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Finite Element Modeling of Rotor using ANSYS

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Abstract: The purpose of this study is to analyze the natural frequencies of the rotor under different boundary conditions like simply support, cantilever support with disc and without disc. Finite element analysis of the rotor has been done in the popular software package ANSYS. ANSYS APDL coding is generated and used to calculate the natural frequency by generating the Campbell diagram. In this paper comparison in natural frequencies is shown between analytical value and ANSYS coding in different disc position. Campbell diagram is used to show the variation of natural frequencies for different spin speed. It has been observed that there is a very close agreement between analytical results and result obtained from ANSYS software.
Keywords—ANSYS-APDL, natural frequency, Campbell diagram, rotor

I. INTRODUCTION

Rotor dynamics is a specialized branch of applied mechanics concerned with the behavior and diagnosis of rotating structures. A *rotor* is a body suspended through a set of cylindrical hinges or bearings that allow it to rotate freely about an axis fixed in space. Stator is a part of the machine which does not rotate. From the several methods (e.g. the transfer matrix, influence coefficient, mechanical impedance and finite element methods) the most popular approaches Finite Element Method (FEM) is one, which is particularly well suited for modeling large scale and complicated rotor systems.

Rankine (1869) performed the first analysis of a spinning shaft. He predicted that beyond a certain spin speed ". . . the shaft is considerably bent and whirls around in this bent form." He defined this certain speed as the *whirling speed* of the shaft.

Nelson and McVaugh [1] studied on the natural whirl speeds and unbalance response of a typical overhung system and made a comparison of results with an independent lumped mass analysis.

Rosyid et al. [2] demonstrated the quality of modal reduction of rotor-bearing-support system through sub structuring. Montgomery and Kusmider [3] studied the Coriolis effects and how it can be applied in a finite element modal and gyroscopic effects and gain confidence in utilizing the capabilities in commercial applications.

Taplak and Parlak [4] studied a program named Dynrut which was used to make dynamic analysis and evaluate the results and how the software can used was also presented in the study. For this purpose, a gas turbine rotor with certain geometrical and mechanical properties was modeled and its dynamic analysis was made by Dynrut program.

Eling et al. [5] studied the modal analysis of the rotor in free-free conditions, as it can be accurately validated by experiments by coupling the fluid film physics directly to the rotor. In this prediction of the rotor dynamics can be made, this helps the design engineer to evaluate the critical speed of rotor bearing.

Jalali et al. [6] studied full dynamic analysis of a high speed rotor with certain geometrical and mechanical properties. In that paper they carried out analysis by using 3D finite element model and experimental modal test.

Wang et al. [7] studied the dynamic behavior of the rotor-journal bearing system. Where calculation was done by solving three-dimensional numerical model using finite element method, and the vibration characteristics of the system were investigated according to the calculation results. From this natural frequencies and vibration modes were obtained.

Fegade et al. [8] presented an alternative procedure called harmonic analysis to identify frequency of a system by ploting graph between critical speed, amplitude and phase angle using ANSYS. Result showed the critical speed of rotor using different bearing.

Mat lab program was developed by Muminovic et al [9] to simulate the rotor bearing model to calculate the natural frequency. The authors have drawn the diagram of natural frequency with respect to length, diameter of rotor and density of material. The authors tested the model using the solid works software also.

From the review of previous papers it is clear that very less work has been done using ANSYS APDL Coding in rotor for different types of supports. Rotating speed and critical speeds are main design criteria of rotating machinery.

In this paper dynamic modeling of a rotor disc system is done in Ansys to calculate the natural frequencies (1^{st} , 2^{nd} and 3^{rd} natural frequency) of the rotor in different support conditions. APDL coding is generated and with the help of that coding Campbell diagram and mode shape in different cases are generated to obtain the natural frequency. In this the effect of disc position on natural

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frequency is studied.

