Strength Analysis and Optimization of Orbital Welding Parameters

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Abstract -This thesis work reports on the modeling and also the experimental identification of a high speed rotor-magnetic bearing test rig. Associate correct nominal model and an uncertainty illustration are developed for sturdy controller synthesis and analysis. A mixture of analytical modeling, model change or modify, and identification is utilized for every system part and for the system as a full. This approach takes advantage of each the behavior modeling and input/output modeling ways. Analytical models of the rotor and also the magnetic bearings are initial developed from physical laws and refined by comparison with the experimental information. The substructure model is directly identified from the experimental information by a structured identification approach. Models of the electronic systems, like the filters, amplifiers, sensors, and digital controller, are developed through experimental identification. These part models are then assembled to get the general system model. Closed-loop tests are conducted to spot parameters within the model. Advanced control techniques supported Hx control and μ synthesis are developed and with success enforced on the test rig, which further validates the model.

I. INTRODUCTION

Flywheel energy storage systems are typical mechanical batteries. The kinetic energy is stored in a high speed rotating disk of the flywheel. This mechanical energy is converted back to electric energy by a generator, which is mounted on the same rotor as the flywheel disk. The stored energy for a flywheel system is proportional to the square of the rotational speed and also affected by the polar moment of inertia of the flywheel disk.

Modern flywheels operate at high rotational speeds to maximize the storage capacity, which results in a high demand on the bearing system for stability and performance. Conventional rolling element bearings, sliding bearings and hydraulic bearings are not adequate to meet such a demand. On the other hand, active magnetic bearings use magnetic forces to suspend the rotor, and the forces they produce can be actively controlled. Moreover, they possess appealing features such as no mechanical contact, no friction losses, no wear, high speed capability and clean operation. As a result, active magnetic bearings are ideal for supporting high speed flywheel rotors. Compared with rotors in many other applications, rotors in flywheel systems are highly complex. First, in an effort to minimize the overall size of the system, the flywheel disk and the generator are usually mounted on the same shaft, causing a coupling effect between the generator and the flywheel shaft. Second, unlike other applications where the ratio of polar-to-transverse moments of inertia is small and gyroscopic effects can be neglected, the large flywheel disk generates strong gyroscopic effects that have to be taken into account in the design of the AMB controller.

The flywheel is an energy storing device, which stores the energy in the form of kinetic energy. This component is helpful in all sorts of auto motives ranging from small vehicles to large earth movers. But for the efficient and optimum use of the flywheel in a required application focuses on the design criteria of the flywheel and the selection of material of the same.

The flywheels used in the earth movers are cumbersome and heavy and are required to withhold a large amount of kinetic energy for the working cycles. Hence the present review is focused on the selection of the most efficient design and selection of the material for the operation and maximum efficiency of the flywheel on the required application.

The survey focuses mainly to determine effective design and material for the flywheel that can help in storing the kinetic energy in the most efficient way possible.

Advantages

Four primary advantages of magnetic bearings are

1. High attainable rotating speed,
2. Low bearing power consumption,
3. No oil lubrication system requirement,
4. Very long life.

II. MODELING AND ANALYSIS

For the gray cast iron, stainless steel, structural steel and titanium alloy materials that we are interested in, the best possible geometry seems to be that of a thin cylinder. Under centrifugal loading, such a rotor is uniformly stressed in the circumferential direction, and completely unstressed in the radial direction. For this geometry, the energy density of a rotor is exactly one half of the strength-to-density ratio of its constituting material. This is still a very high value, and practical cylindrical rotors deviate from this ideal because they are rarely very thin in the radial direction. Thick rotors are desirable for practical applications because of the need to store some finite amount of energy. For this purpose the rotor not only needs a high energy density, but it also needs to be sufficiently massive.

Two factors tend to limit the energy density of practical cylindrical rotors:

Firstly, they experience non-uniform stress distributions in the circumferential direction.

