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Reveiw Article

"FAULT DETECTION OF ROTOR SYSTEM DUE TO DICS MISALIGNMENT IN FLANGE COUPLING"

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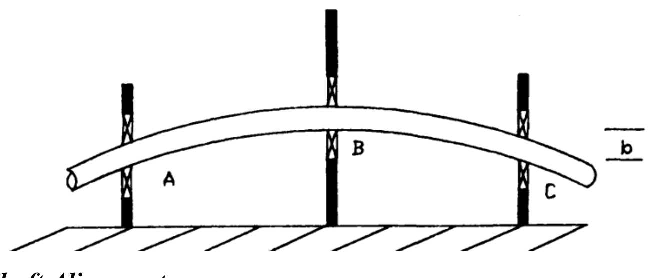
ABSTRACT

The problem of misalignment encountered in rotating machinery is of great concern to designers and maintenance engineers. On several occasions stability conditions can change the shaft alignment between the driver and driven machines. Owing to high speed of rotating machinery, a good understanding of the phenomena of misalignment is becoming necessary for maintenance engineers for troubleshooting. Mostly, rotating equipment consists of a driver and a driven machine. Coupled through a mechanical coupling. Rigid mechanical coupling are widely used in rotating machinery to transmit torque from the driver to the driven machine. When two connected machines are under misalignment, they produce higher vibrations to the machine assembly. In this study an analysis of rigid flange coupling is done. The two dimensional analysis of whole system having flanged coupling was performed numerically using MATLAB programming in order to detect faults from unbalanced and misaligned parts. The results are compared with the experimental results obtained from literature and were in good agreement. Moreover a frequency plot obtained from MATLAB of aligned and misaligned shaft was compared to detect faults in the design. Thus after detection of fault using MATLAB, rpm of shaft is varied and its effects on whole coupling system are noted. While the three dimensional rigid coupling model was analyzed in ANSYS in order to determine stress and model frequencies under normal and misaligned condition. The results were in good agreement with literature study. The healthy system in ANSYS was considered to be of bonded nuts and bolts while in misaligned Flange model nuts and bolts were given frictional contacts.

INTRODUCTION

Misalignment is an important cause of vibration problems in rotating machinery. Misalignment in the context of this thesis includes any deviation from the ideal case in which a straight shaft rotates in perfectly aligned bearings [1-3]. Thisstudy performs a survey on the various types of misalignments often encountered in rotating machinery and the vibrational characteristics which arise due to these misalignments are examined. In particular lateral, axial and angular coupling misalignments will be studied as a function of flexible coupling vibrational behavior [3-4].

A single uncoupled rotor may exhibit vibration problems for a variety of reasons. Sources of these vibrations may include shaft bearing misalignments, bowed rotors and mass unbalance. Bearing-shaft misalignments may from the vibrational analysis point of view be the hardest to detect. A shaft-bearing misalignment occurs when the bearing Journal placements are not axially concentric and a straight shaft is forcefully fitted into the bearings. An extreme case of a shaft distorted by bearings not axially aligned. The forces exerted by each of the bearing foundations cause the shaft to bend. As this forcefully bent shaft rotates, the forces exerted by the foundations remain constant as the shaft rotates at its operating angular velocity.



Shaft Alignment

Shaft alignment is a process where two or more shafts are aligned within permissible margin when the shafts are connected with the help of suitable coupling. It is mandatory to align the shafts within this permissible margin before the machinery is put in service.

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Alignment Tolerances for Flexible Couplings

The suggested tolerances shown on the following pages are general values based upon over 20 years of shaft alignment experience at Pruftechnik and should not be exceeded. They should be used only if no other tolerances are prescribed by existing in-house standards or by the machine manufacturer.

Symptoms of Misalignment

It is not always easy to detect misalignment on machinery that is running. The radial forces that are transmitted from shaft to shaft are difficult to measure externally. Using vibration analysis or infrared thermography it is possible to identify primary symptoms of misalignment such as high vibration readings in radial and axial directions or abnormal temperature gradients in machine casings, but without such instrumentation it is also possible to identify secondary machine problems which can indicate inaccurate shaft alignment.

