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Rotor Dynamic Analysis Applicable to Vertical Axis Wind Turbine

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Abstract: ***Requirements and the Demands for sustainable energy have results in increased interest in wind mill or wind turbines. Thus, despite widespread economic difficulties, global installed wind power which is increased by over 20% in 2011 alone[1]. Recently the magnetic bearing technology has been proposed to improve the wind turbine performance by mitigating vibration in shaft and bearing to reducing frictional losses. While magnetic bearing has been used to reduce friction in other applications, little data has been presented to establish magnetic effect on vibration and friction in wind turbines. Accordingly, this study provides a functional method for experimentally evaluating the effect of a magnetic bearing on the vibration and efficiency characteristics of a wind mill, along with the associated results and conclusions. The magnetic bearing is used is a type of passive magnetic bearing, The design of concentric rings and it's Vibrationalbehavior, and the dominant parts of frequency, and results of efficiency are tabulated for the bearing are to be tested in two systems in that a precision test by fixtures, and a small economical use of commercial available wind mill or wind turbines. Data of the equivalent of ball bearings are compared with magneto type, also providing a reason behind the advantage of the magnetic type of bearings with respect to their performance and efficiency [2]. There are wide range of requirements of magneto type bearings due to ease of lubricating system which needs the extra parts like pump, in hydrostatic and also the lubricating oil.***

1. Introduction

In vertical axis wind mill is more dominant to catching of wind in all directions where the no need of any yaw mechanisms downwind conings. The position of electric generator is at the bottom [1]. There mainly two types in the vertical axis wind mill a) Darricus and b) savonious.In the modern or latest type of vertical wind mill the helical type of bearings are introduced that leads to small increment in the efficiency and also the reducing noise and thermal problems[2]. Like that the Improvement in the vertical type wind mill by changing their gear systems or materials and design of fan blades are made. Now after knowing the application and advantages of the vertical wind mill it is necessary to minimize heat losses in the turbines due to wear and friction which occurs at the contact parts which are sliding or rotating.When friction and wear leads to thermal loss then it is necessary to replace the mating parts while rotating that is nothing but the bearings so that I have chosen the magnetic bearings and foil bearings to replace the normal bearings [3].The rotor dynamic analysis of the vertical axis wind turbines is nothing but the finding of the vibrational properties such as natural frequencies (free from external force) critical speeds and the mode shapes.To the rotor dynamic analysis for the shaft of wind mill which is subjected to the special type of bearings (magnetic and foil) can be done in the ANSYS 19 software's.

2. Methodology

2.1 Procedure to Find the Vibration Analysis in ANSYS Workbench of Windmill Shaft

Step 1: prepare e geometry of rotor and import it in ANSYS workbench the standard dimensions of the shaft from wind turbine has been taken for design where the shaft is stepped shaft and two foil bearings and one magnetic bearing is supported

In the 2-D diagram of stepped shaft where all the dimensions are taken in account to the designing purpose.

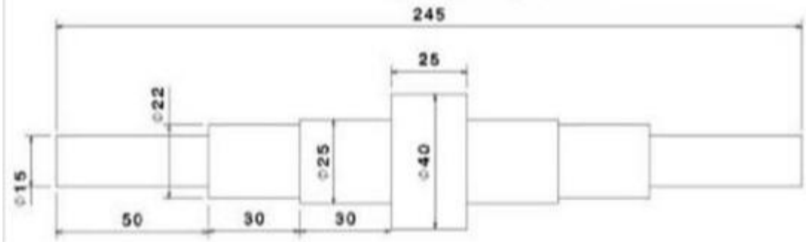

Figure 1: 2D Diagram of shaft

Magnetic bearing dimensions

Table 1: Magnetic bearing dimensions

	Inner Ring Dimension	Outer ring dimension
Inner radius (mm)	R1 = 10	R3 = 22
Outer radius (mm)	R2 = 20	R4 = 32
Thickness (mm)	10	10
Flux Density (T)	1	1

Table 2: Material and bearing properties

Properties	Units
Young's modulus	2e11 N/m2
Density	7800 Kg/m3
Poisons Ratio	0.3
Mass Moment of Inertia of Magnetic Bearing	Ixx =7.21e-5 Kg-mm2 Iyy = 3.51e-5 Kg-mm2 Izz = 3.51e-5 Kg-mm2
Mass of Magnets	0.137 Kg

Bearing	Stiffness
Magnetic Bearing	K11 = 93800 N/m K22 = -46900 N/m
Foil Bearing	1e6 N/m

Step 2: slice the geometry at the steps of shaft and at bearing to make the slice first we have to create the planes at stepped shaft and at the bearing position

Step 3: add mass and its inertia -The mass participation is also a n important point. For the present problem because of change mass participation leads to large errors

Step 4: add bearing elements-The bearings elements are added as per the requirements where previously slice are made the upper two bearings are foil bearings.

