Enhancement of Stiffness Through Parametric Optimization of Structural Bearing Support

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Abstract- *A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts. In the present work a structural bearing support is considered. A study for importance of bearing support in service condition is carried out. For a structure stiffness plays a vital role hence, the main aim for the work is improving stiffness of bearing support. This is carried out by utilizing HYPERMESH for meshing and ANSYS software for analysis. The bearing support model is first subjected to a structural analysis for evaluating the initial stiffness. The design of experiments procedure is followed for obtaining an optimum design. The optimized design is subjected analysis to check whether the stiffness of bearing support is enhance or reduced. After the check is completed bearing support is subjected to a modal analysis to check the stability of the support.*

Keywords- Structural bearing support, In-service condition HYPERMESH, ANSYS,Design of experiments.

I. INTRODUCTION

Rotary bearings hold rotating components such as shafts or axles within mechanical systems, and transfer axial and radial loads from the source of the load to the structure supporting it. The simplest form of bearing, the plain bearing, consists of a shaft rotating in a hole. Lubrication is often used to reduce friction. In the ball bearing and roller bearing, to prevent sliding friction, rolling elements such as rollers or balls with a circular cross-section are located between the races or journals of the bearing assembly. A wide variety of bearing designs exists to allow the demands of the application to be correctly met for maximum efficiency, reliability, durability and performance.

The term "bearing" is derived from the verb "to bear" a bearing being a machine element that allows one part to bear (i.e., to support) another. The simplest bearings are bearing surfaces, cut or formed into a part, with varying degrees of control over the form, size, roughness and location of the surface. Other bearings are separate devices installed into a machine or machine part. The most sophisticated bearings for the most demanding applications are very precise devices; their manufacture requires some of the highest standards of current technology.

The design of experiments (DOE, DOX, or experimental design) is the design of any task that aims to describe or explain the variation of information under conditions that are hypothesized to reflect the variation. The term is generally associated with true experiments in which the design introduces conditions that directly affect the variation, but may also refer to the design of quasi-experiments, in which natural conditions that influence the variation are selected for observation.

In its simplest form, an experiment aims at predicting the outcome by introducing a change of the preconditions, which is reflected in a variable called the predictor (independent). The change in the predictor is generally hypothesized to result in a change in the second variable, hence called the outcome (dependent) variable. Experimental design involves not only the selection of suitable predictors and outcomes, but planning the delivery of the experiment under statistically optimal conditions given the constraints of available resources.

The stiffness, k, of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single degree of freedom (DOF) (for example, stretching or compression of a rod), the stiffness is defined as
Where,

$$k = \frac{F}{\delta} \quad \text{Eqn.1}$$

F is the force on the body

δ is the displacement produced by the force along the same degree of freedom

In the International System of Units, stiffness is typically measured in newton per meter. In Imperial units, stiffness is typically measured in pounds (lbs.) per inch. Generally speaking, deflections (or motions) of an infinitesimal element (which is viewed as a point) in an elastic body can occur along multiple DOF (maximum of six DOF at a point).

II. PROBLEM DEFINITION

Bearing support is a critical structure where the stiffness is important. The stiffness value of bearing support is arrived from the rotor dynamic requirement. Bearing plays a vital role in transmitting torque or rotational speed from one shaft to another. Generally in a critical machine the rotational speed varies from 8000 to 14000 rpm. The engine critical speed placed either below idle speed or above maximum operating condition. Hence, stiffness plays a major role in engine dynamics. The objectives of the present work is as follows

Objectives for the present work:

- To study the importance of bearing support.
- To perform a structural analysis for bearing support
- To optimize the design parameters of bearing support
- To enhance the stiffness of bearing support and identifying the influencing parameter.
- To perform a modal analysis and obtain the natural frequency of bearing support.

III. MATERIAL SELECTION

Structural steel is a category of steel used as a construction material for making structural steel shapes. A structural steel shape is a profile, formed with a specific cross section and following certain standards for chemical composition and mechanical properties. Structural steel shapes, sizes, composition, strengths, storage practices, etc., are regulated by standards in most industrialized countries.

Table 1 shows mechanical property of material

Property	Value	units
Co-efficient.T.E	1.2e-5	/ °C
Young's Modulus	2e5	MPa
Poisson's Ratio	0.3	
Yield Strength	250	MPa
Density	7.85e-9	Tones/mm^3

IV. MODEL AND SIMULATION

This section discusses the detailed three dimensional modeling of bearing support model.

