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"A STUDY ON EFFECT OF VIBRATION ON SHAFT UNDER DIFFERENT LOADING CONDITION IN STEAM TURBINE BY USING FEM"

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ABSTRACT

The effective uses of a shaft are limited at its maximum operational junction frequency. The study was conducted by using the Finite element method. The shafts are used with flow of with rotation such as compressors, turbine and industrial applications. The major study will be done on shaft by using different materials with different shaft profile. A natural frequency was analyzed and critical speed was predicted by using Campbell diagram and analysis was also performed for validation.In our analysis, ANSYS will be used and the model will be developed on CAD software . In order to verify the present simulation model, the Natural frequency with their modes considering different types of materials is to be compared with the available experimental results and the design of shaft with different diameter 70-100 mm, 80-100 mm. In this study, the simulations of different profile shaft and four types of materials i.e. Gray cast iron, Stainless steel, Structural steel ,Titanium alloy and was analyzed for critical speed and natural frequency the configurations of shaft design are proposed.

Key Words: FEA, ANSYS, Cre-O ,Gray cast iron, Stainless steel, Structural steel ,Titanium alloy, Shaft

I. INTRODUCTION

Shaft is a component for transmitting mechanical energy and torque and rotation, generally used to connect different additives of a drive train that can't be related without delay because of distance or the need to allow for relative movement between them. As torque carriers, drive shafts are problem to torsion and shear stress, equal to the distinction between the input torque and the burden. They need to therefore be robust sufficient to endure the strain, whilst keeping off too much extra weight as that would in flip growth their inertia. To allow for variations inside the alignment and distance between the riding and driven components, force shafts regularly comprise one or extra widespread joints, jaw couplings, or rag joints, and now and again a splined joint or prismatic joint.

1.1 Overview

In the 1970, to meet consumer call for, the crossovers become modified from cars in Europe and the US. It stemmed from SUVs, progressively advanced into an arbitrary combination of automobile, SUV, MPV, and choose-up. It set the comfort, fashion, and appearance standards for such cars; it had the manage of an SUV and the potential of an MPV internally. Crossovers are divided into SAV, CDV, trucks, and different methods. Qualitative research into the impact of transmission shaft perspective and intermediate support stiffness on meshing vibration of gears remains sparse.

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Impact Factor : 4.256

1.2 Types

- Line Shaft
- Crank Shaft
- Axle shaft.
- Spindle shaft.

1.3 Critical Speed of Shafts

All rotating shafts, even within the absence of external load, will deflect during rotation. The unbalanced mass of the rotating item reasons deflection so that it will create resonant vibration at positive speeds, known as the crucial speeds. The significance of deflection relies upon the following:

- Stiffness
- Total mass
- Unbalance of the mass
- Damping in the system

1.4 Materials Used

The material used for everyday shafts is slight steel. When excessive energy is needed, an alloy metal along with nickel, nickel-chromium or chromium-vanadium metal is used. Shafts are usually fashioned via warm rolling and finished to size by way of cold drawing or turning and grinding.

1.5 Damping

Damping is an influence within or upon an oscillatory machine that has the effect of decreasing or preventing its oscillation. In physical systems, damping is produced by approaches that deplete the power saved within the oscillation. Examples consist of viscous drag in mechanical systems, resistance in digital oscillators, and absorption and scattering of mild in optical oscillators.

1.6 Natural Frequency

Natural frequency, additionally referred to as Eigen frequency, is the frequency at which a system has a tendency to oscillate inside the absence of any driving or damping pressure. The motion sample of a machine oscillating at its herbal frequency is called the regular mode (if all components of the system move sinusoidally with that equal frequency).

1.7 Gyroscopic Effect

Gyroscopic impact is ability (tendency) of the rotating frame to hold a consistent route of its axis of rotation. The gyroscopes are rotating with recognize to the axis of symmetry at high velocity.

1.8 Mass Imbalance of Rotating Shaft

it is determined that the effect is forward whirling and when masses whirl at unbalanced condition then this effect is known as backward whirling, a synchronous speed line that passes by intersecting backward whirling and forward whirling frequency determines critical speed due to mass imbalance of rotating shaft.

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II. FINITE ELEMENT METHOD

The finite element method (FEM) is an extensively used approach for numerically solving differential equations springing up in engineering and mathematical modeling. Typical trouble regions of hobby consist of the conventional fields of structural evaluation, heat transfer, fluid drift, mass delivery, and electromagnetic ability. The FEM is a trendy numerical technique for fixing partial differential equations in two or 3 area variables (i.e., some boundary cost problems). To solve a problem, the FEM subdivides a massive device into smaller, less difficult components which might be called finite elements. This is finished by way of a particular space discretization inside the area dimensions that is implemented by means of the construction of a mesh of the item: the numerical domain for the answer, which has a finite variety of points. The finite element method of a boundary price problem subsequently consequences in a gadget of algebraic equations. The method approximates the unknown function over the area. The easy equations that model those finite factors are then assembled into a larger machine of equations that models the entire trouble. The FEM then uses variational methods from the calculus of versions to approximate an answer by using minimizing associated errors characteristic.