II. ANALYSIS

ANSYS is a common tool for finite element analysis. In Ansys there are different rotating beam elements like BEAM188, BEAM4 element and PIPE16 element which can be used to model any shaft. In case of rotating beam element gyroscopic effect can be taken into consideration. Other factors like internal damping, axial load, shear deformation etc can also be considered

PIPE16: It is an uni-axial element with tension-compression, torsion and bending capabilities. It is two node element which has six degree of freedom. Rotation and translation about x, y and z direction. It includes specification like diameter, thickness, density, surface area etc. In this nodal displacement involved in the overall nodal solution.

MASS21: This is a point element having up to six degree of freedom, rotation about x, y and z axes and translation about x, y and z direction. In this we can assign different mass and rotary inertia at each coordinate direction. In this there is no element solution unless element reaction force are requested it include overall displacement solution.

SHELL181: It is well suited for linear and large rotational application. It is used for composite shell or sandwich construction. Shell181 is suitable for analyzing thin to thick shell structure. In this 4 nodes element are present with six-degree of freedom at each node translation and rotation about x, y and z axes.

In Ansys the rotor is modeled with Pipe16 element and disc is modeled with mass 21 and beam 181 element.

III. MODELING IN ANSYS

In this study the rotor is modeled in Ansys with pipe 16 element. The modal analysis of the rotor has been done for different boundary conditions with the presence of disc and without disc. The disc is considered at different position of the rotor.

Table 1 the material properties of the rotor

S. N	Parameter	Value
1	Material(shaft and disc)	Mild Steel
2	Young's Modulus(E)	200×10^9 N/m^4
3	Density (ρ)	8000 kg/m^3
4	Poisson's ratio(μ)	0.3

Table 2 Dimension of Rotor and Disc

S.No	DIMENSION	
1	Dia. of shaft	.01 m
2	Dia. Of disc	.12 m
3	Thickness of disc	.01 m
4	Length	.45 m

IV. SHAFT WITH CENTRAL AND NON CENTRAL DISC

In this model the effect in natural frequency is studied. First shaft without disc is taken and then with disc at different positions. In this the Campbell diagram is generated using APDL coding and studied the effect in natural frequency. For this the eccentricity e = 0 is assumed.

