Finite Element Analysis of Centrifugal Pump Shaft With Composite Reinforcement

Mr. Rajaram Ghutukade[1], Prof. Namdev Gavade[2]
[1, 2] Dept of mechanical Engineering
[2]Assistant Professor, Dept of mechanical Engineering
[1, 2] SKNSITS Lonavla, SPPU Pune, India,

Abstract- *Pumps are used in a wide range of industrial, irrigation and residential applications. Pumping equipment is mainly diverse; varying in type, size, and materials of construction. Centrifugal pump is one of the oldest water pumping devices in the world. The current work deals with the study of shaft of centrifugal pump for two cases viz.*

1] Shaft with composite reinforcement
2] Shaft with composite material.

The two shafts will be statically analyzed by using finite element analysis technique for stresses and deflections. The software used for the finite element meshing is HYPERMESH. Shaft will be designed in CATIA V5. Result values obtained for deflection and stresses in both cases will be compared with FEA results of existing shaft. These FEA results will be validated through experimental testing on UTM.

Keywords- Aluminium2024 matrix, hexagonal Boron nitride (HBN) reinforcements, Liquid-state processing stir casting technique, Al2024/ boron nitride MMC

I. INTRODUCTION

Pump is one of the oldest water pumping device in the world. There have beennew importance of developments in the area of pumping equipment. The most widely used type of pumps is centrifugal pump. Centrifugal force is used to lift the liquid from lower level to higher one. Working of centrifugal pump in brief: It comprises of impeller rotating at high speed within the stationary casing or volute. Liquid led into the center of the impeller is picked up by the impeller vanes and accelerated to high velocity by rotation of impeller and then discharged by centrifugal force into the casing and out to the discharge piping. When the liquid is forced away from the center, a vacuum is created and more liquid flows in.
Centrifugal pumps are widely used for irrigation, water supply plants, stream power plants, sewage, oil refineries, chemical plants, hydraulic power service, food processing factories and mines. They are also used extensively in the chemical industry because of their suitability and are mostly used in many applications such as water pumping project, domestic water raising, industrial waste water removal, raising water from tube wells to the fields. Pumps have a place of importance in human life.

A lot of research work has been performed to improve the centrifugal pumps by many researchers. They have concentrated more on impeller and housing of centrifugal pumps. In this project work, we are going to focus on the improvements in the shaft of centrifugal pump. In this paper we are going to analyze the two shafts viz. case hardened shaft and shaft made of composite material.

II. LITRATURE REVIEW

Daset al. [1]carried out an analysis of the premature failure of two counter shafts used in centrifugal pumps for lifting slurry. Chemical analysis, microstructural characterization fractography hardness measurement tensile and Chirpy impact tests were used for the analysis. The chemical compositions for the shafts were as per recommendation. The microstructure of one of the shafts was ferritic-pearlitic and its mechanical properties were inferior to the recommended values. For the other shaft the microstructure was tempered bainite; although the impact energy satisfied the specification, the other properties (hardness\ UTS)were inferior. It was concluded that the improper heat treatment was the prime cause for the premature failure of the shafts.

Pasca et al. [2]investigated onfailure analysis of a shaft, from a double suction hydraulic pump in operation of approximately 30 years, in a storage station. The shaft material as a Romanian steel was used, mechanical characteristics are considered from American SAE 4340 as a data for failure analysis.The paper is structured in two parts: finite element analysis of the pump shaft and an analytical failure analysis for a circumferential crack type, using the failure assessment diagram (FAD). In a modeling program for stress and strain analysis the 3D shaft was loaded in torsion. The numerical results show the maximum stress zones, the stress concentration effect, and the possibility of crack occurrence. For circumferential crack type the failure assessment diagram for Mode III loading were plotted using the stress intensity factor solution. The results indicate the unsafe zone respectively the critical circumferential crack depth, where the shaft cannot operate with defects. This study presents an opportunity related to safe operation condition and remaining life estimation for a storage pump.

Pramod et al. [3]experimented the Shaft of centrifugal pump for static and dynamic analysis. As we know rotodynamic machineries are designed keenly as there is lot of fluctuation in the loads and speeds. The shaft is analyzed by using finite element analysis technique for stresses and deflections. The total work is carried out in two stages first stage is static analysis. In this stage pump shaft is analyzed for stresses and deflection and same results are verified using graphical integration method and second for dynamic analysis, in this stage result obtained by static analysis are used to calculate dynamic forces coming in pump shaft. Later shaft is analyzed in dynamic input condition and results are verified by using graphical integration method.