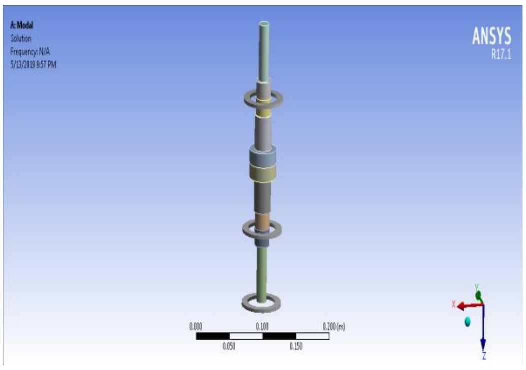

Figure 3: Assembly of Bearing and Shaft

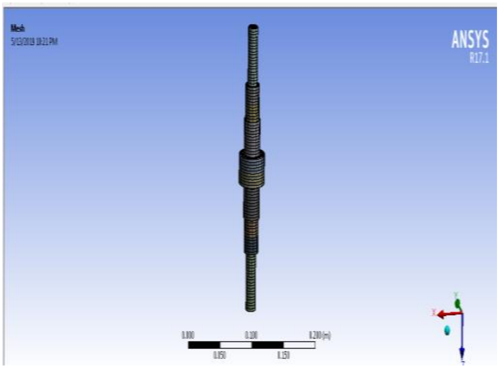

Figure 4: Meshed Shaft

Step 5: meshing is done by sweep mesh :Meshing will make the shaft stronger and also high finish surface in present problem the swipe mesh has been used we can take a close look of that the lines of meshing does not change their directions If line has changed their direction then we have to modify the meshing Operation.

Step 6: Define the rotational speed: The high rotational speed is taken for the above analysis because foil bearings efficiency is more only at high speed so that the rotational speed is taken as 40000rpm and the rotational speed is given from the bottom side in because the rotor is fixed at the bottom.

3. Result

Solve model and investigate critical speed using Campbell diagram: The solution will give the deformation or deflection at the different frequency and also gives the critical speed of the shaft so we get to know that at what speed we cannot run the shaft to avoid friction, noise, and failure.

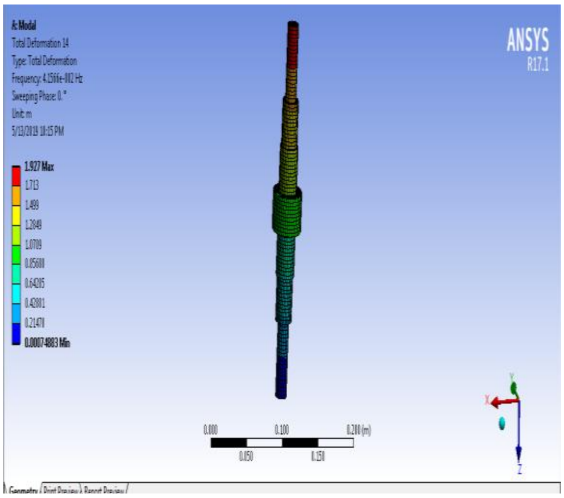

Figure 5: maximum deflection 1.927mm and minimum deflection $7.4*10^{-4}$ of shaft