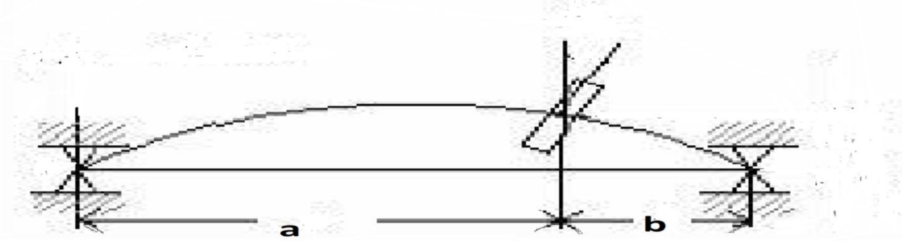

Fig.1 Non central disc of length L

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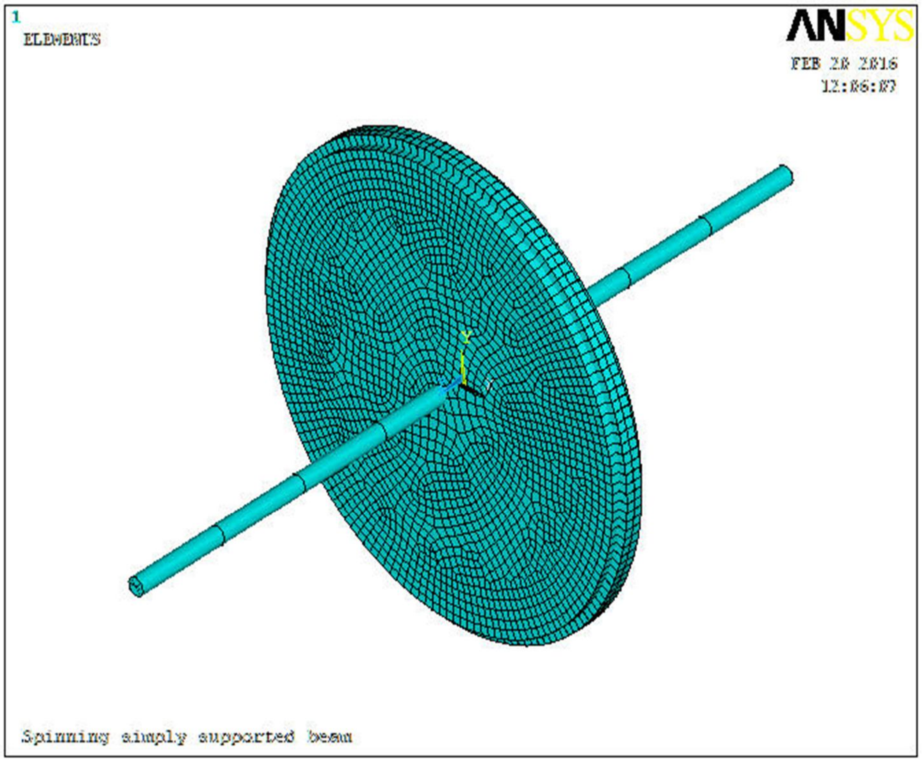

Fig.2 Messed simply support rotor with disc at centre

Table 3. Natural frequencies of rotor in different boundary condition according to above dimension

S.No	Disc Position	Natural Frequencies (Hz)
1	Shaft without disc	1st - 68.418 68.418 2nd - 248.78 248.78
2	Shaft at centre position (a=b=.225)	1st - 38.932 39.11 2nd - 237.08 239.56
3	Shaft at 1/3 position from right (a=.3 , b=.15)	1st - 43.58 43.58 2nd - 295.88 295.88
4	Shaft at 1/6 position from right (a=.375 , b=.075)	1st - 55.11 55.76 2nd - 321.40 321.40

