International Journal of Scientific Research and Engineering Development-– Volume 6 Issue 1, Jan-Feb 2023

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Study on Effect of Vibration on Different Materials Shaft of Steam Turbine by using Ansys

Dr. Rajeev Arya[1], Rajeev Kumar Roshan[2], Ishan Khan[3]

[1]Director, NIIST, Bhopal

[2]Research Scholar Master of Technology (MD&R)Department of Mechanical Engineering, NIIST, Bhopal

[3]Assistant Professor Department of Mechanical Engineering, NIIST, Bhopal

Abstract:

Brakes are the main control system of industrial machineries and automobiles and used to slow down any moving or rotating component by means of friction between their moving and rotating parts. This friction cause heat generation in relative components and sometime it is responsible for failure of that components. In present automobiles basically two types of brakes used i.e. drum brakes and disc brakes. As disc brake has some advantages over drum brakes, it has some limitations too. The cooling characteristics of disc brake rotor are the subject of research. An attempt is made to improve effectiveness of cooling characteristics in this study.

In the present study some existing rotor geometry with ventilated flow passage between their mating surfaces has been analyzed and some modifications are done to obtain more heat dissipation. The heat generated while braking is stored in brake disc rotor and dissipated to surrounding mainly by forced convection. It is observed that heat transfer rate is increase with increase in mass flow rate. Effective design with large flow passage can improve the mass flow rate as well as heat transfer rate. In order to achieve more effectiveness different types of disc brake rotor configurations analyzed such as such as tapered radial vane, straight radial vane, Circular pillared rotor and variable diameter circular pillared rotor. ANSYS based code is used for simulation and is validate from previous experimental work. The obtained data from simulations for heat transfer and mass flow through the ventilated passage is compared with experimental data. It is observed that VDCP rotor gives the better cooling effect on disc brake rotor by means of uniform distribution of temperature and fluid flow. Two modifications have been done in VDCP by changing their diameters and named as VDCP1 and VDCP2. The coefficient of heat transfer for VDCP1 is found 24.6 % greater than VDCP1 and 20-30% than others. Pillared rotor can be used bi-directionally that is why it may more appropriate to use in high-speed vehicles than others.

Keywords: *Ansys, Ventilated Disc Brake Rotor, Mass flow rate, Heat Flux, Heat Transfer*

1. Introduction:

Shaft is a component for conveying mechanical energy, torque, and rotation, and is commonly used to link separate components of a drive train that cannot be connected without delay due to distance or the necessity to allow for relative movement between them. Drive shafts, as torque carriers, are subject to torsion and shear stress, which is proportional to the difference between the input torque and the load. They must consequently be strong enough to withstand the pressure while avoiding gaining too much weight, which would increase their inertia. Force shafts frequently have one or more common joints, jaw couplings, or rag joints, and occasionally a splined joint, to allow for changes in the alignment and distance between the riding and driven components.

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.As shown in figure 1.