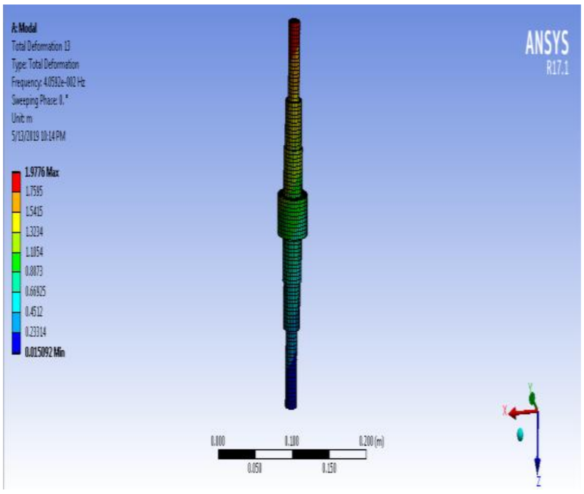

Figure 6: Maximum deflection 1.977mm and minimum deflection $1.5*10^{-2}$ of shaft

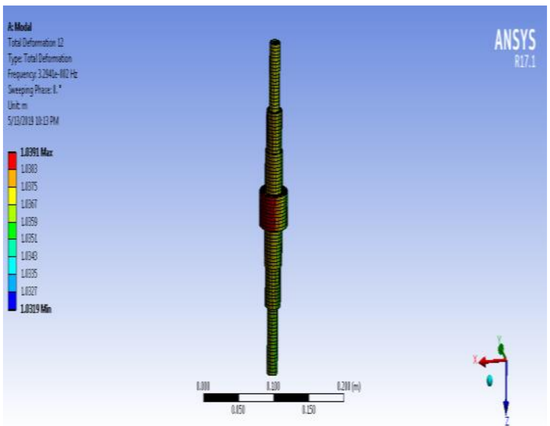

Figure 7: Maximum deflection 1.0391mm and minimum deflection 1.0319mmofshaft

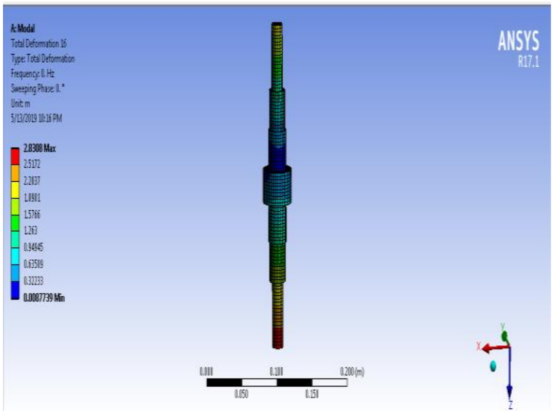

Figure 8: Maximum deflection 2.8308mm and minimum deflection 0.0087 mm of shaft

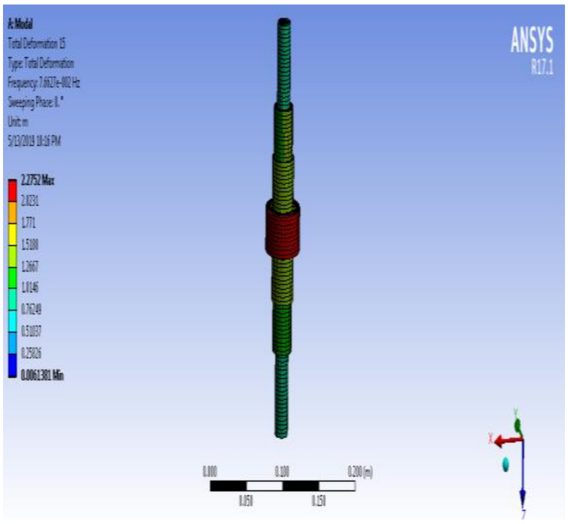

Figure 9: maximum deflection 2.2752mm and minimum deflection 0.006138mm of shaft

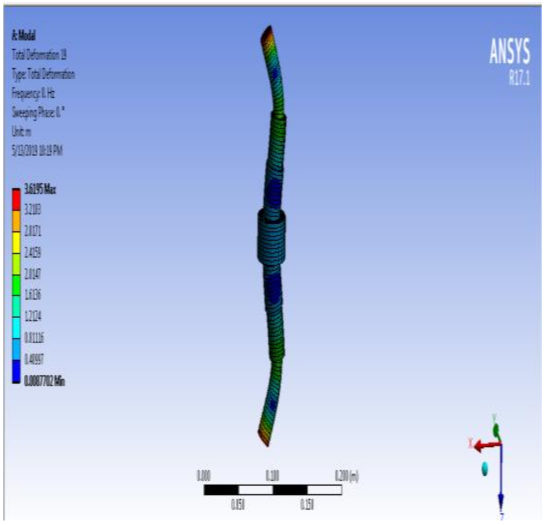

Figure 10: maximum deflection 3.61951mm and minimum deflection 0.00877mm of shaft

Campbell Diagram

The Campbell diagram is a graph in which the x-axis indicates the rotational velocity and y-axis is frequency where the stability of the component will get to know from the graph, and the graph also gives the information like critical speed of shaft for the present problem the component is stable at all the modes and the model is safe.