III. OBJECTIVE

Main objectives of study

1. The main objective of this project is to increase the strength of shaft through composite reinforcement.
2. To use composite for shaft for making it light weight, corrosion free without compromising over its strength.

IV. METHODOLOGY

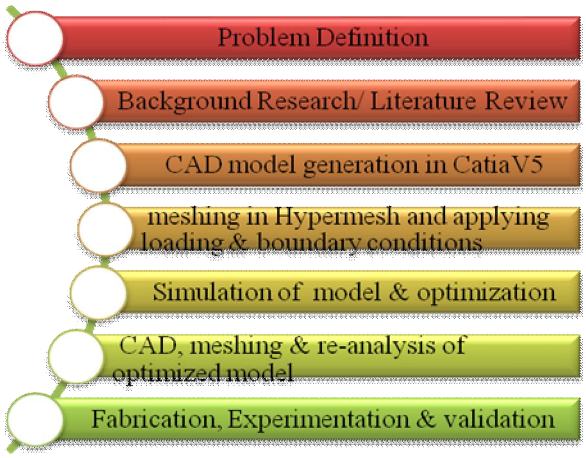

Figure 1. Flow Chart

V. FINITE ELEMENT ANALYSIS OF PUMP SHAFT

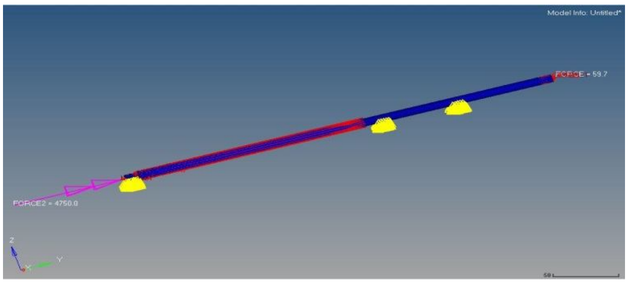

Fig.2 Constraints and forces applied on model in Hypermesh Deformation plot

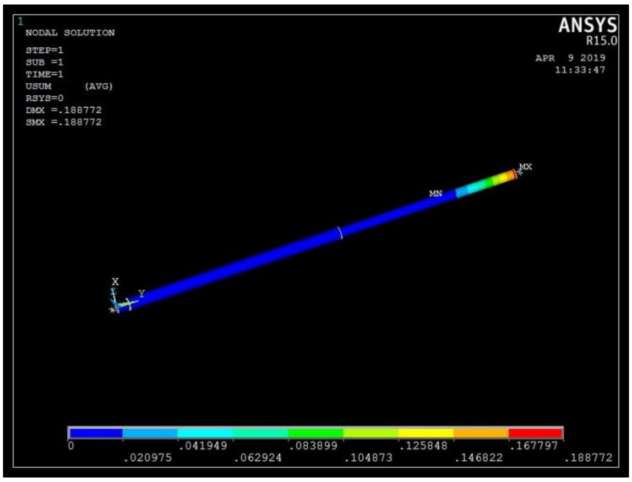

Fig 3. Deformation produced

Deformation is 0.188 mm which is very less

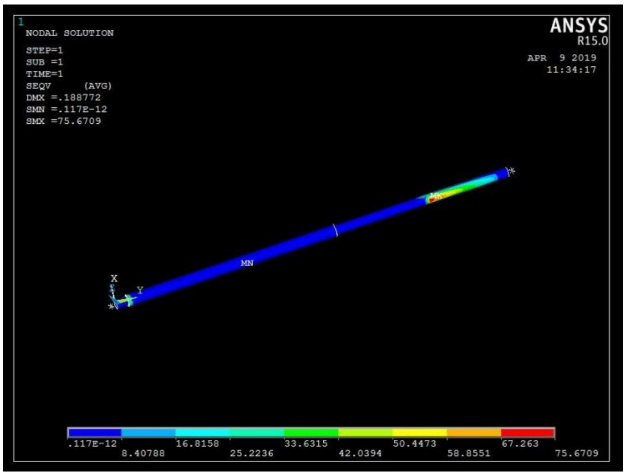

Fig 4. Von mises stress produced

Von mises stress produced is 75.67 Mpa. As the deformation is very low and stress produced is less than critical stress of steel it shows scope for optimization.After this optimization is done by doing finite element analysis using composite material.