2.1 Advantage of FEM

- Nonlinear issues simply solved.
- Easy formulations enable many various varieties of drawback to be solved.
- Advantages of the finite component methodology over area unit as follows.
- The methodology is often used for any irregular-shaped domain and every one varieties of boundary conditions.
- Domains consisting of over one material are often analyzed.
- Accuracy of the answer are often improved either by correct refinement of the mesh or by selecting approximation of upper degree polynomials.

2.2 Basic Steps to Perform Finite Element Analysis

2.2.1 Preprocessing

- **CAD Modeling-** In CAD modeling a computer aided designing is done by using UNIGRAPHICS, CREO and CATIA software’s in this a model was created for simulation and to fulfill the necessity of boundary condition in CAD modeling we can create a model as per research methodology of research papers or an experimental setup.
- **Meshing-** It is a group of nodes and elements and seems in a form of grids it could be in many shapes like; Triangular shaped, square shaped, hexagonal shape etc.
- **Defining Material Properties –** In case of different material simulation material properties could be varied and material should also changed as per requirement.
- **Mesh Size-**Sizing of meshing should be defined like mesh size i.e. component edge length and No. of divisions to generate the mesh.
- **Defining Boundary Condition-**In this step a rotational velocity, bearing constraints was defined for finite element analysis.

2.2.3 Post processing

- **Solve-** In this step a preprocessing step is solved to determine convergence values for solution.
- **Results –** In this step the results are often viewed in numerous formats; graph, values, animation etc.

III. MODELING & SIMULATION

3.1 Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

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3.1.1 CAD Model

Table No.:1 Dimension of Shaft.

Length of shaft.	1000mm
Diameter	100mm
Diameter of shaft 1	70-100mm
Diameter of shaft 2	80-100mm
Mass of Flywheel 1	14.58 Kg
Mass of Flywheel 2	45.94 Kg
Mass of Flywheel 3	55.13 Kg
Bearing Contact with Shaft	Revolute Joint