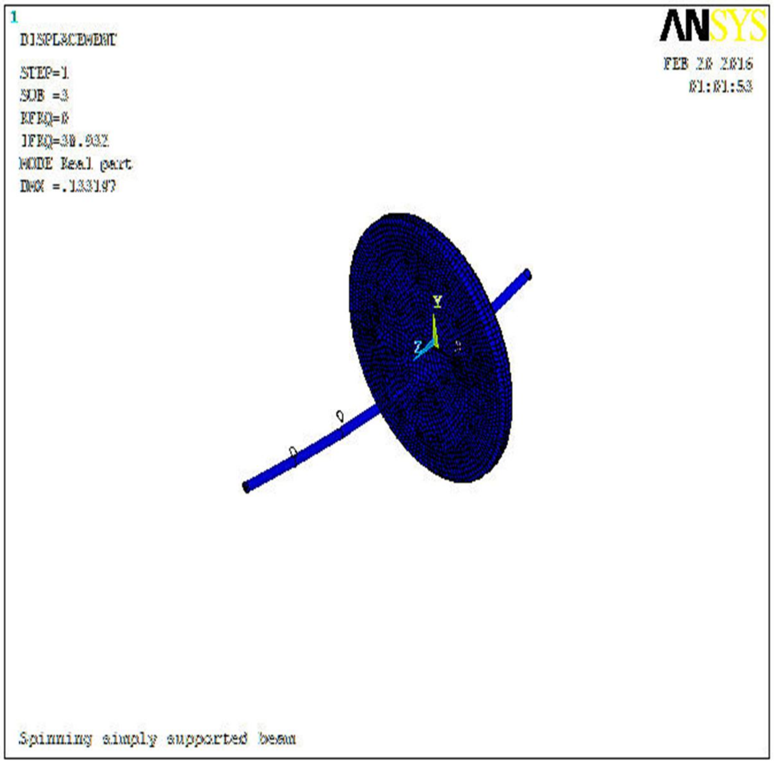

Fig.3 1st Mode shape of simply support disc at centre

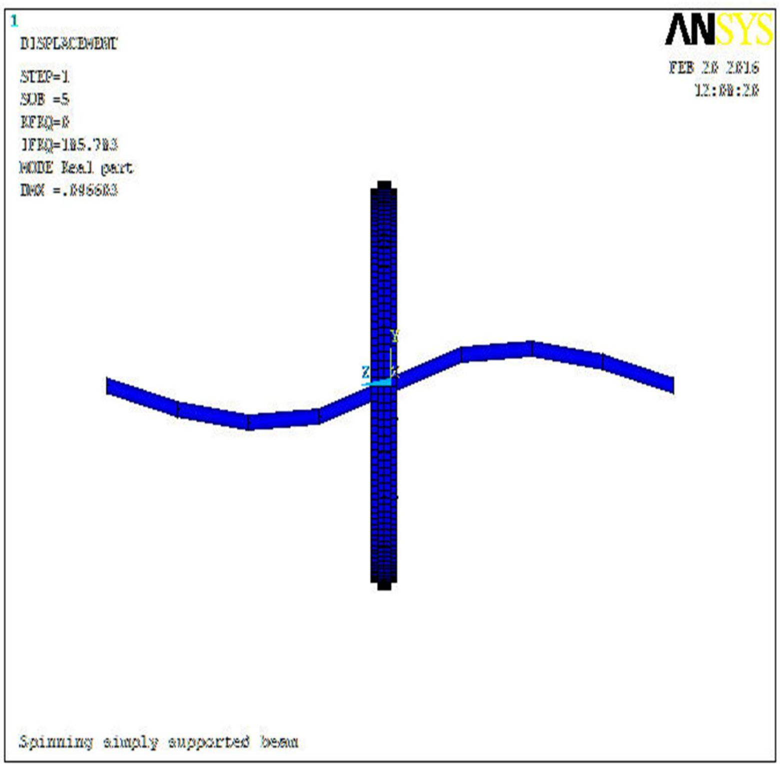

Fig.4 2nd Mode shape of simply support disc at centre

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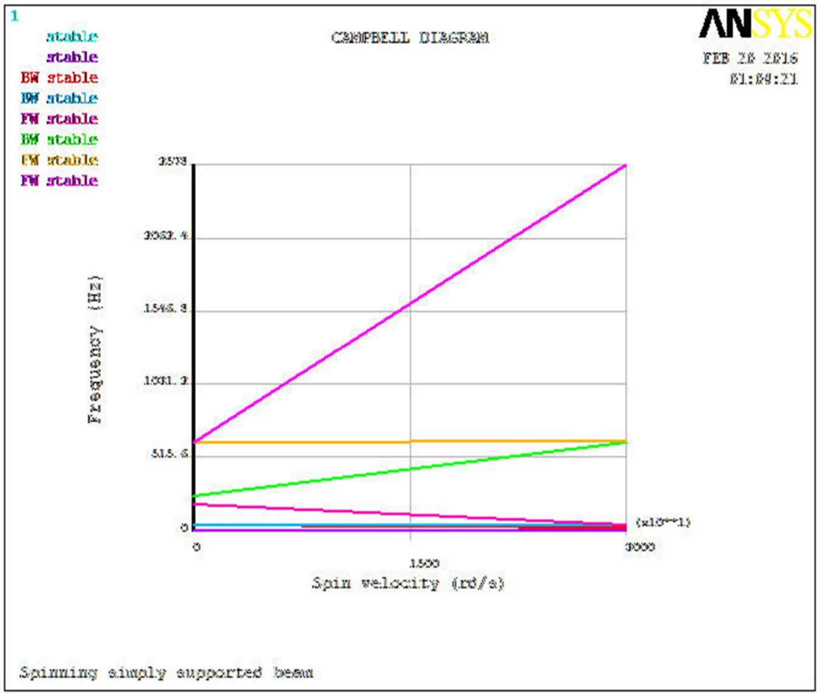