VI. MATERIAL OPTIMIZATION USING COMPOSITE MATERIAL

Iteration-1

In this we make finite element analysis on pump shaft totally made of composite material

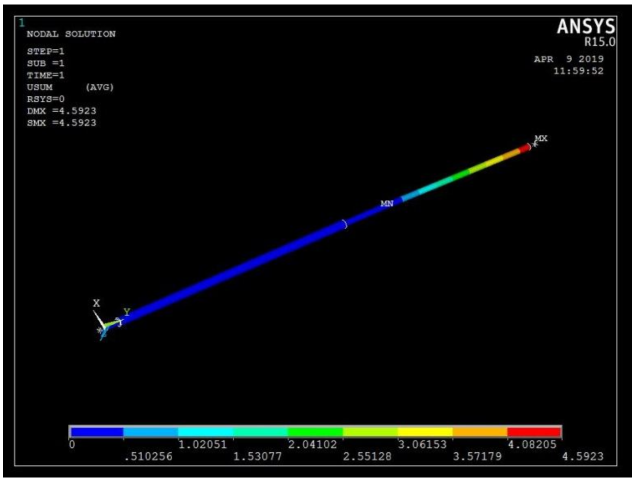

Fig 5. Deformation produced

Deformation is 4.59 mm which is very high

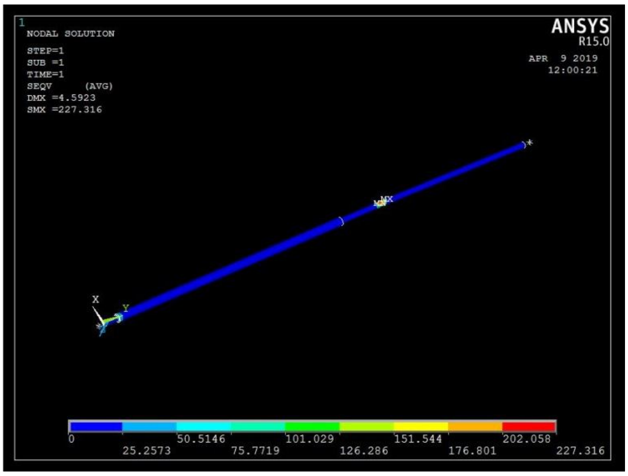

Fig 6. Von mises stress produced

Von mises stress produced is 227.316 Mpa

As deformation and stress produced in composite pump shaft is high hence this iteration is failed. So it is not feasible to make a total shaft of composite material

Iteration 2

In this iteration a glass fiber reinforcement is applied on steel pump shaft. A layer glass fiber of 1mm thickness is applied on smaller diameter and a layer of glass fiber of 2mm is applied on larger diameter.

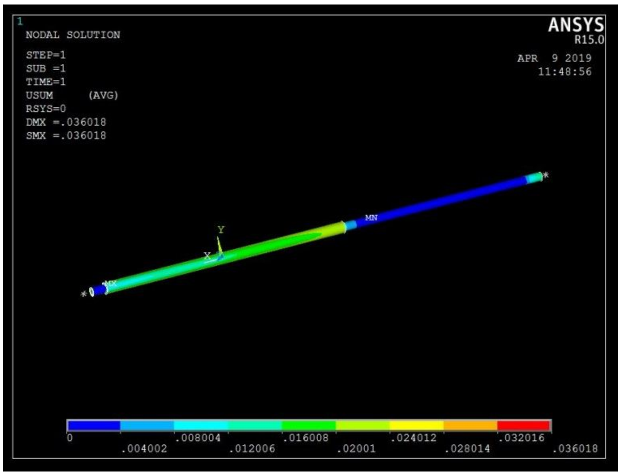

Fig 7. Deformation produced

Deformation produced is 0.036 mm

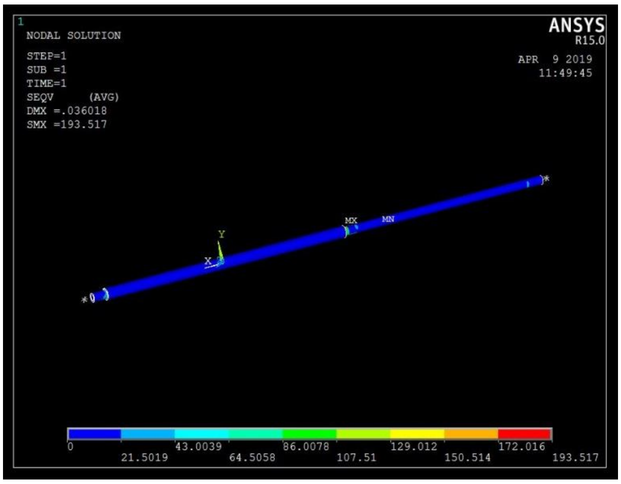

Fig 8. Von mises stress produced

Von mises stress produced is 193.517 Mpa which is still high hence one more iteration will be done on pump shaft.