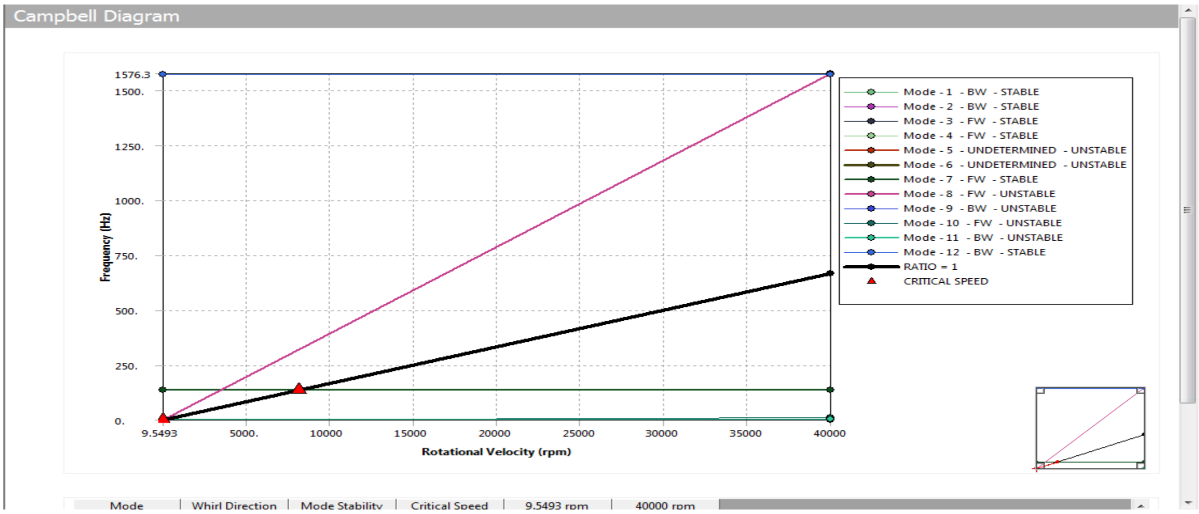

Figure 11: Campbell diagram

Result Table

Table 3: Frequency Results

Set	Damped frequencies	Stability	Mode Shape
1	$3.2941e^{-002}$	$-7.0227e^{-009}$	$2.1319e^{-002}$
2	$4.0592e^{-0.002}$	$2.3446e^{-008}$	$-5.776e^{-002}$
3	$4.15666e^{-0002}$	$-1.455e^{-008}$	$3.5055e^{-002}$
4	$7.6627e^{-002}$	$1.3176e^{-006}$	$-1.7194e^{-002}$

Procedure to Find the Vibration Analysis in ANSYS Workbench of Shaft with Disc

Designed Model: The model designed with two rotors mounted on a shaft along with the three bearings which support the shaft.

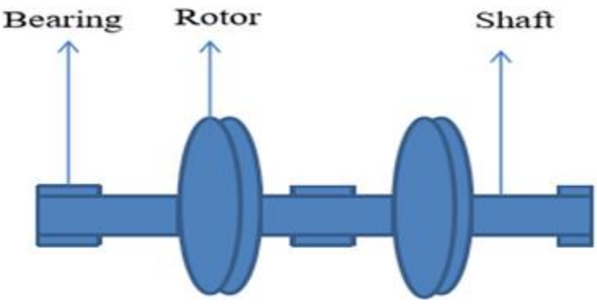

Figure 12: Design of the model

Table 4: Dimension of rotor shaft modal

Description	Values
Diameter of the rotor	70mm
Mass of the rotor	25 kg and 30kg
Thickness of the rotor	10mm
Speed of the rotor	Upto 3000rpm
Length of the shaft	1200mm
Distance between the bearings.	70mm
Force	280N
Stiffness	N/mm

Step 1: prepare e geometry of rotor and import it in ANSYS workbench:as per the dimensions of given shaft with rotor disc is designed, we can also design the model in other softwares and then converting it to m. file but sometimes it will give the errors better to prepare the model in ANSYS workbench.

