in y direction there is no effect $M_{xc}$ loading condition on shaft deflection.

## V. Experimental Setup

The block dig showing the layout of multistage centrifugal pumps which consists of the following parts-



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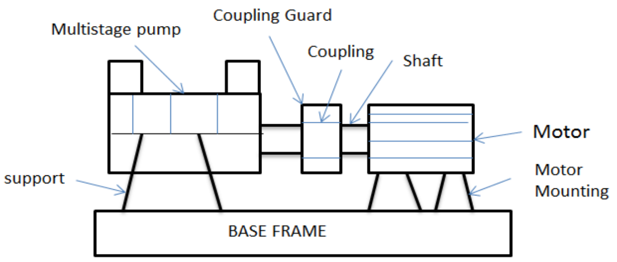


**Fig.1. Experimental setup**

Centrifugal multistage pump, Electrical motor, base frame, coupling, coupling guard, shaft, motor mounting and pump mounting on the base frame. Multistage centrifugal pump having 16 stages .Motor having capacity 650 kw and running at speed 2986 rpm. Motor is a machine that converts one form of energy to other, such as electrical energy into mechanical energy or motion. Squirrel cage motors are generally used to drive multistage pumps. These motors are simple and rugged in construction. Motors relatively cheap and require very less maintenance, so used for industrial pumps. 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 support are provided the mounting the pump & motor .the coupling is provided to connecting the motor & pump shaft. Coupling guard is used for protecting from high speed of pump & physical damage.

## VI. Analysis of shaft defection of multistage centrifugal pump by FEA

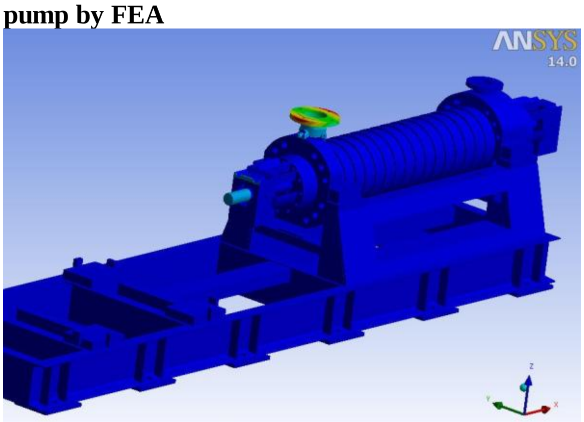


**Fig.2. Solid model of modified pump base frame**

The complete assembly consists of shell elements, Beam elements, rigid element and Gap elements.

SOLID168 is a higher order 3-D, 10-node explicit dynamic element. It is well suited to modeling irregular meshes such as those produced from various CAD/CAM systems. The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions

MPC184 comprises a general class of multipoint constraint elements that apply kinematic constraints between nodes. The elements are loosely classified here as "constraint elements" (rigid link, rigid beam, and slider) and "joint elements" (x-axis revolute, z-axis revolute, universal, slot, point-in-plane, translational, x-axis cylindrical, z-axis cylindrical, x-axis planar, z-axis planar, weld, orient, spherical, and general).

TOTAL ELEMENT AND NODE COUNT:
Node Population Count- 8, 21,434.
Element population count- 4, 54,685.

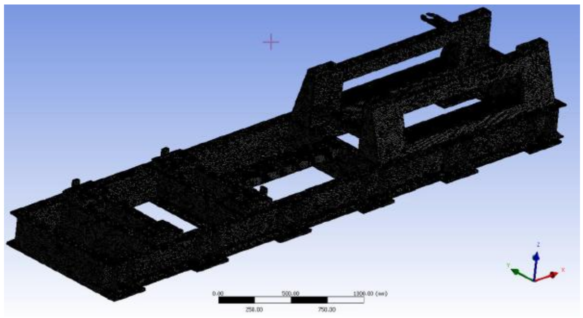

**Fig.3. Meshing of New pump base frame**

## VII. Material properties of base frame

Material used for base frame centrifugal frame is IS2062 Gr.Fe 410B. The material properties are as follows. The material IS2062 is used mostly for fabrication work.

**Table 2. Material properties of base frame**

| | |
|---|---|
| Density of material | 7850 kg/mm$^3$ |
| Young's modulus | 21000 kg/mm$^3$ |
| Poisons ratio | 0.3 |
| Ultimate tensile strength | 410 MPA |
| Yield strength | 250MPA |

## VIII. Modification in Existing base frame of pump

The existing Base frame modified as shown in fig.4 and 5.