Iteration 3

In this iteration a glass fiber reinforcement is applied on steel pump shaft.A layer glass fiber of 2mm thickness is applied on smaller daimeter and a layer of glass fiber of 3mm is applied on larger diameter.

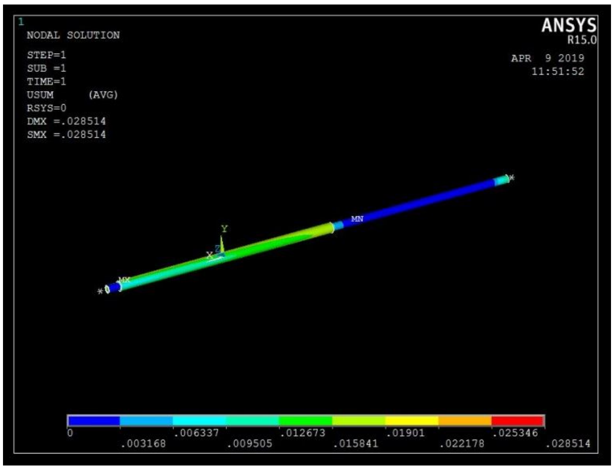

Fig 9. Deformation produced

Deformation produced is 0.0285 mm

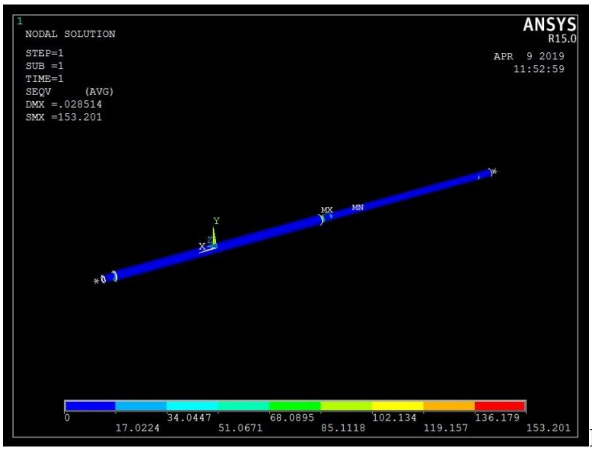

Fig 10. Von mises stress produced

Von mises stress produced is 153.201 Mpa which is less than critical limit hence design is safe.

Table 1: Stress and deformation comparison table

Iterations	Von mises stress	Deformation
Existing	75.67 Mpa	0.188 mm
Iteration 1	227.316 Mpa	4.59 mm
Iteration 2	193.517 Mpa	0.036 mm
Iteration 3	153.201 Mpa	0.0285 mm

Table 2: Weight reduction table

Model	Weight (kg)
Existing pump shaft	0.177
Optimized pump shaft	0.074

% weight reduction = (Existing Weight-Optimized weight)/ Existing weight

=(0.177-0.074)/0.177

= 58.19 %

VII. EXPERIMENTAL VALIDATION

The experimental investigation is performed on fabricated model on universal testing machine at Praj Metallurgical Lab, Kothrud, Pune. Bending test has been performed on the model produced. The input conditions are recreated in the lab while the component is being tested. The loading and the boundary conditions are matching the practical working conditions in which the vehicle is expected to perform.

Fig.11. Experimental set up

Percentage error = (Experimental – FEA)/ Experimental

= (0.03 - 0.0285) / 0.03

= 0.0015/0.03

= 5 %

VIII. CONCLUSION

The FEA analysis of pump shaft is carried out over conventional model. The pump shaft with glass fiber reinforcement is analyzed for the given operating conditions. The best of all the iteration is chosen for the fabrication i.e.iteration 3 having stress value as 153.201 Mpa which is less than critical limit. The model is fabricated and tested for the same loading conditions as that of the conventional. A comparative study of FEA with experimental results were analyzed. From the results it can be concluded that the validation of results shows close resemblance with an error of 5 % and weight reduction of 58.19 % is achieved without compromising the strength of pump shaft.

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