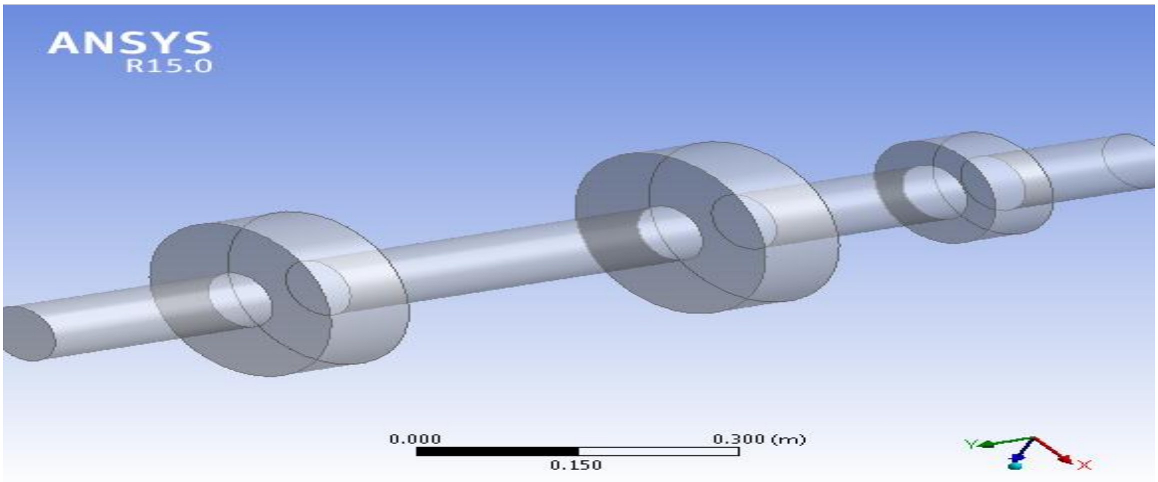

Figure No.: 1 CAD Model of constant diameter Shaft

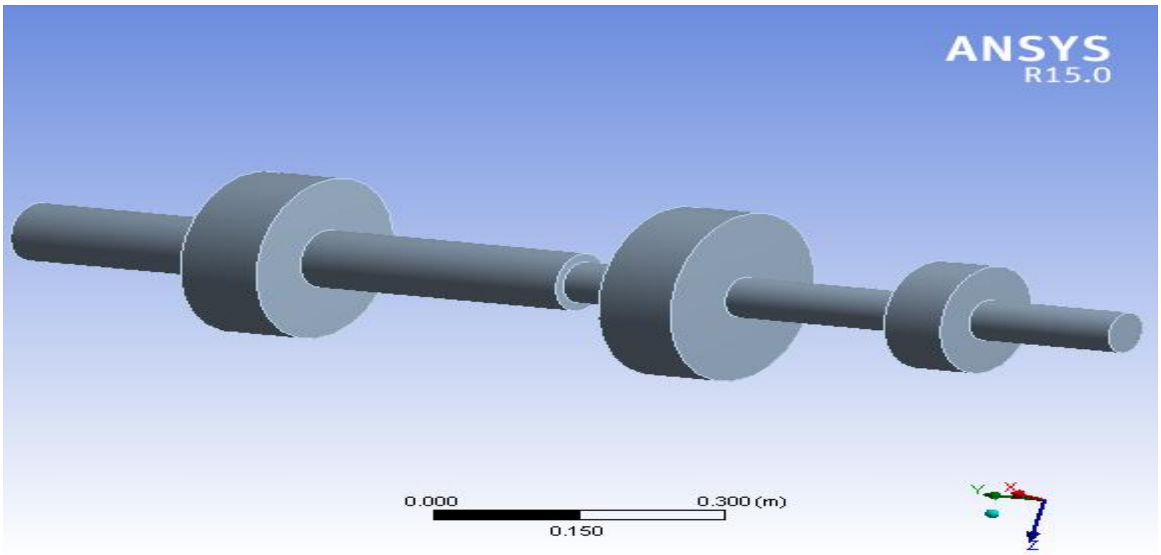

Figure No.: 2: CAD Model of Shaft1

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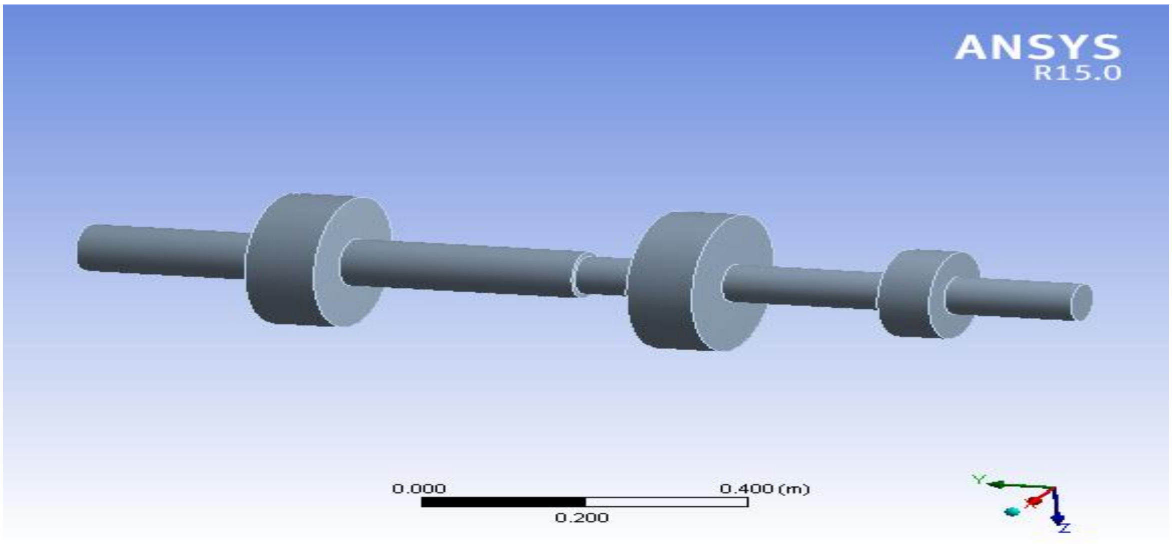

Figure No.: 3: CAD Model of Shaft2

3.1.2 Meshing

The group of nodes and elements is known as meshing this process is done to determine convergence of solution the phenomenon convergence of solution is a relation between accuracy, degree of freedom and no. of nodes and elements as the quantity of nodes and elements are increased at variable iteration a convergence of solution is obtained. Meshing are of different types i.e. Tetrahedral, Quadrahedral, Hexahedral, Square mesh and triangular mesh, tetrahedral mesh gives better convergence during finite element simulation a stiffness matrix, damping matrix, stress matrix is solved on ANSYS at each and every node and element by iteration methods like runge-kutta etc. to determine convergence of solution.