- Loose or broken foundation bolts.
- Loose shim packs or dowel pins.
- Excessive oil leakage at bearing seals.
- Loose or broken coupling bolts.
- Some flexible coupling designs run hot when misaligned. If the coupling has elastomericelements look for rubber powder inside the coupling shroud.
- Similar pieces of equipment are vibrating less or have longer operating life.
- Unusually high rate of coupling failures or wear.
- Excessive amount of grease or oil inside coupling guards.
- Shafts are breaking or cracking at or close to the inboard bearings or coupling hubs.

Good shaft alignment practice should be a key strategy in the maintenance of rotating machines. A machine properly aligned will be a reliable asset to the plant, it will be there when it is needed and will require less scheduled (and unscheduled) maintenance.

Vibrational Analysis

Vibration measurement is normally a non-intrusive measurement procedure; it can be carried out with the machine running in its normal operating condition. Vibration is an effect caused by machine condition.

Fault Mode analysis

The machinery diagnostics technique viewed here is based on a technique known as "fault mode" analysis. This technique utilizes the fact that specific mechanical events, such as unbalance, misalignment, looseness, bearing defects, aerodynamic and hydraulic problems, and gearbox problems usually generate vibration frequencies in specific patterns. The frequency, amplitude and pattern of the peaks in a vibration spectrum can be a telling indication of the type of problem being experienced by the machine.

Literature Review

Most of the study of literature was focused mainly on experimental results which were bind to dimensional and experiment set up constraints. While in present study we will deal with numerical study of shaft and bearings in which we can analyze angular and axial flexibility without any dimensional constraints.

More over a proper fault detection method is not suggested in literature. In present study we would use MATLAB for generating frequency plots and compare the misaligned and aligned shaft frequencies.

The method has been demonstrated the model based fault detection for a simple rotor system. This method may be useful for large systems like in motors, turbines, gearboxes and the like. The present approach allows for on-line fault identification effectively.

Static and Modal Analysis

Introduction

Static and modal analysis of solid crank shaft is used to determine stresses and displacement while modal analysis is done to obtain vibration characteristics namely natural frequency and mode shapes to calculate crankshaft stiffness and response of rotor system.

Modeling and Analysis

Design of pin type flexible coupling for shaft alignment

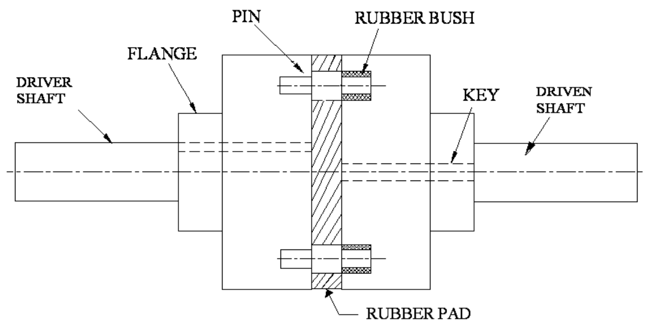


Figure Shaft coupled through Flange

Preparation of CAD Model

ANSYS design modeler software is the gateway to geometry handling for analysis with software from Ansys. Ansys design modeler technology also provides powerful tools for construction of geometry from the ground up. A complex model can be produced using familiar solid modeling operations. Two-dimensional sketches can be extruded into 3-D solids and then modified with Boolean operations. A history of construction is recorded during the geometry creation, allowing the user to make changes and then update the design.

Building CAD model in Ansys Design Modular

We consider a model of two flange couplings. The system is driven with a smooth loading shaft (driving) connected via flange which rotates another shaft (driven) connected via flange. The coupling is coupled with four Bolts and Nuts .In order to study the force and stresses in initially parameters and loading conditions are shown in Table 3.

Model Dimensions

Part specification	Dimensions in mm
Hub diameter (dh)	120
Hub length (lh)	90
Bolt circle diameter (D)	180
Flange thickness (t)	30
Web thickness	15
Diameter of spigot and recess (dr)	90
Outside diameter of flange (Do)	270

Material used

Item Name	Material
Shaft	Plain Carbon Steel- 40C8
Flange	Grey Cast Iron
Key, Nuts, Bolts	Plain Carbon Steel- 40C8

Shaft, nuts and bolts are made up of plain carbon steel with young's Modulus 210GPa and density 7850 kg/m^3 contains approximately 0.05–0.25% carbon. While Flange is made up of grey cast iron with 280MPa and density of 7200 kg/m^3.