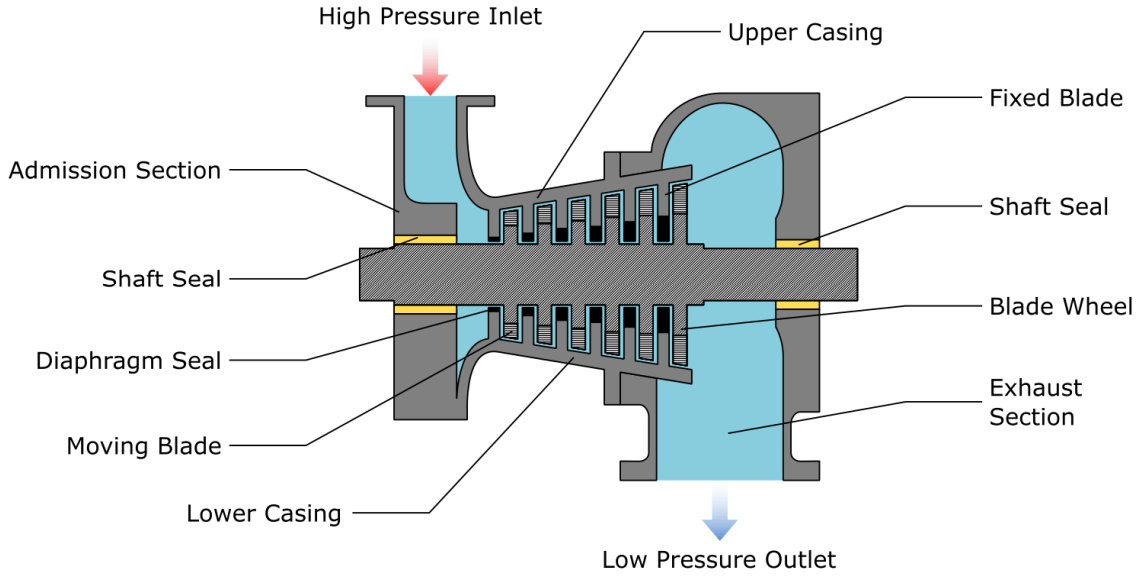


Fig.1 A Simple Steam Turbine Shaft

Shafts for common usage are made of mild steel. When a large amount of energy is required, an alloy metal including nickel, nickel-chromium, or chromium-vanadium metal is utilized. Shafts are usually fashioned via warm rolling and finished to size by way of cold drawing or turning and grinding.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.

Natural frequency, additionally referred to as Eigen frequency, is the frequency at which a system tends 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). 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. 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.

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.Literature Review:

Chun-Ping Zouet al. (2002) - This paper proposes a modal synthesis method of lateral vibration analysis for such type of rotor-bearing device. When the proposed method is evolved, the elastic

coupling unit is defined as ‘‘flexible substructure’ that's handled for my part and the alternative parts are partitioned into some substructures which are analyzed by finite element method.**[1]**

S.P. Harsha et al. (2003) -The paper offers with the structural dynamic response of rotor supported by ball bearings. The mathematical model takes into account the assets of nonlinearity together with Hertzian touch pressure, surface waviness, varying compliance and internal radial clearance resulting transition from no contact to touch state among rolling elements and races. In phrases of the function that the nonlinear bearing forces act on the machine, a brand-new discount method and corresponding integration method is used to increase the numerical stability and lower laptop time for system analysis.**[2]**

Erik Swanson (2005) - The purpose of this article is to present a sensible understanding of terminology and conduct based in visualizing how a shaft vibrates, and examining problems that affect vibration. It is hoping that this presentation will assist the non-specialist better apprehend what goes on within the machinery, and that the specialist may gain a unique view and/or a few new examples. **[3]**

F. C. Nelson et al. (2007) - The analysis of the lateral and tensional motion of spinning rotors is replete with packages of Newton's and Euler's equations. Sometimes the intricacies of these equations overshadow their less difficult bodily meaning. This paper tries to make amends for this by means of explaining the dynamic conduct of spinning rotors without writing any equations.**[4]**

Keyu Qi et al. (2008) - The single mode responses can be obtained via HWF and then RDT technique is employed to manner those responses, respectively, to extract single mode free responses of the rotor structures. Finally, HT approach is implemented to attain modal parameters of the rotor systems from those unmarried mode loose responses. The experimental effects of the proposed technique are close to those of the finite element method which suggests that the proposed method is effective in practical programs.**[5]**

Keyu Qi et al. (2009) - this investigation disturbs relate degree pivot symmetric flexible rotor worked up by dissipative, moderate and non-preservationist point powers started at the contact with the aeolotropic stator loop. The Campbell graph of the unruffled framework could be a work like structure inside the frequency speed plane with twofold physicist frequencies at the hubs.**[6]**

R. Whalley et al. (2009) -The response of the device for precise shaft–rotor dimensions and rotational speeds is determined, establishing the dynamic traits inside the place of the whirling pace. A cantilevered shaft–rotor machine with an exponential – sinusoidal profile is investigated for

purposes of illustration. The flexibility of the method and the general applicability of the method proposed are emphasized.**[7]**

R. Whalley et al. (2009)-The multivariable irrational, hyperbolic and circular characteristic, input–output dating for the system, is derived. Arbitrary, geometrical shaft profiling may be accommodated within the analytical strategies mentioned. Conventional frequency response methods are employed in the dedication of the critical speed condition. Specific studies, incorporating cantilevered rotors with non-linear shaft duration–diameter configurations are exact. The widespread applicability of the procedures outlined is emphasized.**[8]**