Figure 1 shows a solid 3-D model of bearing support

The solid 3-D model is designed using CAD software for a suitable dimension. For minimizing the complexity for analysis a axis-symmetry model is considered. This model is further transferred HYPER MESH software for meshing.

Figure 2 shows a mesh model of bearing support

Above shown figure 2 is obtained by utilizing HYPER MESH software. A hex-dominate mesh is considered for the present work.

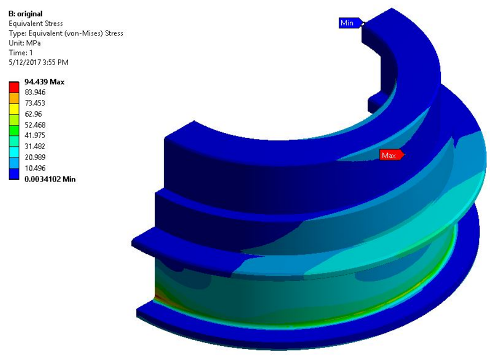

Figure 3 shows the von-mises stress

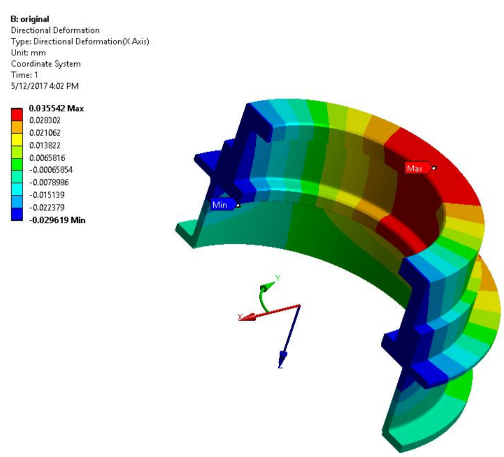

Figure 4 shows the directional deformation

In the above figures 3 and 4 it can observe that von-mises stress is margin of 2.65 which very well in the yield limit. The directional deformation is below 1mm. the above model is considered for further analysis since the present work is on optimizing the stiffness for a typical Bearing support geometry.

V. DESIGN OPTIMIZATION

For enhancing the stiffness of the bearing support a design optimization process is considered. To avoid the complexity the bearing support is divided into three sections, where one section results are discussed below,

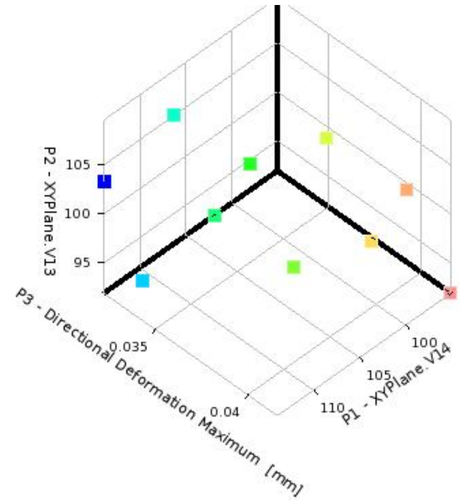

Figure 5 shows the fesiable design points

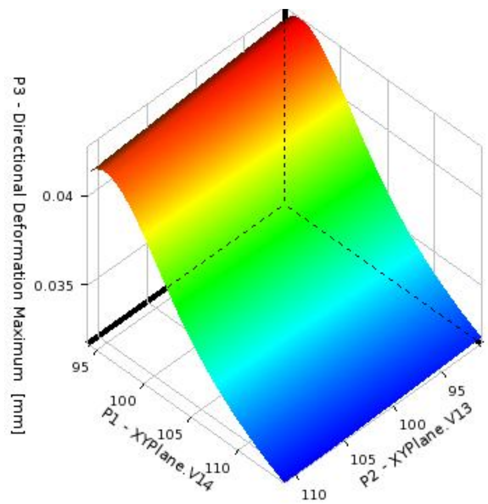

Figure 6 shows variation of defromation with design points

From the above result best fesiable design points are selected and the further analysis is carried out.

VI. RESULT AND DISCUSSION

From the figures 7 and 8 it is observed that the stress and deformation of the bearing support is improved. The deformation it is decreased when compared to the previous result. From which the stiffness is improved since, it is indirectly proportional to deformation. Hence, the required result has been achieved by optimizing the influential parameter of bearing support.