Fig 5. Campbell diagram of simply support rotor

V. CANTILEVER ROTOR WITHOUT DISC AND WITH DISC

In this model one end of rotor is fixed. The disc is placed at the different position of the rotor. ANSYS APDL coding is generated for the rotor. The natural frequency is obtained using the modal analysis of the rotor. In this model the effect of disc position on natural frequency is observed

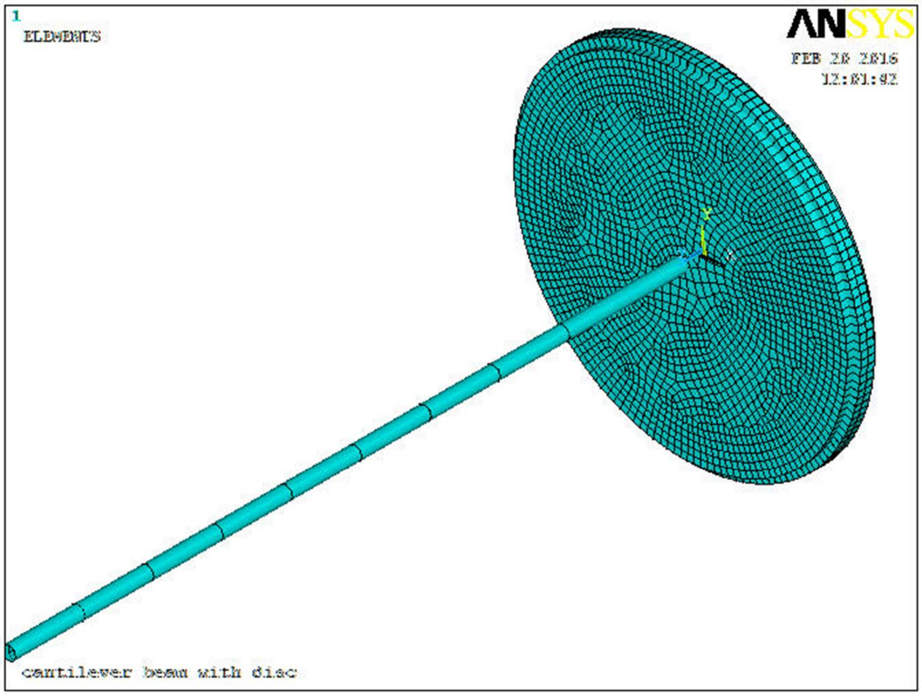

Fig.6 Messed cantilever rotor with disc at free end

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Table.4 shows the variation of Natural Frequency due to change in disc position

S.No	Disc Position	Natural Frequency (Hz)
1	Cantilever without disc (L= .45)	14.03
2	Disc at free end	9.1357
3	Disc at .4m from fixed end	10.723
4	Disc at .35m from fixed end	12.776
5	Disc at .3m from fixed end	15.469
6	Disc at .25m from fixed end	19.025
7	Disc at .2m from fixed end	23.6
8	Disc at .15m from fixed end	28.772