S.A.A. Hosseini et al. (2009) - The outcomes of mass second of inertia, eccentricity and outside damping coefficient are investigated on the constant nation reaction of the rotating shaft. The loci of saddle node bifurcation points are plotted as features of damping coefficient and eccentricity. Results of perturbation method are demonstrated with numerical simulations.**[9]**

Mohammad HadiJalali et al. (2014) - In this paper, full dynamic evaluation of a high velocity rotor with certain geometrical and mechanical houses is carried out the use of 3D finite detail model, one-dimensional beam-kind model and experimental modal take a look at. Good agreement among the theoretical and experimental effects shows the accuracy of the finite element method. The Campbell diagram, essential speeds, operational deflection shapes, and unbalance response of the rotor are acquired that allows you to completely look into the dynamic conduct of the rotating system.**[10]**

Ma Jing-min et al. (2015) -The numerical results calculated by Galerkin method are analyzed to indicate the consequences of ply perspective, taper ratio, and transverse shear deformation on the first herbal frequency and essential rotating pace. The outcomes are in comparison with those received by means of the use of finite element package ANSYS and to be had within the literature the usage of different method.**[11]**

Rohit Tamrakaret al. (2015) -This paper offers with the study of whirling of shaft with 3 rotors. Natural frequency of the system is found with the aid of effect hammer look at accompanied by way of figuring out the speed at which whirling happens in the gadget. Experimental consequences had been demonstrated through using Dunkerley's method for natural frequency. Rayleigh-Ritz equation is used to find out the essential velocity of the shaft and for this reason to validate with experimental result.**[12]**

Piotret al. (2015) - The fundamental intention of this paper is to show dynamic conduct of carbon fiber power shaft. In the paper, authors confirmed the impact of passing shaft resonance (1st critical

speed). The effect of a shaft passage thru crucial kingdom underneath conditions of acceleration and deceleration was shown. The fundamental conclusion of the research is the need of considering an influence of adjustments rate on the traits of the composite shape elasticity.**[13]**

O. N. kirillov (2015)– The singularities join the issues of wave propagation within the rotating continua with that of electromagnetic and acoustic wave propagation in non-rotating anisotropic chiral media. As mechanical examples a model of a rotating shaft with two ranges of freedom and a continuous version of a rotating circular string passing through the eyelet are studied in detail.**[14]**

XujunLyuet al. (2016) - In this paper to emulate the operation of such flywheels on a rotor-AMB take a look at rig we recently constructed. Specifically, the 2 AMBs placed at the 2 ends of the rotor are used as supporting bearings, while the other two placed at the rotor mid span and quarter span are used to emulate the generator negative stiffness and gyroscopic results on the rotor dynamics caused by the flywheel disk. Simulation and experimental outcomes are supplied to expose the effectiveness of the proposed emulation method.**[15]**

I Crâştiuet al. (2017) - The purpose of this paper is the development and validation of an impulse excitation method to determine flexural important speeds of a single rotor shaft and multy-rotor shaft. The experimental size of the vibroacoustic response is done through the use of a condenser microphone as a transducer.**[16]**

I Geoneaet al. (2018) - In this paper it's presented the theoretical, experimental and numerical simulation of important pace for proper shafts. For this reason, its miles designed a digital version of a test bench for shaft essential speed analysis. The studied shaft is established on bearings and on the middle it has set up a heavy disc.**[17]**

Suhas S. Jadhav et al. (2019) - Present paper deals with theoretical study of crucial pace of shaft wearing single rotor. Every item has its very own frequency, known as as natural frequency. The measurement of this vital velocity and related whirling movement is one of the critical troubles to be addressed with the aid of a layout and protection engineer.**[17]**

A. M. A. Wahab et al. (2019) - It was found that the effect of torsional degree of freedom on the whirling frequency behaviour is significant especially for shaft at high speed where at the spin speed of 20000 RPM, the difference between the whirling frequencies corresponds to FEM model that considers tensional degree of freedom and model that does not consider can be as high as 45.3%.**[18]**

The preceding literatures represent an investigation of experimental and simulation of shafts, which demonstrates that critical speed is a major issue for shaft failure. Thus, in our current analysis, critical

speed is analysed for different materials and profiles of shaft to determine and optimise the effect of critical speed of shaft and its vibration at working conditions.

