Design, Analysis & Optimization of Baseplate of Centrifugal Pump System

D. V. Yadav[1], Prof. S.J. Madki[2]

*[1,2] Department of Mechanical Engineering,
Brahmdevdada Mane Institute of Technology,
Solapur, Maharashtra, India.*

***Abstract* - Centrifugal pumps are perhaps the most common type of pump in operation today. With many different configurations available, centrifugal pumps are widely-used because of their design simplicity, high efficiency, wide range of capacity and head, smooth flow rate and ease of operation and maintenance. These pump baseplates come in as many configurations, designs and styles as there are pump models. No matter the design, the main purpose of the baseplate is to mount the pump and driver together, while maintaining shaft alignment between the two pieces of equipment. This paper is about the work carried out to study and identify the most used baseplates for API centrifugal pumps for customer orders, analyzing the baseplate properties using Finite Element Technique, modification in baseplate and optimize the weight of the baseplate of one of the model of centrifugal pump to achieve cost reduction in baseplate fabrication.**

Keywords- Centrifugal Pump, FEA, API, Baseplate, Optimization

I. INTRODUCTION

A pump is a hydraulic device which is used to move fluids such as liquids, gases and slurries. It converts mechanical energy into hydraulic energy. It increases the kinetic energy and / or pressure energy of the fluid. Energy of the fluid is increased by either Roto-dynamic action or Positive Displacement action. Centrifugal pumps are perhaps the most common type of pump in operation today. With many different configurations available, centrifugal pumps are widely-used because of their design simplicity, high efficiency, wide range of capacity and head, smooth flow rate and ease of operation and maintenance. Pumps are widely used in various industries like petrochemical, textile, chemical, based on application. However, for petrochemical industry compliance of API 610 is mandatory. ITT Corporation's India manufacturing facility is located in Vadodara, Gujarat. The Pumps and Valves manufactured at Vadodara plant cater to Oil & Gas, Power, Chemicals, Petrochemicals and general industrial markets. When designing and fabricating a baseplate for centrifugal pump, it is the hope that the complete unit is robust enough to survive the travel to the site and be simple to install. It should allow for final alignment of the pump and driver, and allow for removal and reinstallation of the equipment if necessary.

II. LITERATURE REVIEW OF BASEPLATE OPTIMIZATION

The extensive literature reviews were carried out from various available databases related to centrifugal baseplate, API standard requirements about baseplate, optimization of baseplate.

Greg Towsley (2011)explains about the various configuration design, styles & requirement of the baseplate. Cast iron baseplates for large horizontal pumps also provide mounting provisions for NEMA (National Electrical Manufacturers Association) motors and have an integral drainage collection feature. For those large pumps that use non-NEMA motors or special drivers, cast iron baseplates are typically flat on top and have a continuous drip lip around the top of the base. Where the pump may be driven by v-belts or drivers supplied by a supplier other than that of the pump, a cast iron baseplate might be available. This design may incorporate a drip lip. When the pump and driver are extremely large, cast iron baseplates may not be the most economical. The use of a fabricated steel baseplate may be required when the dimensions of the baseplate are greater than 32 inches (81.3 cm)wide or 114 inches (289.6 cm) long, or both. When reviewing the stress levels of the baseplate, the materials of construction and the type of welding used need to be considered. After fabrication, the stress that may be caused during skidding, transportation or lifting must also be included in the review. The rigidity of the baseplate affects many areas of the pump unit after the final installation. Inadequate rigidity may cause distortion of the baseplate after installation, grouting and piping, and difficulty in the final alignment. Motor torque may also affect the pump unit if the baseplate is not rigid enough. The Standard recommends that the motor torque and piping loads combined should not cause more than 0.554 mm parallel and 0.427 mm/mm angular distortions.

Amit V. Chavan and S.S. Gawade, Mechanical Engineering Department, R.I.T, Sakharalehad done work related to Experimental and Finite Element Analysis of Base Frame for Rigidity is presented. The assurance of rigidity as per API 610 is mandatory for pumps base frame supplied in petrochemical industry. A proven rigidity test procedure is used for testing the structural stiffness of base frame in line with API 610 clause 6.3.5. For typical base frame, the stiffness is measured by means of rigidity test (actual measurement) for different load cases. The test is carried out to check the conformance of the existing design to API 610 stiffness requirement. Since the existing design fails to meet this requirement, few potential design modifications are suggested. These modified cases are simulated using FEA techniques for stiffness qualification. ANSYS is used for simulation of these cases including that of existing design, for bench marking and comparison purpose. The results of FE analysis are presented in terms of deflection at coupling side shaft end (guideline form API 610), which is supported between bearings in pump bearing housing at static condition. Based on these results, best feasible design solution is proposed and validated experimentally.