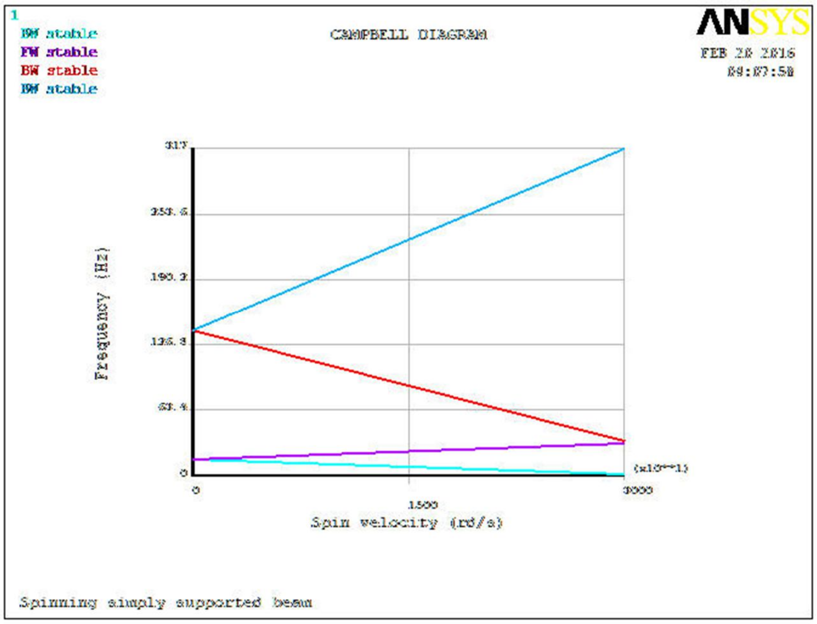

Fig 7. Campbell diagram of cantilever rotor

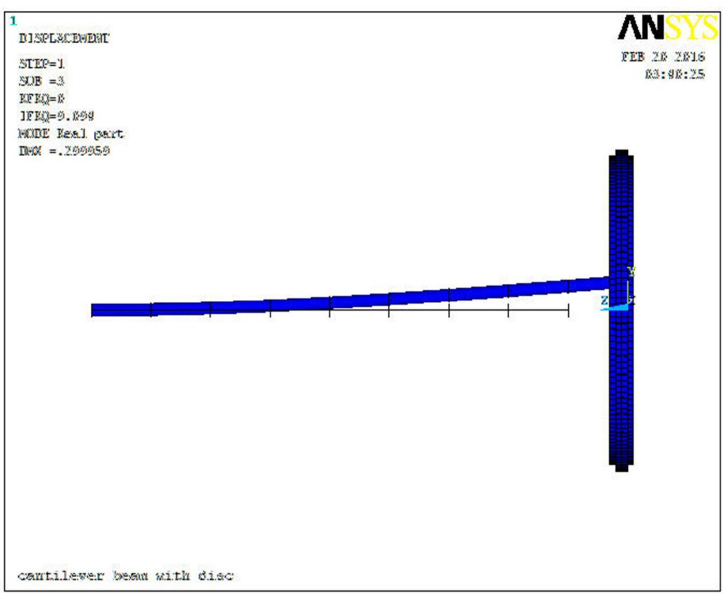

Fig.8 1st mode of cantilever with disc

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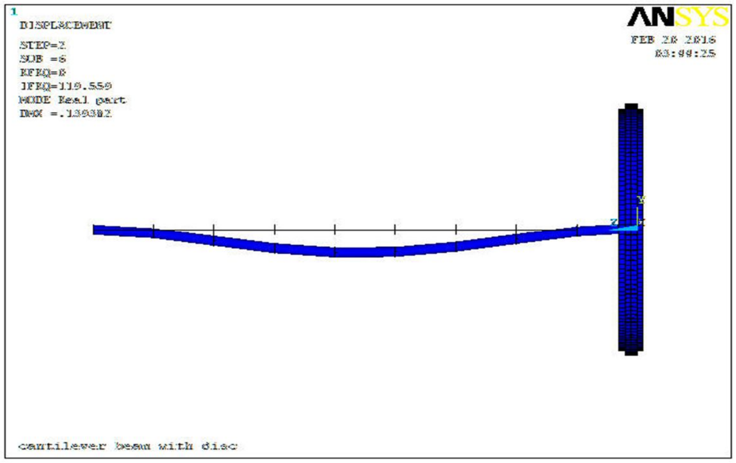