Step 2: Slice the geometry at the step of shaft and at bearing: the model is sliced in parts to better meshing to make the slice first we have to create the planes and then slicing.

Step 3: add mass and its inertia

Step 4: add bearing elements: The three bearings has been used in the above model as per their properties where the slice is already done. We can use 2 bearings also but that will makes whirling of shaft because of its weight 25kg to 30kg so for better support 3 bearings are used.

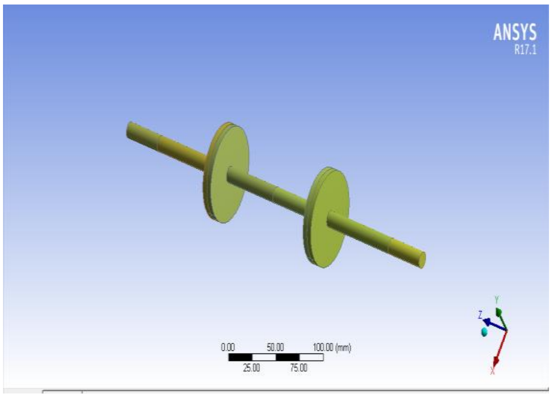

Figure 13: ANSYS Model

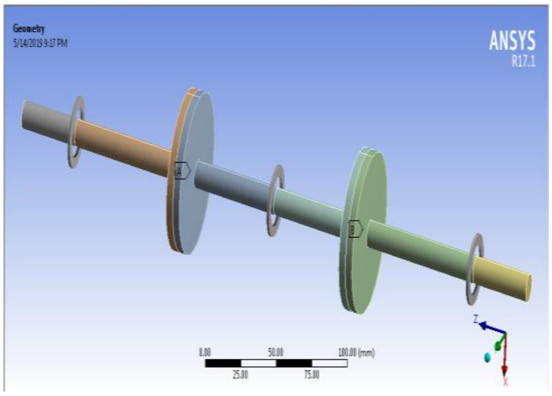

Figure 14: Assembly of ANSYS Model

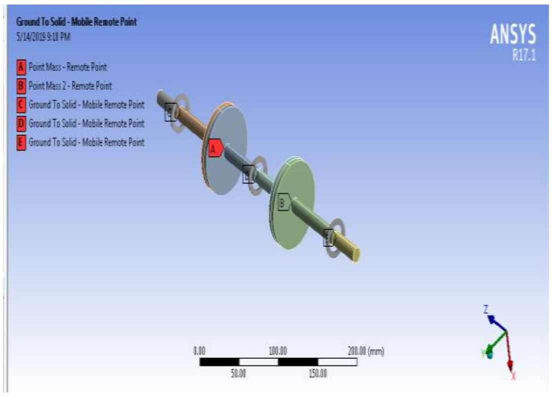

Figure 15: Addition of mass moment of inertia

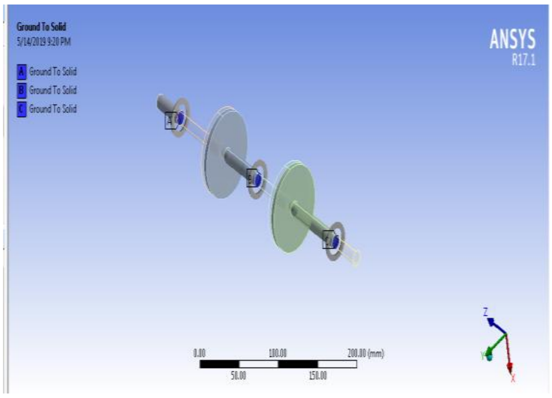

Figure 16: Bearing location of elements

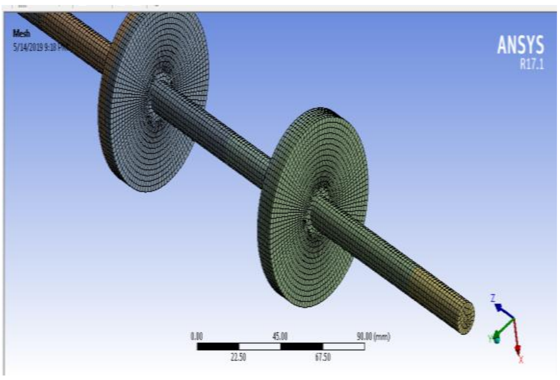

Figure 18: Meshing of component

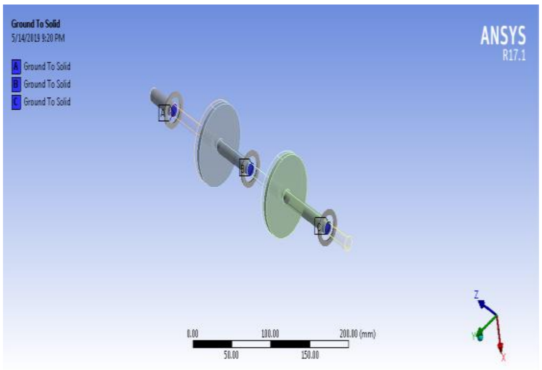

Figure 19: Rotational Speed at 30000 rpm

Step 5: meshing is done by sweep mesh : the swipe mesh has been done with clear meshing line we can observed from the model this swipe mesh gives the strength to the model to withstand for high load.
Step 6: Define the rotational speed: The maximum speed is given as 30000 rpm from the rotor side.

Result

Solve model and investigate critical speed using campbell diagram: The solution has done and the different deformation at different frequencies are observed from the result summery so that the stability can be observed