Validation from Literature

For validation, considering a standard motor with power of 37.5kw and 180 RPM [9], the meshed flange coupling was analyzed in Ansys structural, the flange was considered to be made of grey cast iron and shaft, and nuts and bolts were made of stainless steel material with poison ratio 0.3. Further, stresses and deformations are calculated using Ansys workbench. The results obtained from Ansys are in good agreement with the literature as given in.

Validation of present Ansys Results from Literature [9]

Parameters	From Literature		From Present Study	
	Maximum	Minimum	Maximum	Minimum
Directional Deformation (Z- axis) (mm)	1.68906187 e-3	-1.71915849 e-3	1.34E-03	-1.24 e-3
Directional Deformation (Y- axis) (mm)	0.48747	0.48715	0.48315	0.48315
Directional Deformation (X- axis) (mm)	0.48741	0.48715	0.48315	0.48315
Total Deformation (mm)	0.48741		0.48315	
Normal Stress (X- axis) (Mpa)	78.854	110.57	78.854	110.57
Normal Stress (Y- axis)(Mpa)	78.854	110.57	78.854	110.57
Normal Stress (Z- axis)(Mpa)	78.854	110.57	78.854	110.57
Equivalent (Von-Mises Stress) (Mpa)	380.24		326.11	

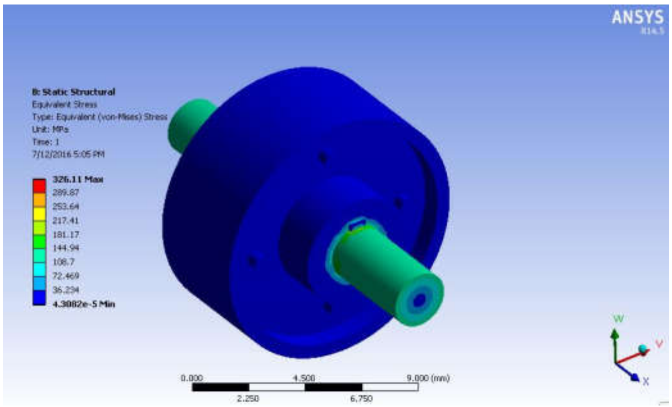


Figure Equivalent Stress

The maximum stress was found to be 326 MPa along the shaft and key when torque of 4000 Nmm was applied over the shaft 1 and other shat was kept fixed.

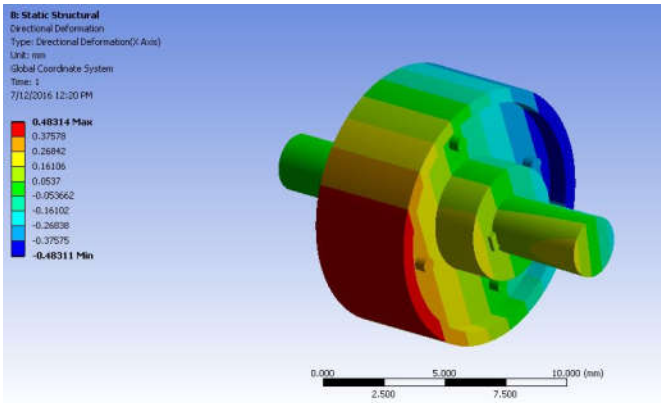


Figure Direction deformation along X axis

The above figure shows total directional deformation existing over flange along X direction

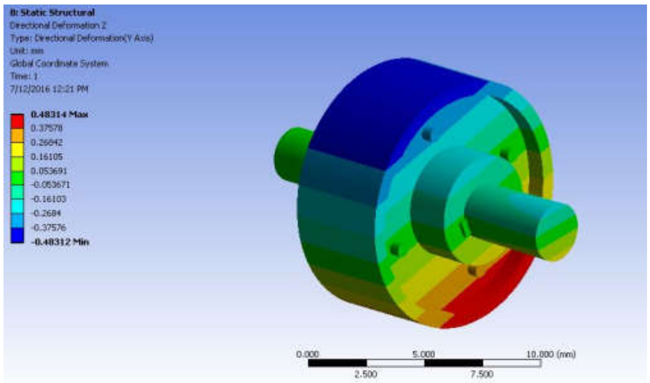


Figure Directional deformation along Y axis

The above figure shows total directional deformation existing over flange along y direction