Fig.9 2nd mode of cantilever with disc

VI. RESULT AND DISSCUSSION

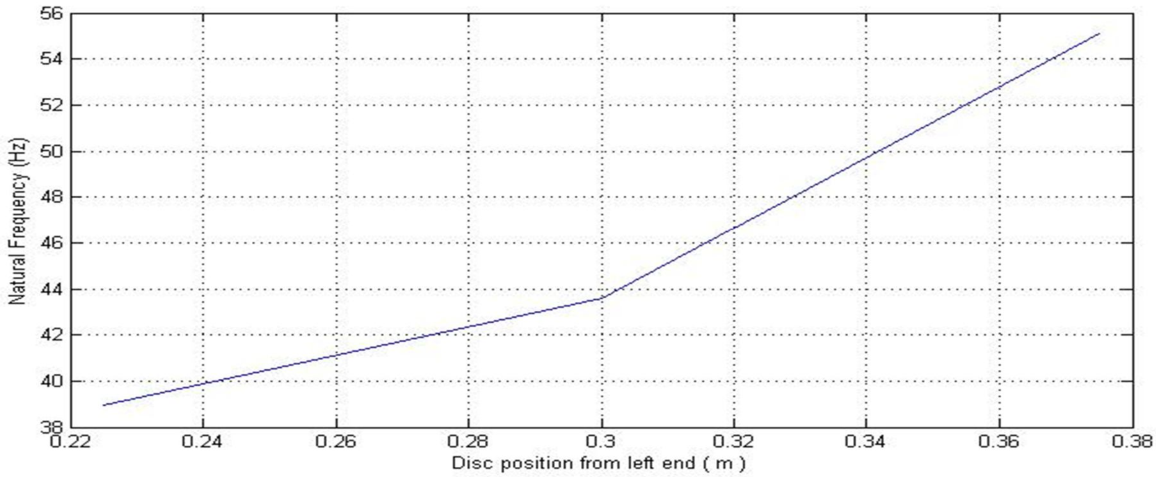

Fig.10 shows the variation in natural frequency in simple support with change in disc position

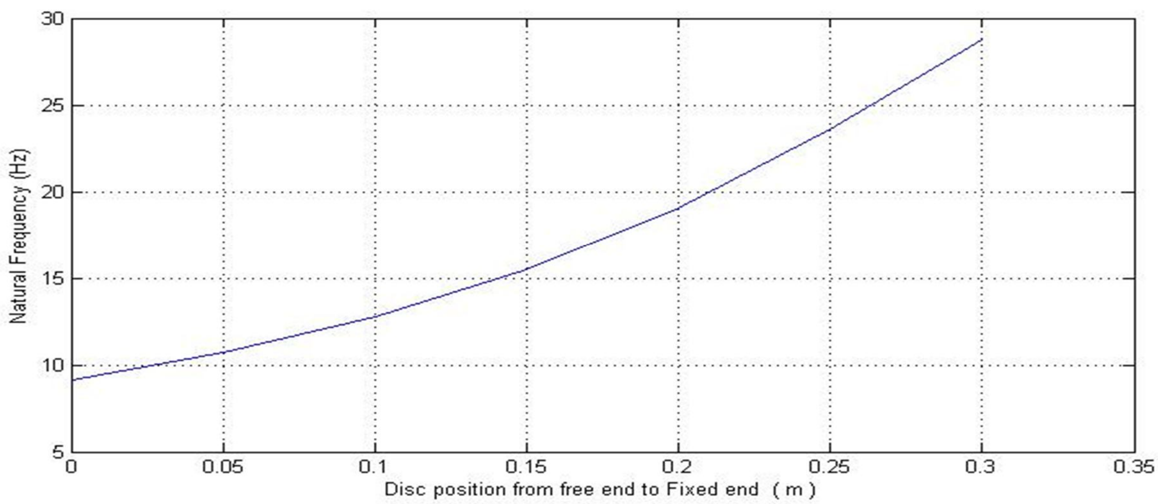

Fig.10 shows the variation in natural frequency in cantilever with change in disc position

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VII. CONCLUSION

In this paper dynamics analysis of rotor model is done using finite element analysis. The finite element analysis of the rotor is done in Ansys APDL. This analysis of natural frequency under different boundary conditions enables the user for quick analysis. This is very useful for the designer of rotary machinery to calculate the critical speed of rotor and natural frequency. In this study the effect of the disc position on the natural frequencies is studied for the simply supported bearings and cantilever types rotor. This is observed that in case of simple supports the natural frequency is increased when the disc is shifted towards the support from the mid position. In case of cantilever rotor the natural frequency is increase when the disc is moved towards the fixed support from the free end.