Problem Statement– In present analysis study of shaft is done on critical speed and their natural frequency from above literature we found that on solid shaft types of vibration analysis were performed by analytically, numerically as well as experimental approach, we found that vibration and amplitude occurred during rotation of shaft is major issue by selecting the research paper of Dumitru et.al. We generated finite element model in ANSYS and solved on same parameter as per base paper values of damped natural frequency and spin speed for validation, after validation of base paper we optimized shaft by using stepped shaft in place of solid shaft used in base paper as well as four types of material were also used on optimized shaft on ANSYS simulation and critical speed was determined by simulating on these optimized parameters we found that gray cast iron gives less critical speed on stepped shaft and different masses mounted on it, Hence gray cast iron shaft could be used on gear shaft.

Objective of the Work

The main objective of the current work is

1. Validation of the ANSYS models by comparing the present simulated results with the experimental result.
2. To predict natural frequency and critical speed effects for different shaft diameter (70-100 and 80-100 mm diameter) on the shaft.
3. To simulate the shaft of the different material having different diameter for variable modes and same RPM.
4. To define natural frequency effects and critical speed effects for the shaft of different diameter profile and different material and constant angular velocity of 3000rad/s.
5. To predict frequency distribution along the shaft.

3. Proposed Methodology:

In order to increase brake efficiency, thermal behaviour of disc brake rotor studied on different parameters. Different flow passage vane configurations were considered for analysis of disc brake. A particular disc brake design was used in simulation to describe a method for calculating the rate of mass flow and the rate of heat dissipation of rotor at different speeds.The heat transfer coefficient was determined using FEM, temperature distributions and rate of mass flow in the flow field of the rotor passage. FEM results were compared with previous experimental work for validation. The previous

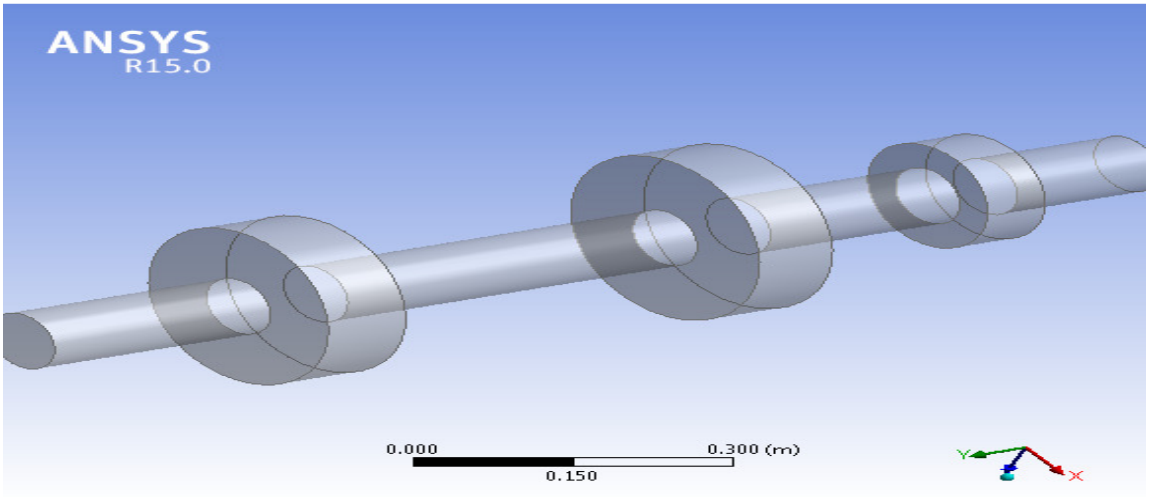
experimental results of different researchers however provide a relative idea of actual performance and give it as a critical validation tool for numerical analysis.Principles of Finite Element Method. The basic idea of FEM is to discretize the domain of interest, where the PDE is defined, in order to obtain an approximate solution of the PDE by a linear combination of basic functions defined within each subdomain.

4. Result and Discussion:

Reprocessing include CAD model, meshing and defining boundary conditions. As shown in figure 2.

Table. 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



6.*Figure No.: 2 CAD Model of constant diameter Shaft*

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 is 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.