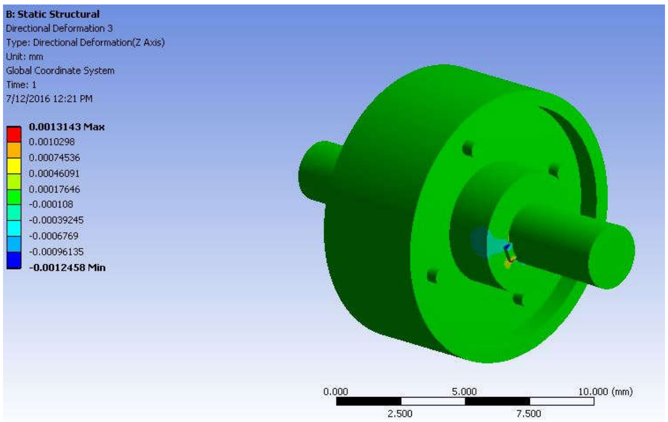
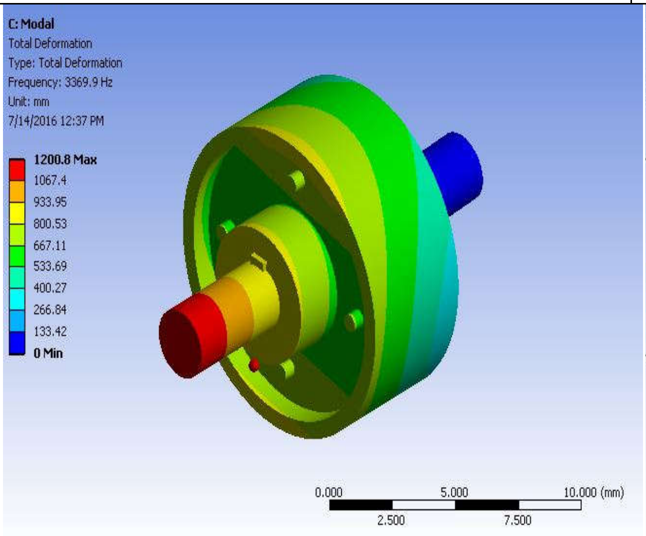
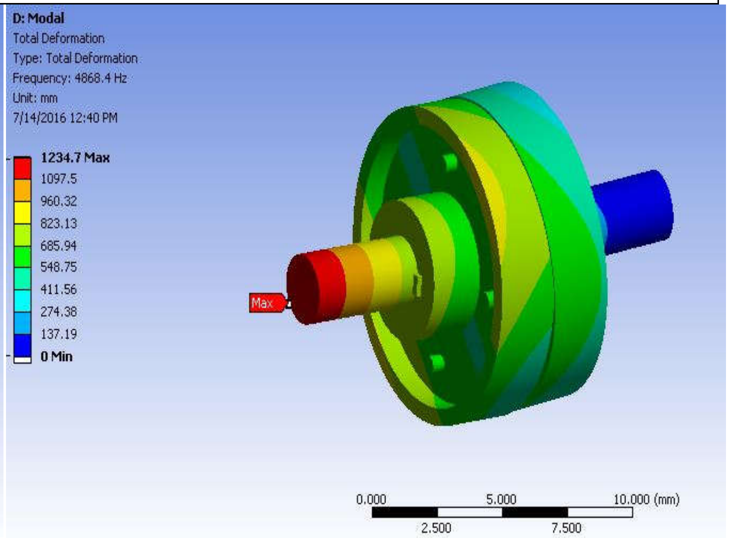


Figure Direction deformation along Z axis

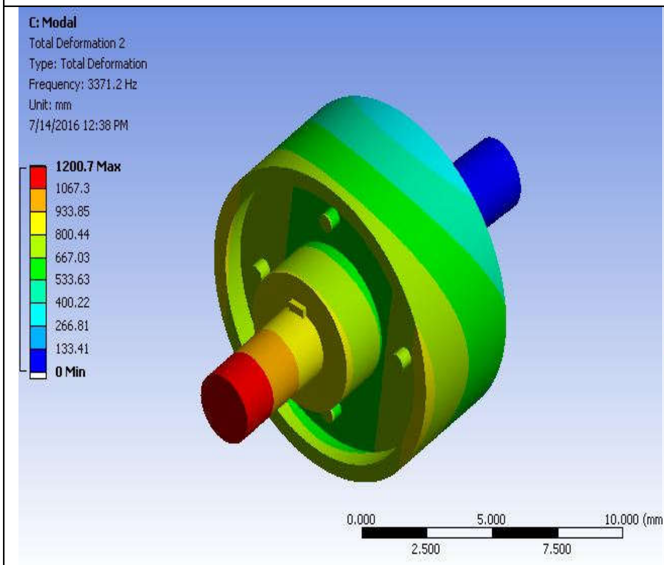
The above figure shows total directional deformation existing over flange along z direction.