3.1.3 Meshing data for diameter 70-100

NODES	1347
ELEMENTS	668

3.1.4 Meshing data for diameter 80-100

NODES	1163
ELEMENTS	556

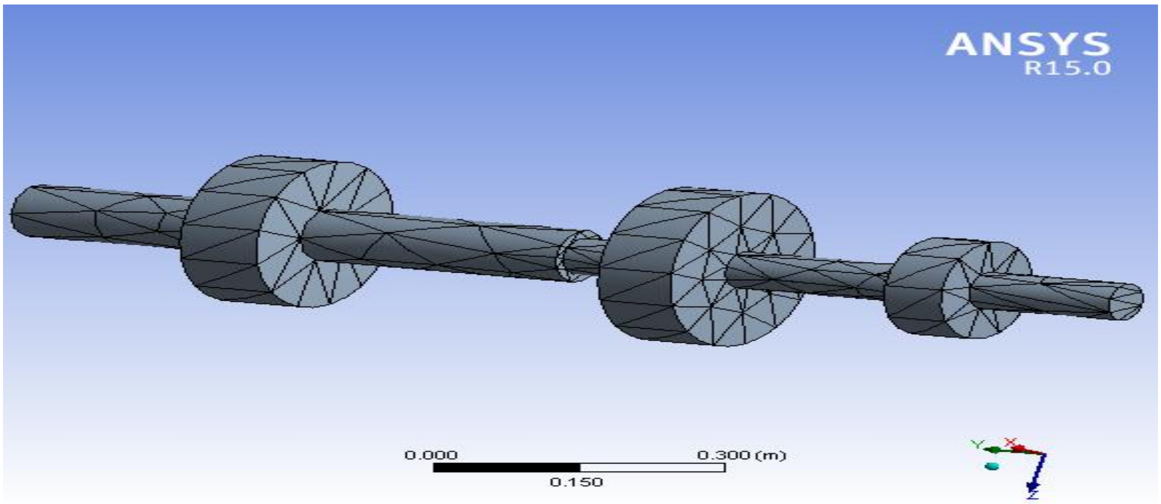

Figure No.: 4Mesh domain of Shaft1

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Impact Factor : 4.256

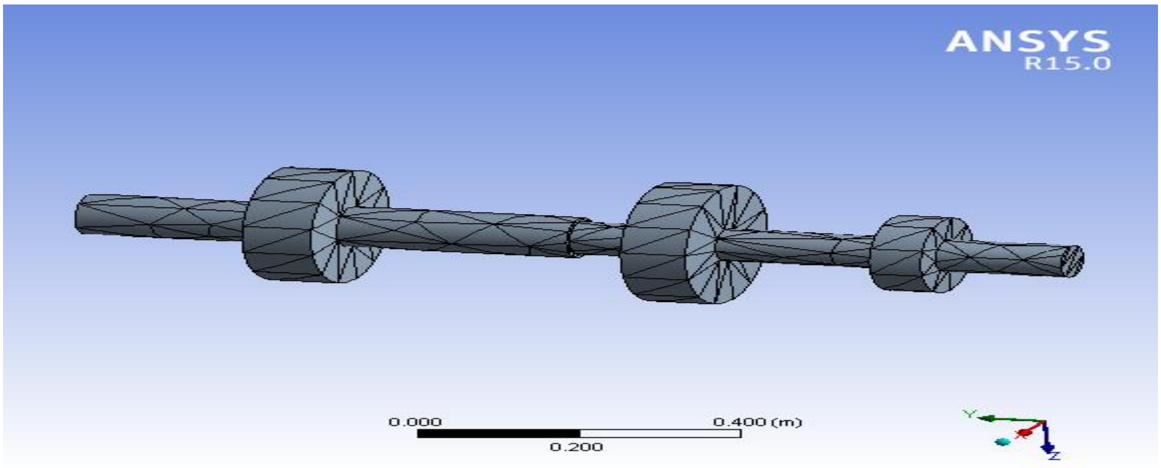

Figure No.: 5Mesh domain of Shaft2

3.2 Boundary condition and Loading

The boundary conditions applied to the finite element model is as follows.

- The Bearing support parallel to the cross-section of shaft.
- Angular velocity of 3000 rad/s is applied on the cross section shaft.

Table No.: 2 Properties of different a material.

Material Properties	Gray Cast Iron	Stainless Steel	Structural Steel	Titanium Alloy
Young's Modulus	1.1e11	1.93e11	2e11	9.6e11
Poisson's Ratio	0.28	0.31	0.3	0.36
Density	7200kg/m^3	7750kg/m^3	7850kg/m^3	4620 kg/m^3

3.3 Problem Formulation

The study of various literatures we find the natural frequency is lower as compared to present study. The purpose of this study is to predict critical speed and natural frequency with different material and decrease in the shaft diameter at constant angular velocity of 3000 rad/s. Thus chosen 70-100 mm, 80-100 mm profiled shaft for analysis.

3.4 Solution

In this step victimization finite component technique by ANSYS 15.0 to solve the matter for the outlined material properties, boundaries conditions and mesh size.

3.5 Post-Processing

For viewing and interpretation of results of on top of solved downside. The result will be viewed in numerous formats graph, value, animation etc.

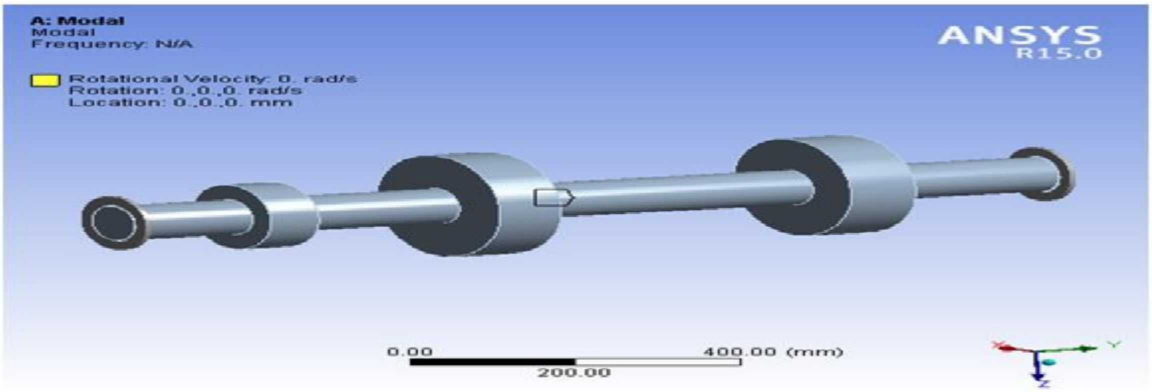

Figure No.: 6 CAD model of Shaft with boundary condition.