This causes some stress concentration to limit the design and keep the rest of the rotor from becoming fully stressed.

Secondly, the rotors do experience stress in the radial direction, and even though the values of these stresses may be relatively low, they act in the material's weakest direction. Such stresses can cause a rotor to fail by delamination while it is still far from being fully stressed in the circumferential direction.

Steps for the Stress and Deflection Analysis

Stress and deflection analysis have been carried out by using ANSYS fem solver.

1. First of all the model i.e the rotor with notch and without notch are modelled using Creo software. The model is then saved in *.iges/*.igs format (iges stands for initial graphics exchange specification, which is a neutral data format file that helps in digital exchange of data among various CAD software).

2. This model is then imported to the ANSYS.

3. Meshing of the solid model is generated by using the meshing function of the ANSYS finite element solver package.

4. Then various boundary conditions are applied to the model and solved for stress and deflection.

Boundary Condition

The rotor is applied to the fixed to fixed support at the hub to restrict its motion along

any axis.

Load

(i) Centrifugal force is applied along Y-axis (Clockwise) to the rotor.

(ii) Earth gravity is applied about Y-axis in negative direction.

Analysis and Results Tetrahedron mesh

(i) Element type -3D solid element (Tetrahedron mesh)

(ii) Number of element- 5057

(iii) Number of nodes- 2497

Material used – gray cast iron, stainless steel, structural steel and titanium alloy

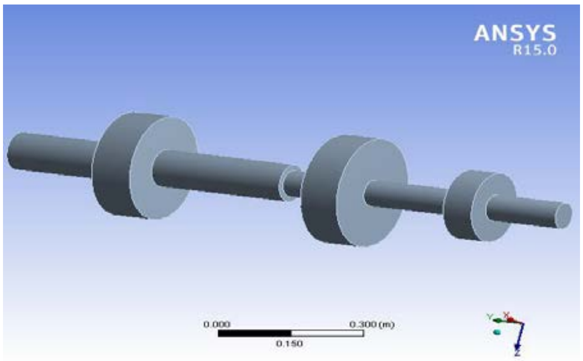
- *Loading*

(i) Centrifugal load is applied to the flywheel along Y-axis (Clockwise) having angular velocity ω = 3758.73 rad/s.

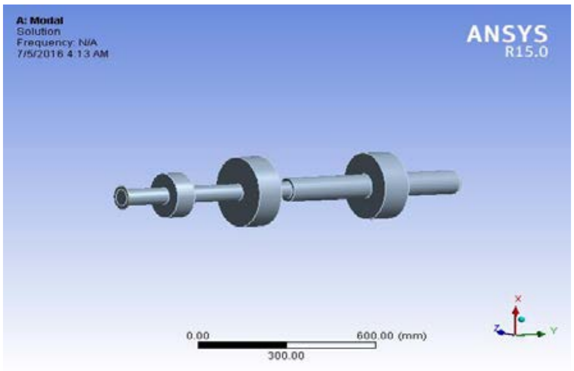
(ii) Earth gravity is applied about Y-axis, g= -9806.6 mm/s^2.

Critical Speed and Normal Stress along the Shaft with Different Diameter and Materials

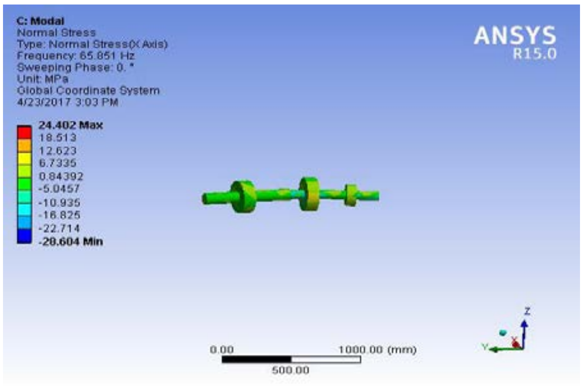
A Modal - analysis was carried out to analyze critical speed of shaft with different material and diameter by using Campbell diagram and relation between natural frequency and spin speed and a four types of materials of gray cast iron, stainless steel, structural steel and titanium alloy with different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