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)

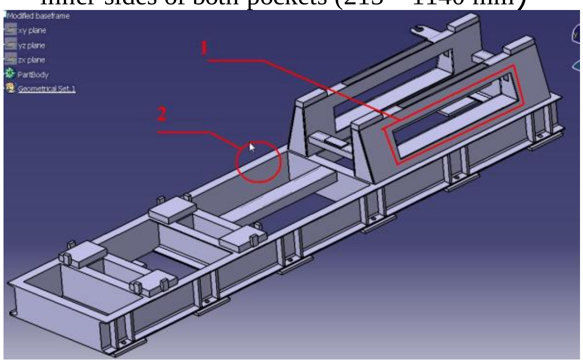


**Fig.4. Modified solid model of pump base frame**



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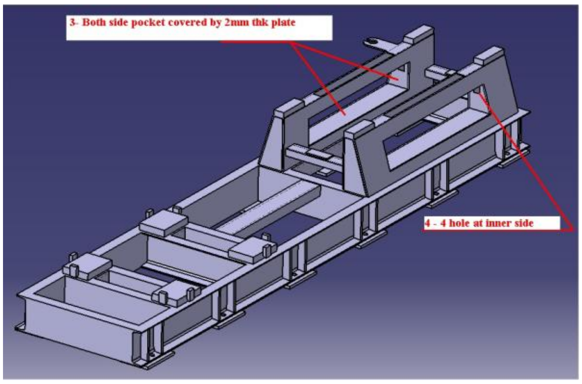


**Fig.5.Modified solid model of pump base frame**

## IX. BOUNDARY CONDITION

The boundary condition is important parameter in FEA analysis the following are the boundary conditions are considered for this project. The bottom plate of frame surfaces provided the fixed support, the moment & forces considered from API standard.

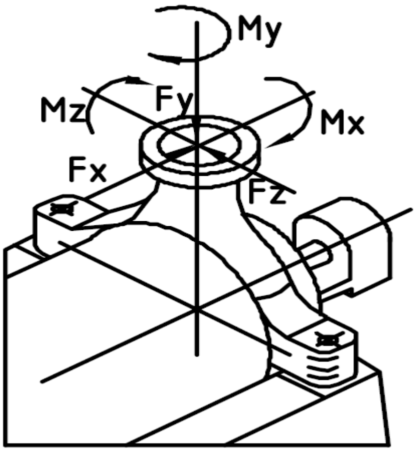


**Fig.6. Forces and moments on pump nozzles**

**Table3: Forces and boundary conditions for shaft deflection analysis**

| Forces | Suction nozzle | Discharge nozzle |
|---|---|---|
| $M_y$ | 930 | 470 |
| $M_z$ | 1380 | 720 |

Moment due to rotation of motor shaft

Torque (T) = (Power (p)*60)/(2*3.14* N(rpm))

T = 2078.61 Nm (running torque)

Starting torque of motor= 5100 Nm

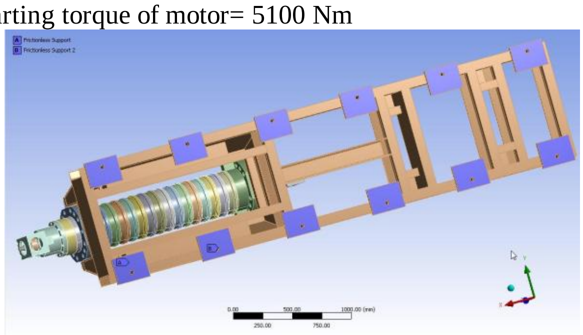

**Fig.7 Pump base frame fixed support**

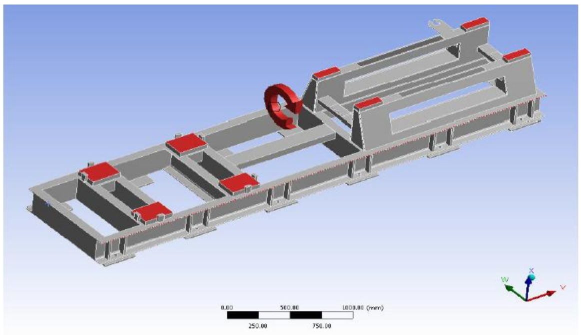

**Fig.8 Moments due to rotation of motor shaft**

## X. RESULTS & DISCUSSION

It is concluded from FEM and Experimental results shaft deflection of the pump coming within range of API standard. And deformation coming in suction & discharge nozzle is negligible for modified base frame.