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Impact Factor : 4.256

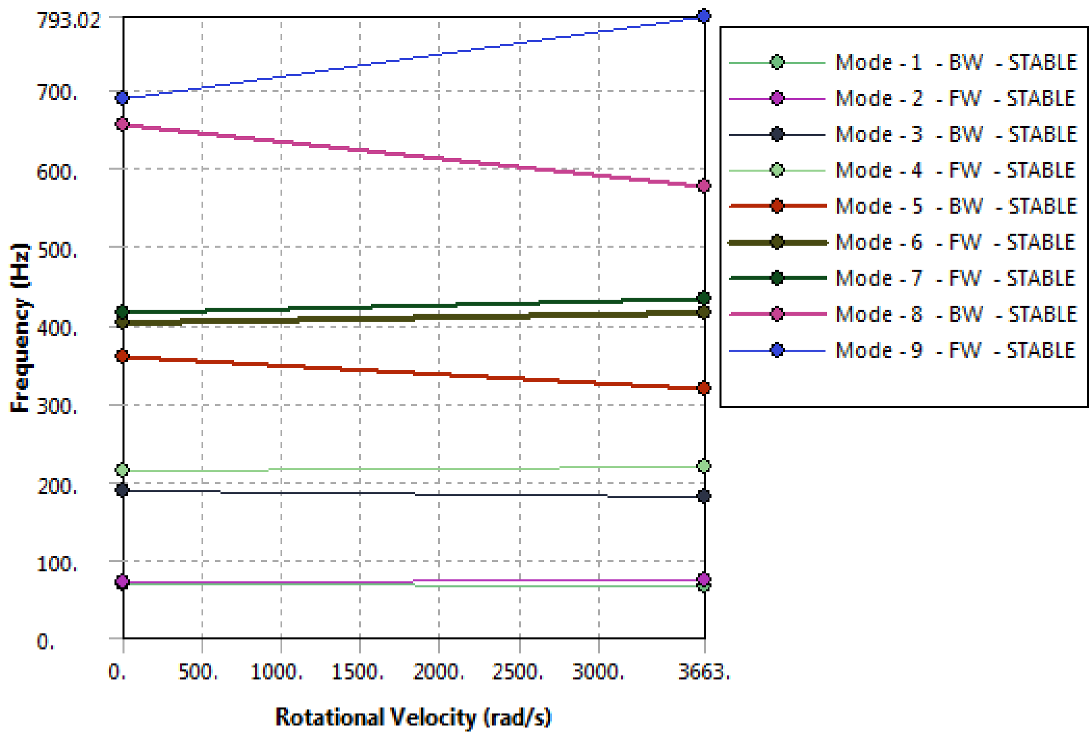

Figure No.: 7 Validation of Frequency and rotational velocity Distributions along the Shaft by Campbell diagram.

Above graph shows the validation result of Campbell diagram with experimental Campbell diagram result of base paper we found that above graph shows convergence with base paper graph, Hence our study is validated.

Table No. 3 Validation of Shaft with reference to Base paper.

Mode	Whirl Direction	Mode Stability	0. rad/s	3000. rad/s
1	BW	STABLE	68.144 Hz	65.702 Hz
2	FW	STABLE	71.982 Hz	74.023 Hz
3	BW	STABLE	188.93 Hz	181.47 Hz
4	FW	STABLE	213.53 Hz	219.3 Hz
5	BW	STABLE	360.47 Hz	318.74 Hz
6	FW	STABLE	402.89 Hz	416.19 Hz
7	FW	STABLE	416.1 Hz	434.35 Hz
8	BW	STABLE	655.9 Hz	575.43 Hz
9	FW	STABLE	689.4 Hz	793.02 Hz

In this analysis validation is done by using structural steel material and frequency vs. rpm relation was plotted on Campbell diagram at constant angular velocity of 3000 rad/s the convergence values are near to base paper Campbell diagram.

IV. Results and Discussion

4.1 Critical Speed and Frequency along the Shaft with Different Diameter and Materials

A Modal - analysis was carried out to analyze critical speed of shaft with different material and diameter by using Campbell diagram and relation between natural frequency and spin speed and a four types of materials of gray cast iron, stainless steel, structural steel and titanium alloy with different diameter to determine the frequency distribution along the Shaft of the different diameter. Frequency distribution contours in case of different diameter for the two different profiles are shown in Figure, and the effect of different shaft profiles on the frequency and modes

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distribution for various different diameter and materials are represented in the Figure.

4.1.1 Analysis of Shaft with Constant Diameter and Different Materials

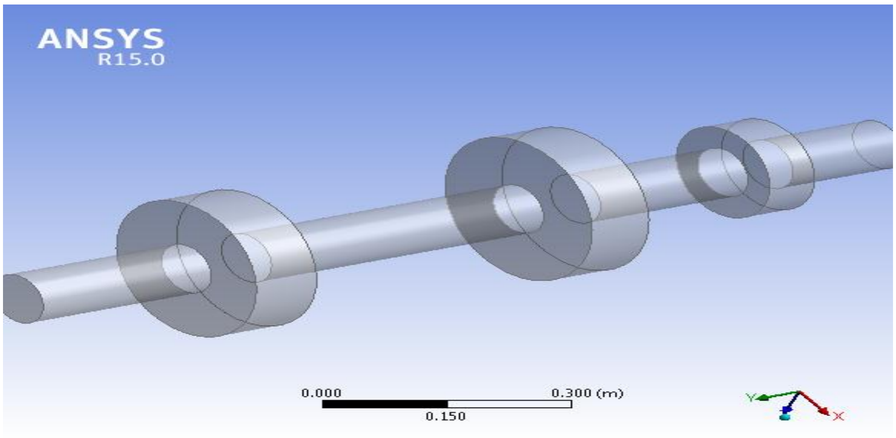

Figure No.: 8 CAD model of Shaft with constant diameter.