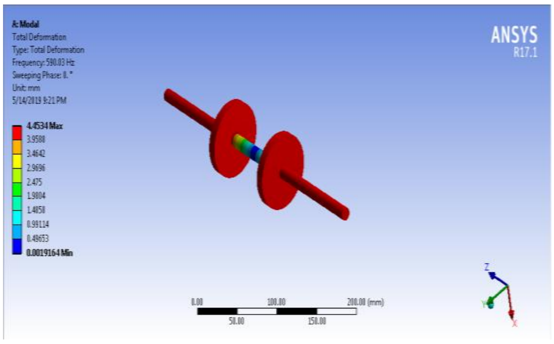

Figure 20: Represents the Total Deformation at 590.03Hz

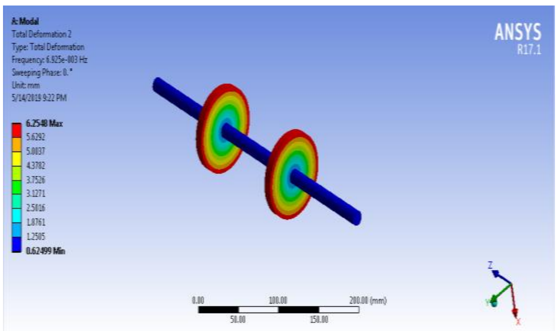

Figure 21: Represents the Total Deformation at 6.925e^{-003}Hz

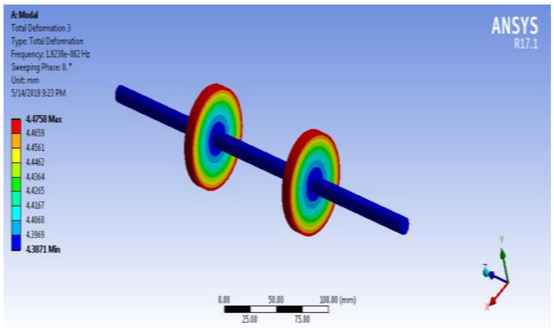

Figure 22: Represents The Total Deformation at 1.923e^{-002} Hz

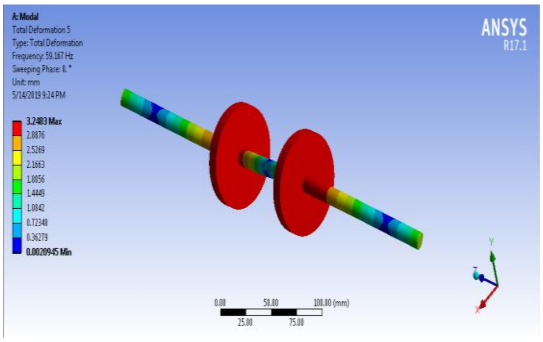

Figure 23: Represents the Total Deformation at 53.01 Hz

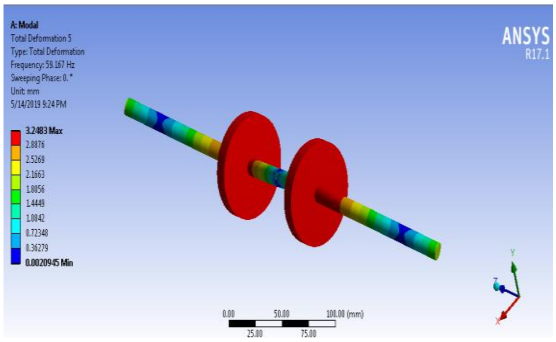

Figure 24: Represents the Total Deformation at 59.167 Hz

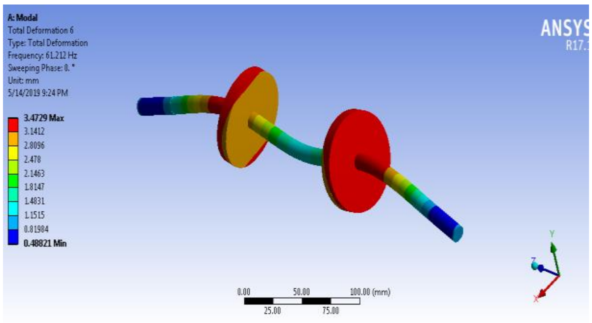

Figure 25: Represents the Total Deformation at 61.212 Hz

Campbell diagram

The Campbell diagram gives the stability, and the critical speeds of the model where the present solution show stable at all the modes and also the mode shape and frequency are observed.