API Standard 610 has been written to ensure safe and reliable pumps are used in a dangerous industry. This international standard specifies centrifugal pumps for petroleum, petrochemical and natural gas industries. Below we have summarized the major features and requirements of API 610. API 610 is a standard that covers the minimum requirements for centrifugal pumps for use in petroleum, heavy duty chemical and gas industry services. This international standard specifies requirements for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines, for use in petroleum, petrochemical and gas industry proves services. This international standard is applicable to overhung pumps, between bearings pumps and vertically suspended pumps. This international standard is not applicable to seal less pumps. API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized.

III. METHODOLOGY

This project work is carried out as ITT India manufactures the centrifugal pumps for the process industries. For each financial year, on an average plant plans to manufacture around 1200 nos. of centrifugal pumps and out of that around 800 nos. of pumps will require baseplates. Currently, the pump baseplate weight varies between 425 kg to 1500 kg of the selected model for this project & this adds to total cost of the pump which ranges from 12,00,000 to 30,00,000 INR.

These baseplates gets fabricated at supplier shop and ITT India pays them based on rate per kg, so it is very important that baseplate weight should be optimum considering working of pump & cost of the pump. Organization is facing very strong competition in market from the competitor in terms of cost of pump assembly and in this assembly they have control on fabrication cost of various auxiliary parts of the pump. So considering baseplate is one of the major part of assembly, we have selected the problem of high cost of baseplate fabrication which is based on weight of baseplate. We used some of six sigma tools also during this work.

1) Scope of work

- Study of various pump models for historical orders for base plate design, customer specifications
- Prepare CAD model, analysis of baseplate model
- Material optimization (Shape Optimization) of baseplate.
- Manufacturing of modified baseplate
- Testing and performance evaluation of modified.

2) Study and Finite Element Analysis of existing baseplate

We started with study of historical orders data for 6 months which has customer name, order acknowledgment number, pump item number, model type, size, motor frame, plan and material type. This data we collected to know which type of baseplate mostly demanded by the customer & we found out that the pump size of 6 X 8 has more frequency. For this purpose, we used the Pareto analysis (Pareto chart).

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention.

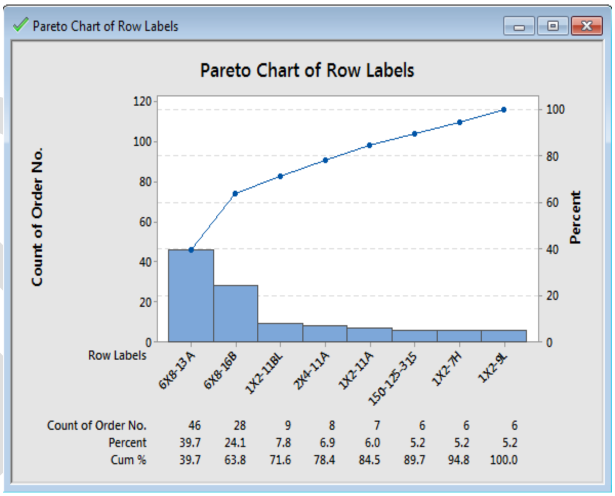

Fig.3.2.1 Pareto chart

Based on Pareto chart decision, we took one sample pump data sheet which had pump size 6 X 8 -13A. This data sheet is very useful to understand the customer requirement based on which designer decides the baseplate size suitable to pump.

Step 1: Preparation of CAD Model

After finalizing the pump size, we proceeded for CAD model preparation of existing baseplate in software called Pro E.

Step 2: Finite Element Analysis

The finite element analysis (FEA) or FEM is a problem solving approach for the practical (engineering) problems. The volume of the equations to be solved is usually so large that arriving solution without using computer is practically impossible. And, that's why the need of different FEA packages is felt. There are many FEA packages available for different applications. Some popular FEA packages are Pro Mechanica, Ansys, Nastran, and Gambit etc. so we started with mesh generation of baseplate model as shown below. We used 46,279 no. of elements and 83,028 nodes.

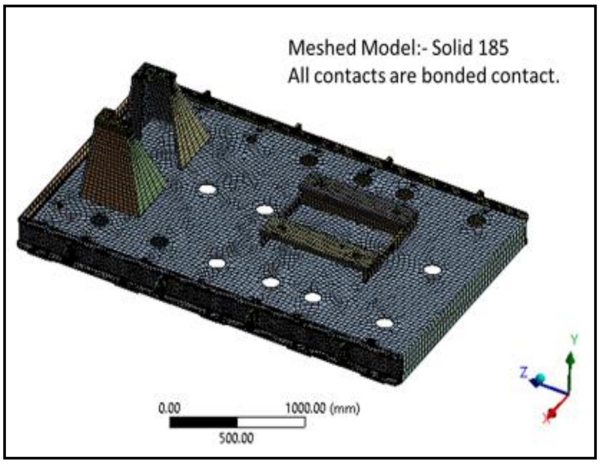

Fig.3.2.2 Meshed model of existing baseplate

Step 3: Applying the material properties and boundary conditions to proceed for stress analysis of existing baseplate and results plotted.