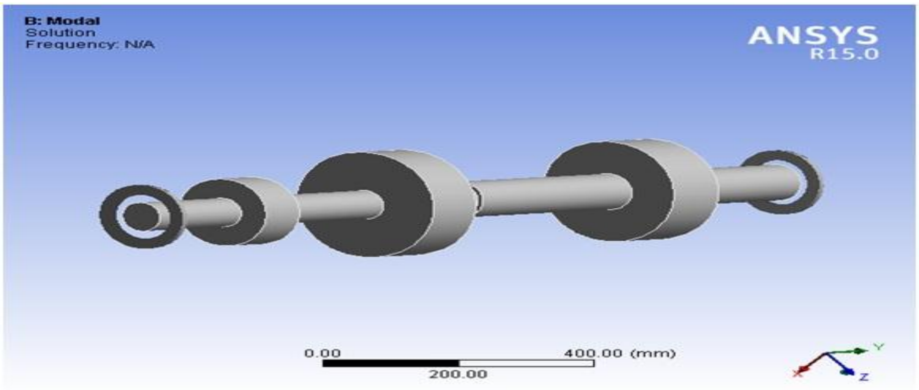

Figure No.: 9 Boundary condition model of Shaft

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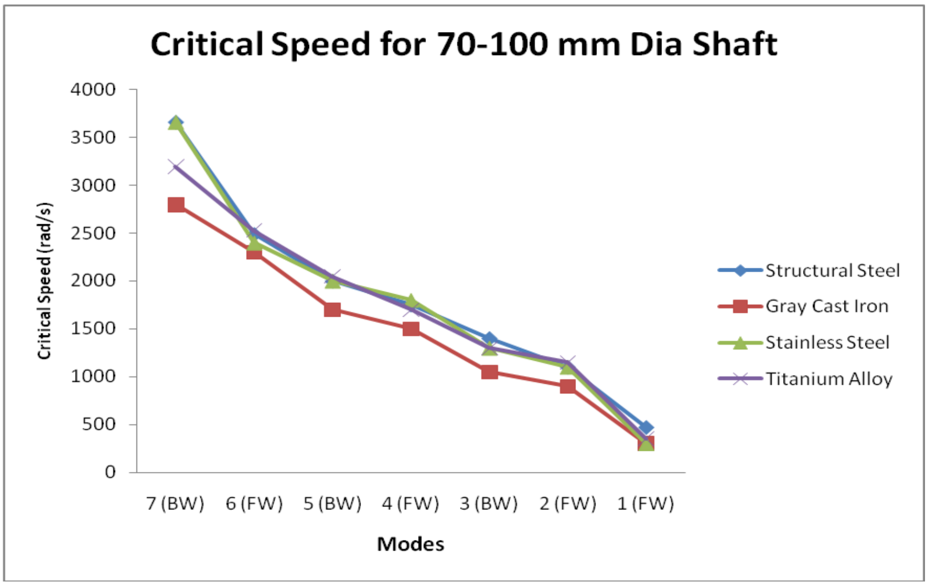

Figure No.:10 Graph shows modes and critical speed of a shaft with variable diameter 70-100 and different material.

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The above table shows the critical speed values of four materials with respect to modes on stepped shaft 80 mm-100 mm diameter, gray cast iron have less critical speed due to its high stiffness and lesser deformation at different whirling modes.

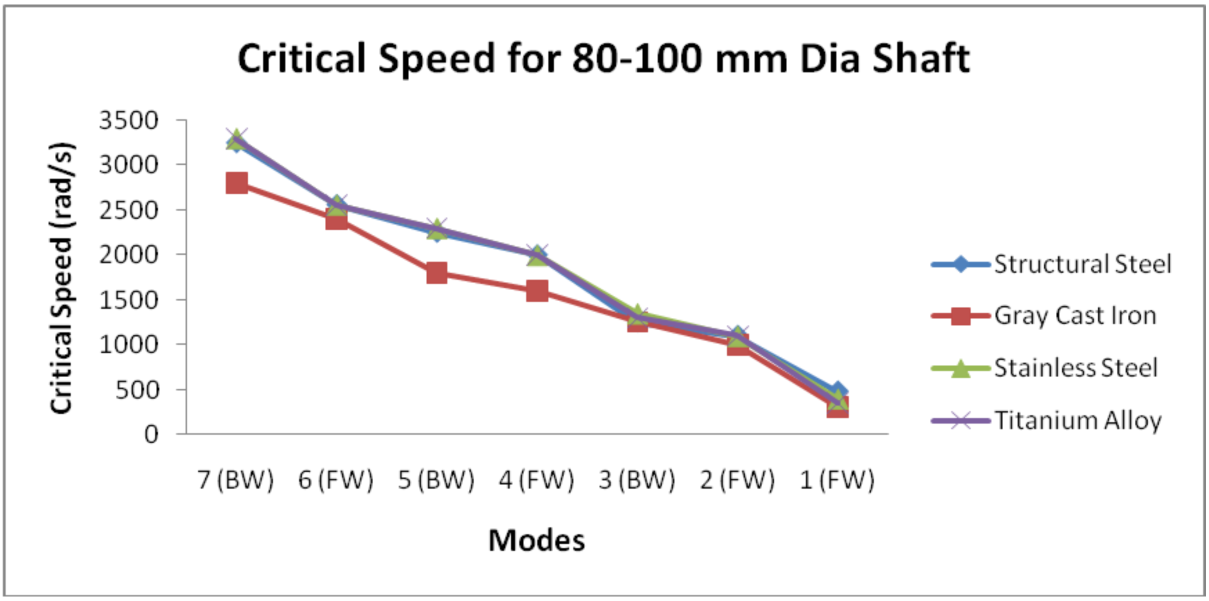

Figure No.:11 Graph shows modes and critical speed of a shaft with variable diameter 80-100 and different material