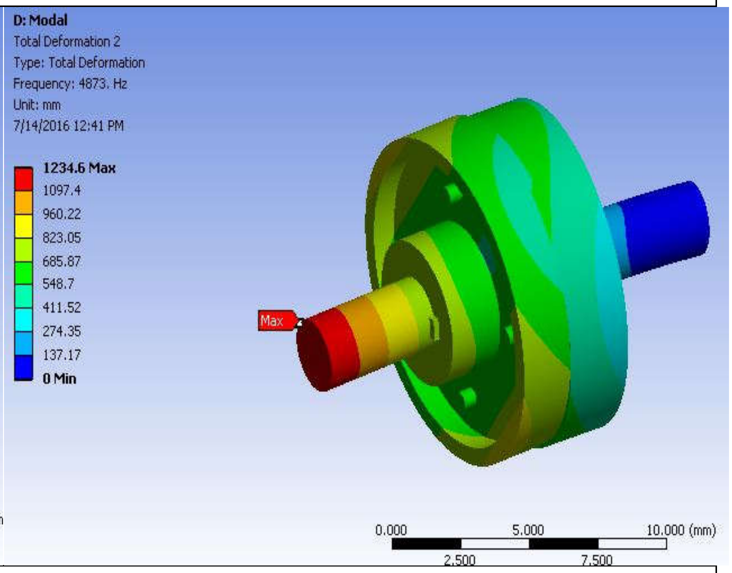
Healthy	Unhealthy



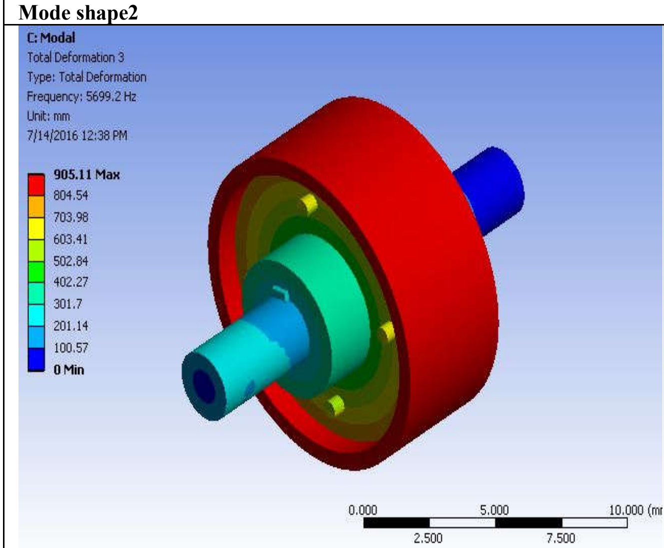


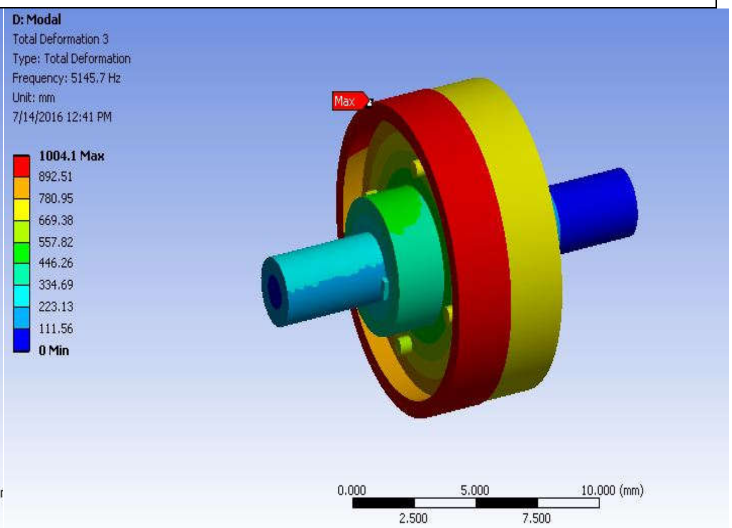
Mode Shape 1





Mode shape2





Mode Shape 3

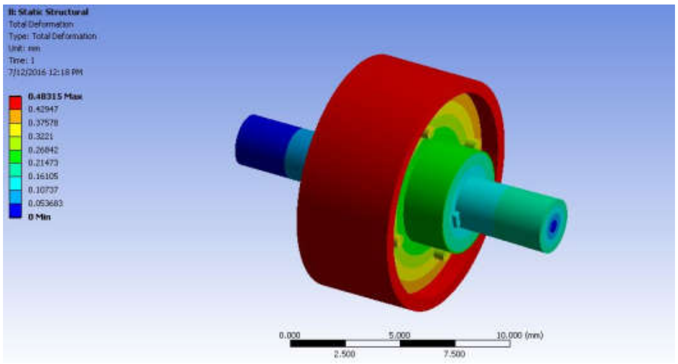


Figure Total deformation of Flange

Now for further study we Comparison healthy model with bonded nuts and bolts and unhealthy model with misaligned shaft with frictional and moving bolts and nuts.

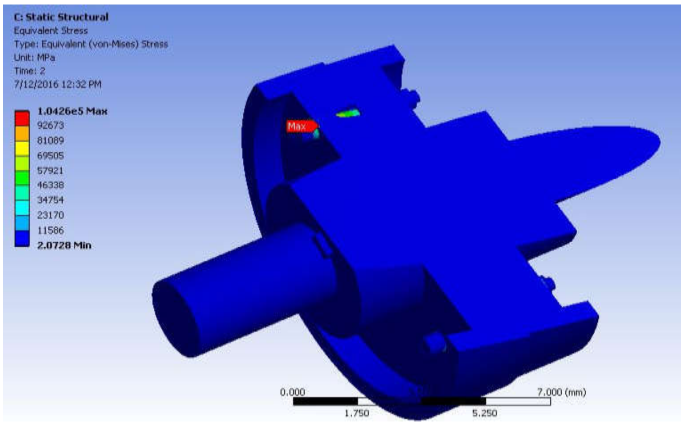


Fig. Equivalent stress when shaft bolts and nuts were given frictional contacts (unhealthy model)

It can be seen from above figure that in unhealthy model maximum stress is acting along the nut connecting the two flanges, While in healthy model no stress were observed at the connection. Thus a loose nut will result in misalignment of shaft either angular or parallel.

Comparison of modal frequencies of shaft with bonded nuts and Flange model with frictional nut contac. The detail values are given in table 6 and mode shapes are compared in figure.

3.10 Comparison of Modal frequencies of normal flange coupling and misaligned coupling

Frequency Flange(withbonded nuts), Hz	Frequency Flange(with frictional nuts), Hz
3358.4	4868
3358.6	4873
5676.8	5145

Different modes for healthy and unhealthy models

Discussion – in validating with literature, we find that how misaligned shaft can cause vibrations, thus producing undesirable stresses in the coupling. Also, by comparing the coupling having frictional contact between nuts and bolts with that of bonded contact, we see how mode shapes and frequency change.

CONCLUSION

A study on dynamic vibration in coupling systems is carried out following based approach using MATLAB where mass imbalance and parallel misalignment of shaft is considered in Flange coupling Model. The results are in good agreement with the literature [9]. Moreover total residual force was plotted against node numbers to know the response of the system where fault occurs. Thus we conclude that one can find the effect of various faults on response of the coupling system. So, accordingly we can design the coupling based on requirements.

This method may be useful for large systems like in motors, turbines, gearboxes and the like. The present approach allows for on-line fault identification effectively.

We have also performed in ANSYS three dimensional analysis of Flanged coupling model to determine misalignment due to change in modal frequencies. Result is validated with literature [10]. Any misaligned shaft due to disc mass imbalance or shaft weight can cause the stresses and vibrations in coupling.

A faulty system of another coupled model was run in Ansys with frictional contact between nuts and bolts to capture the misalignment caused due to their movements in coupling. Thus Stress and modal frequencies of faulty system was found to be different from healthy system

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