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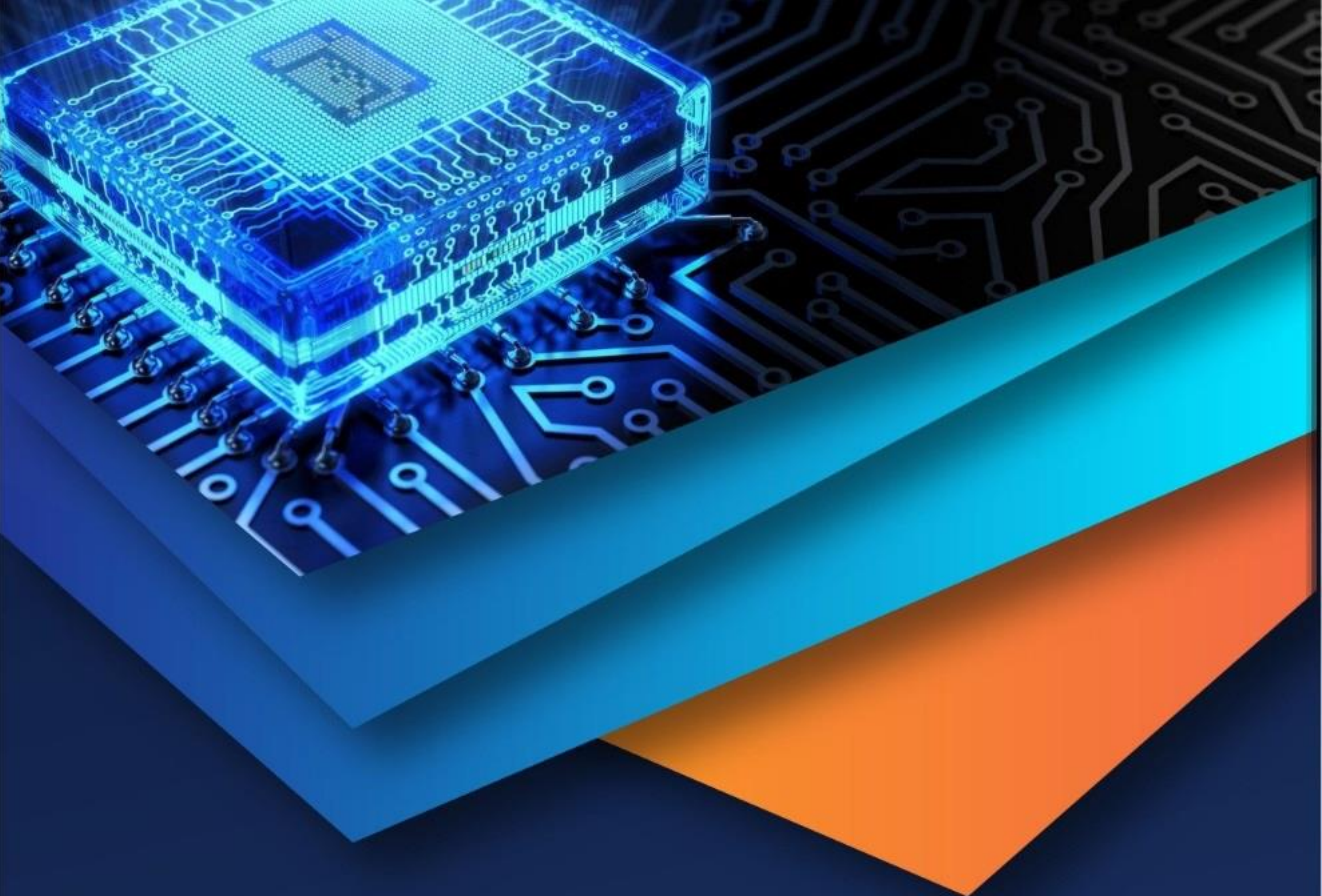

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