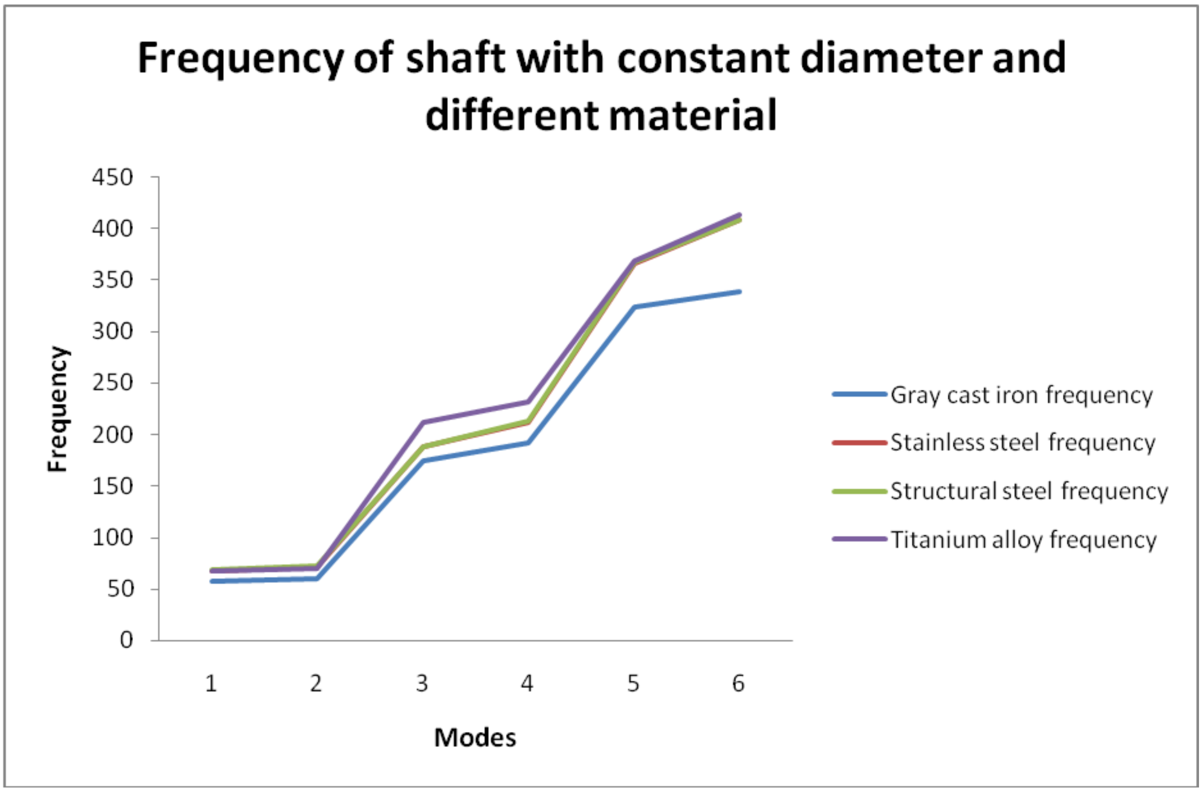

Figure No.: 12 Graph shows modes and frequency of a shaft with constant diameter and different material.