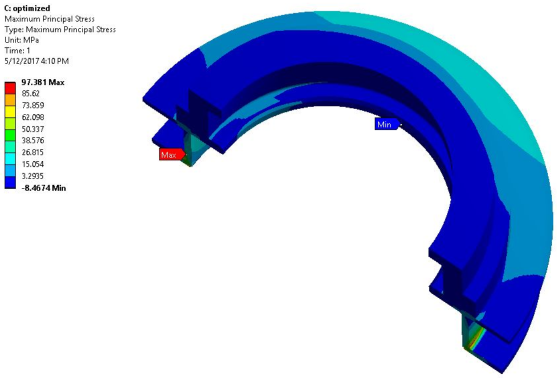

Figure 7 shows von-mises stress for optimized design

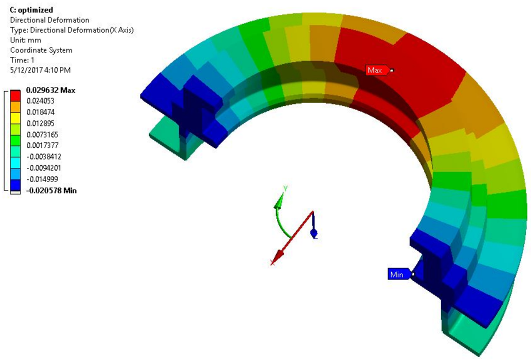

Figure 8 shows deformation for optimized design

6.1 Modal Analyses

The modal analysis is carried out to ensure the operational stability by placing the engine critical away from the operating range.

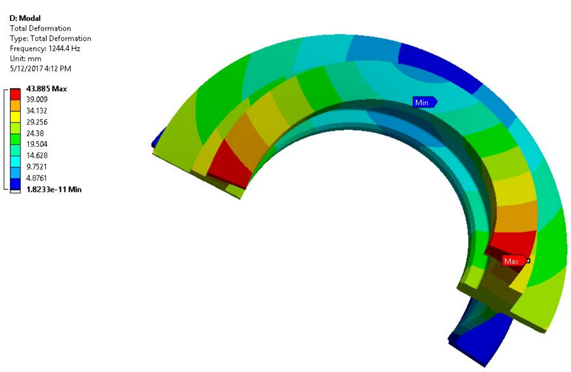

Figure 9 shows the 1st mode shape of bearing support

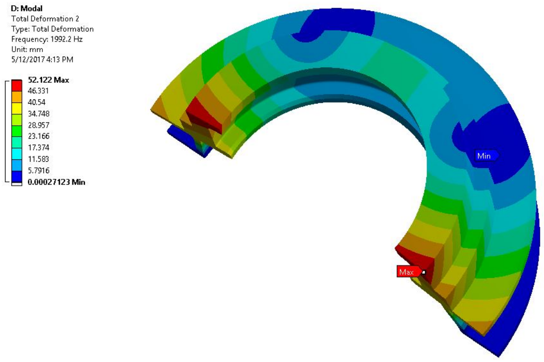

Figure 10 shows the 2nd mode shape of bearing support

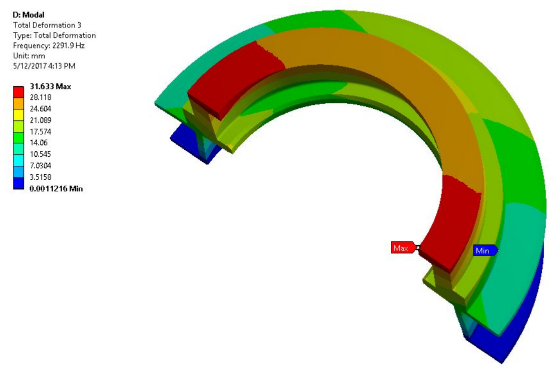

Figure 11 shows the 3rd mode shape of bearing support

From figure 9, 10 and 11 it is observed that natural frequency obtained is very much greater than the operating range. Hence, the design is considered as safe.

VII. CONCLUSION

- A study of Bearing support stiffness is completed
- A structural analysis was performed; stiffness and von Mises stress were obtained.
- A parametric design optimization was successfully carried out
- By performing an optimization the stiffness of bearing support was enhanced
- In the present analysis it was found that diameter and the thickens of the bearing support play a vital role for enhancing the stiffness
- A modal analysis carried out to obtain the natural frequency of bearing support.

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