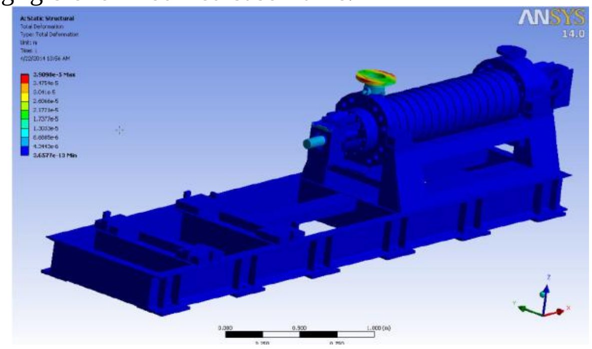


**Fig.9. Deformation at suction due to $M_y$**

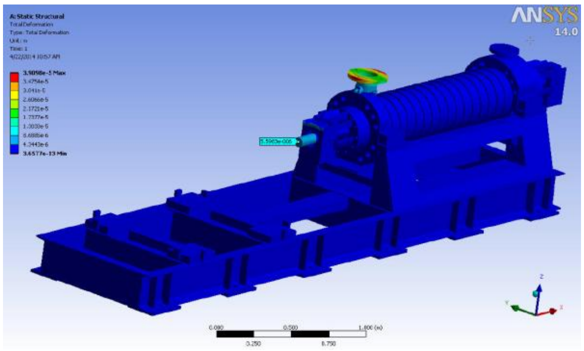


**Fig. 10 Deflection at shaft end due to $M_y$**

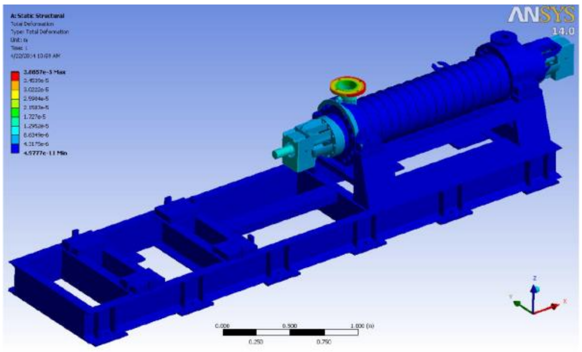


**Fig.11 Deformation at suction due to $M_z$**



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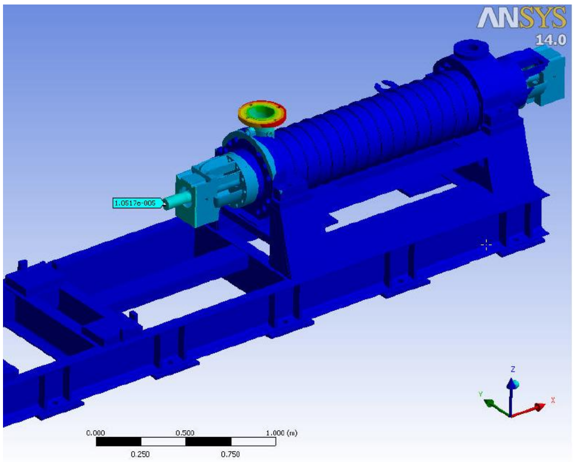


**Fig. 12 Deflection at shaft end due to $M_Z$**

**Table No.4 Shaft deflection due to the suction and discharge nozzle**

| Direction | Deformation at suction(New frame)(mm) | Deflection of new frame suction [µ] | Deformation at discharge new frame(mm) | Deflection new frame discharge [µ] |
|---|---|---|---|---|
| $M_y$ | 0.000039 | 5.98µ | 0.000012 | 0.53µ |
| $M_z$ | 0.000038 | 11µ | 0.000010 | 2.44µ |

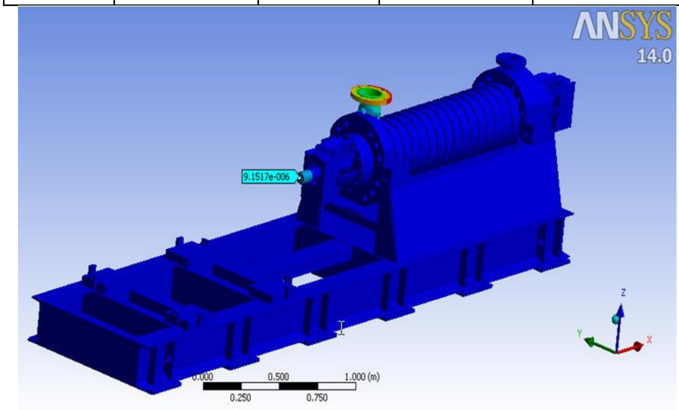


**Fig. 13 Existing frame Deflection at shaft end due to $M_Z$**

## XI. Conclusions

The modifications made in the Base frame sufficiently rigid considering following:-

1. For sustaining double the values of API 610/11 forces and moments applied on suction and discharge nozzle at a time.
2. Displacement of the pump shaft end complies with API 610/11 Cl. No. 7.3.20 – for un-grouted base frame.
3. For sustaining starting and operating torque of the motor.
4. The Shaft deflection of multistage pump coming very less as compared to the API standard and is very near to old frame shaft deflection.
5. Finite element method & the experimental analysis the shaft deflection of existing base frame found 9.1 micron and after modifying the base frame of pump, the maximum deflection getting in shaft is 11 micron.

## Acknowledgment

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