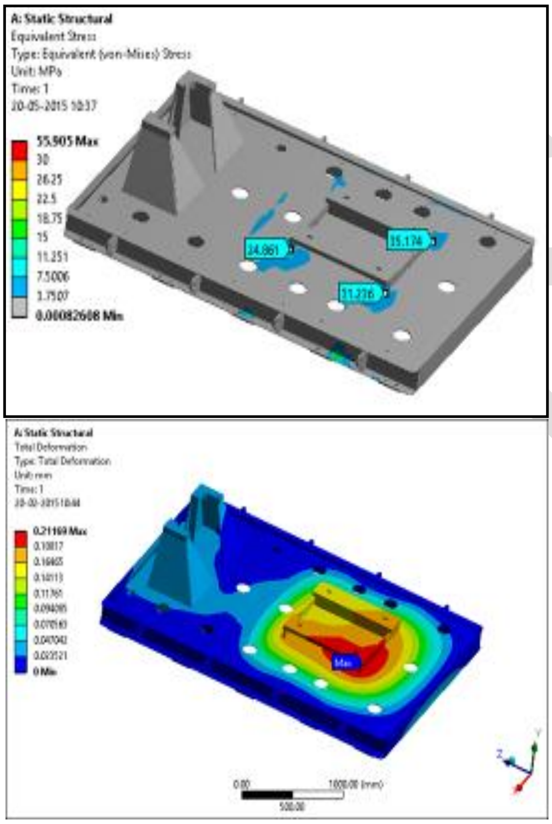

Fig.3.2.3 Equivalent stress and Total Deformation (Resultant) of baseplate

Step 4:Modification in existing baseplate

We tried 4 to 5 modification in existing baseplate considering all requirement of API standard for the baseplate and came up with final modification as removal of extra channels and reduction in thickness of plate as defined in part list. Then we followed the same method for stress analysis of modified baseplate as previous and results plotted for comparison. r_i

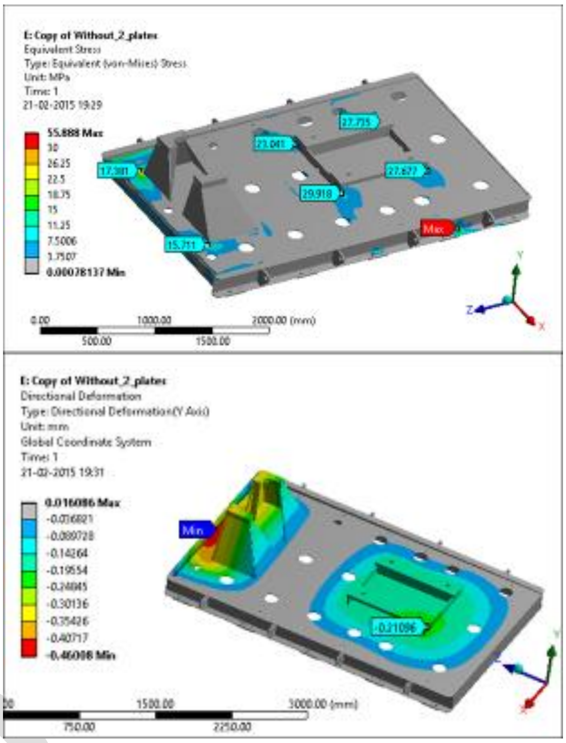

Fig.3.2.4 Equivalent Stress and Total Deformation of modified baseplate

Step 5: Comparison of part list with respect to quantity and weight of components, so that we can see the reduction in total weight of baseplate and thus reduction in cost by 20%.

RESULT

Table 3.2.1Baseplate material weight reduction result

Baseplate Weight Reduction Result table	
Before Optimization Weight (Kg.)	1409.63
After Optimization Weight (Kg.)	1118.54
Weight Reduction (Kg.)	291.09
Rate of fabrication of baseplate per Kg. weight (INR)	96
Forecasted number of baseplate for fabrication per annum (Nos.)	300
Net cost saving per annum (INR)	8,383,392.00

After this, we proceeded for test piece manufacturing of modified baseplate and same got inspected from the quality department to ensure the baseplate is as per requirement of QAP or data sheet.

IV. CONCLUSION

As we had taken objectives of weight reduction of centrifugal pump baseplate and to achieve the cost reduction of the baseplate; so conclusions of work carried out are as below.

Comparison table clearly shows the weight reduction of the baseplate is achieved by 21% and it is achieved by reduction of extra channels, reduction of thickness of plate without comprising on performance of the baseplate. The successful optimization and the weight reduction in baseplate model provide a new economic model of the baseplate for the same pump system. The weight reduction of 289.78 kg in the baseplate model saves approximately 27,819 INR in the production of one baseplate. This enables an annual saving of 83,45,664 INR per annum, as the forecasted number of baseplate planned at manufacturing plant at Savli. The FEA analysis on this optimized model of the baseplate is successful with all the results lying within the requirements as per QAP or standard.

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