Meshing data for diameter 70-100

NODES	1347
ELEMENTS	668

Meshing data for diameter 80-100

NODES	1163
ELEMENTS	556

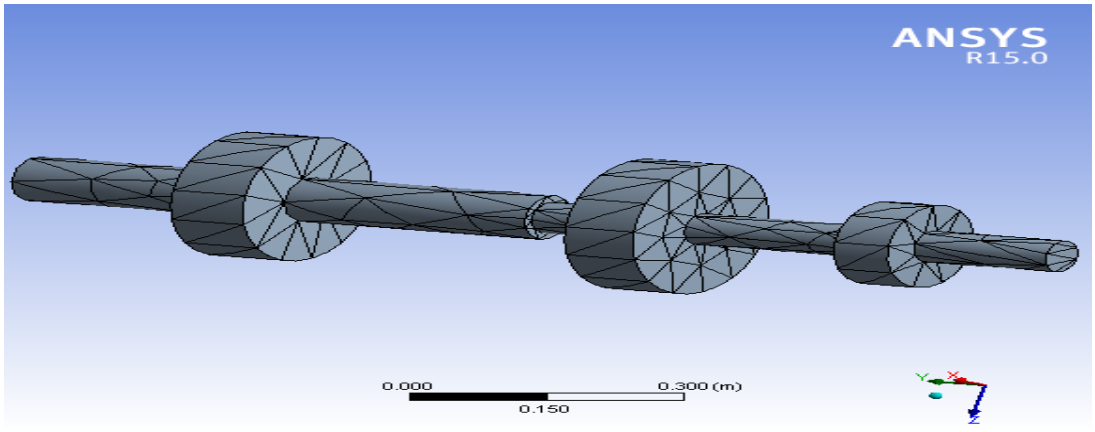


Figure No.:3 Mesh domain of Shaft1

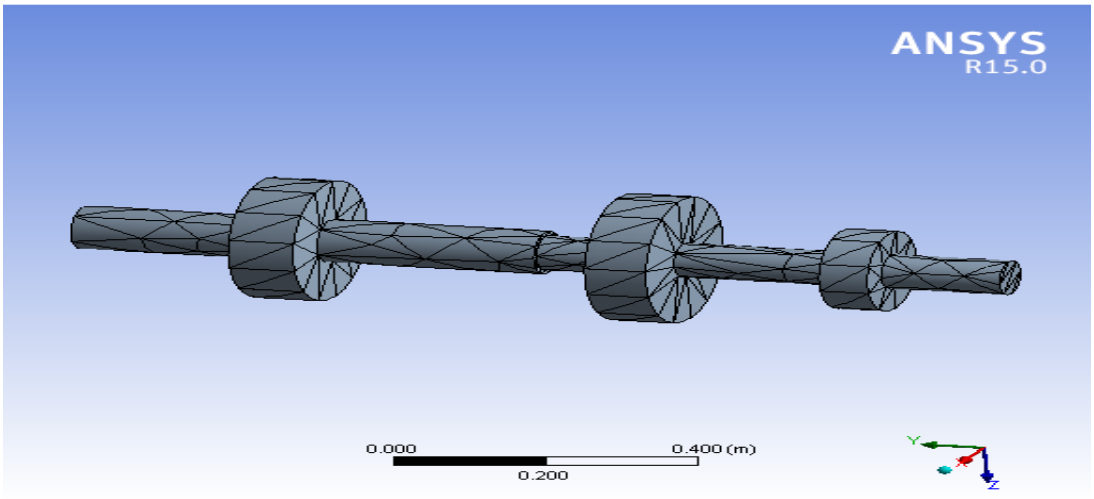


Figure No.:4 Mesh domain of Shaft2

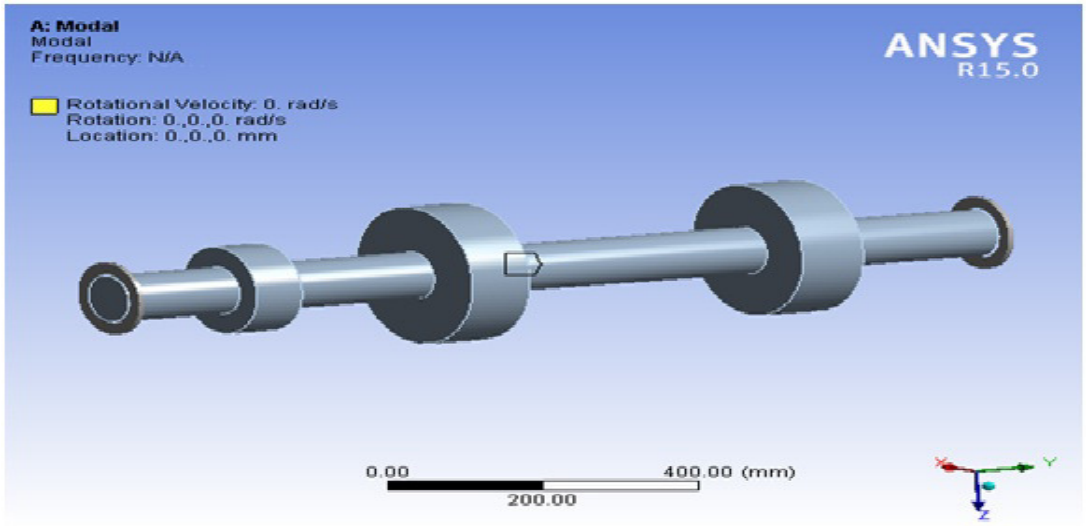
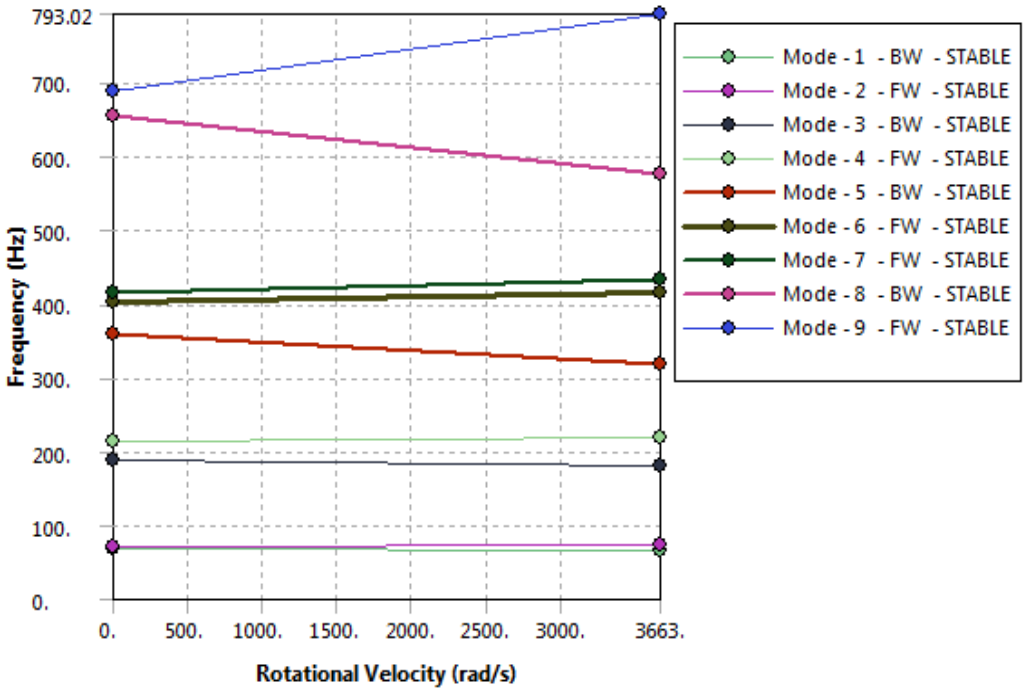


Figure No.: 5 CAD model of Shaft with boundary condition.



Conclusion:

The current analysis presents a study of natural frequency characteristics of a shaft of different profiles. The modal analysis was carried out on Gray cast iron, Stainless steel, Structural steel and Titanium alloy system.

The effect of diameter with different profiles of the Shaft with diameter 70-100 mm and 80-100 mm on the natural frequency and modes of different materials and critical speed effects were analyzed on different profile and materials of shaft and distribution along the shaft was studied. From the analysis of the results, following conclusions can be drawn.

- 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.

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