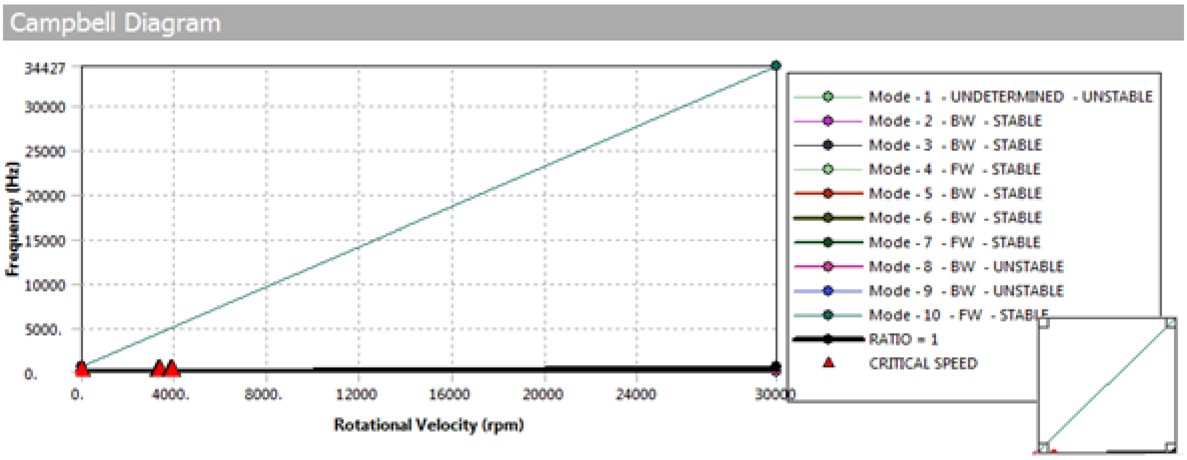

Figure 26: Campbell diagram of model

Comparison of Results

Mode	Previous Stability	Stability	Previous Critical speed	Critical speed	Error
1	Stable	Stable	3157.6	3053.1	3.3
2	Stable	Stable	3291.8	3091.1	6.7
3	Stable	Stable	3537	3500.3	1.04
4	Stable	Stable	3569.5	3542.5	0.7
5	Stable	Stable	3599.6	3546	1.48

4. Conclusion

The followed procedure to find the critical speed is nearly matches with mathematical model results and an error of 2.5% is obtained which is acceptable hence the procedure used could be suitable for rotor dynamic analysis of shaft supported by special bearings.

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