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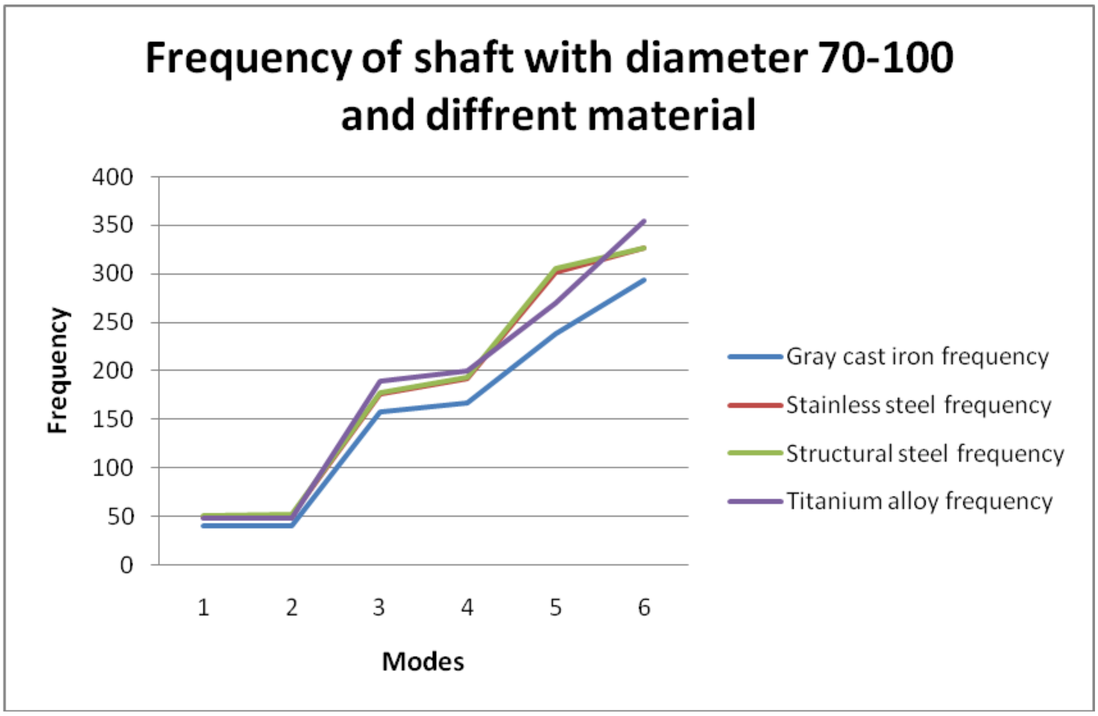

Figure No.: 15 Graph shows modes and frequency of a shaft with variable diameter 70-100 and different material

Above contour plots shows total deformation of shaft at sixth mode of frequency 318.81 the deformation value varies between 0.00076875mm (minimum) to 0.18165mm (maximum), the red zone area at end of the shaft shows maximum deformation.

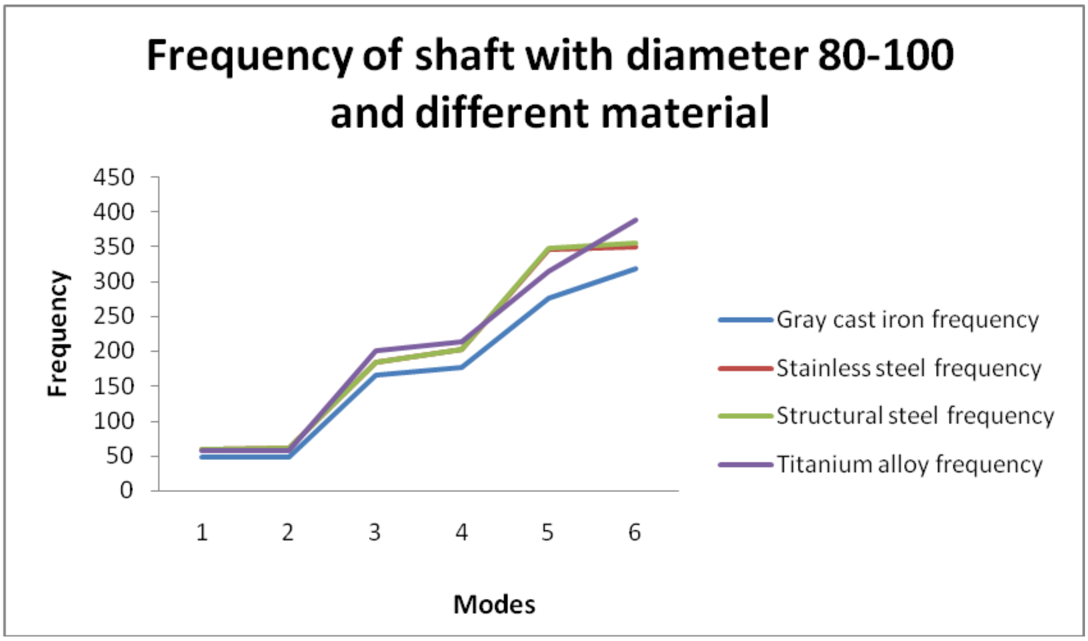

Figure No.: 14 Graph shows modes and frequency of a shaft with variable diameter 80-100 and different material.

The above table& graph shows the natural frequency values of four materials with respect to modes on stepped shaft 80 mm-100 mm diameter, all four materials were compared with respect to their modes.

ISSN : 2455-9679
Impact Factor : 4.256

V. CONCLUSION

5.1 Influence of different shaft profiles

- The natural frequency along the shaft profile is found to be maximum for the titanium alloy material profile with shaft diameter 80-100 mm and 70-100 mm and varies along the length up to the shaft for all the two profiles. The critical speed distribution along the shaft is maximum for structural steel and minimum for gray cast iron of a shaft with different profiles.
- The magnitude of frequency is minimum in the case of gray cast iron material profile with diameter 80-100 mm and 70-100 mm. The nature of the natural frequency is maximum near its end in 3^{rd} and 4^{th},6^{th} mode.
- The nature of the critical speed is maximum near its masses and between the end of the shaft where masses are placed of shaft and changes with respect to shaft material with different profile towards the end and between masses of the shaft for the same RPM and different modes of natural frequency.
- In a comparison with the gray cast iron, stainless steel, structural steel and titanium alloy material resulted in higher frequency characteristics close to the end of the shaft for a different shaft diameter profile. The critical speeds are maximum for structural steel at high frequency and minimum for gray cast iron at less frequency on same RPM

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