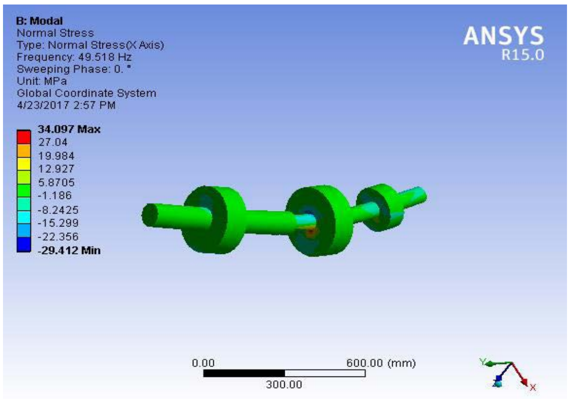
Shaft with Variable Diameter diameter (70-100) and Different Materials



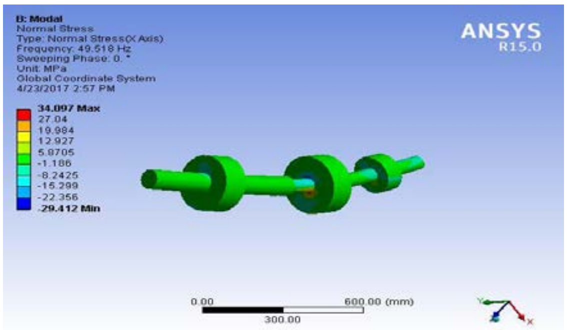
Analysis of Shaft with variable diameter (80-100) and Different Materials



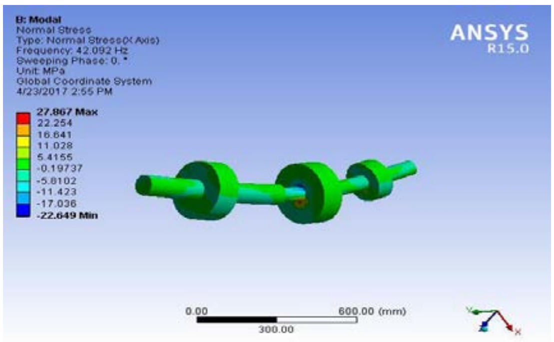
Stress of structural steel



Stress of stainless steel



Stress of Titanium alloy



Stress of Gray cast iron

Stress for (70-100)mm Diameter Shaft

Material	Stress
Structural steel	50.091
Stainless steel	49.321
Gray Cast iron	34.097
Stainless steel	27.867

Stress for (80-100)mm Diameter Shaft	
Material	**Stress**
Structural steel	24.402
Stainless steel	24.471
Gray Cast iron	18.673
Stainless steel	13.158

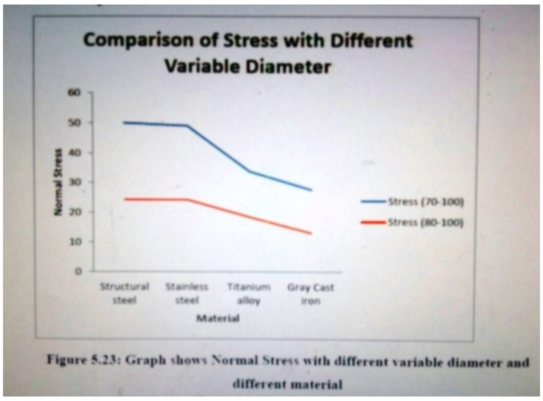


Figure 5.23: Graph shows Normal Stress with different variable diameter and different material

III. CONCLUSION

The current analysis has presented a study of Normal Stresses characteristics of a shaft of different profiles. 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 Normal Stress 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.

Influence of different shaft profiles

- The Normal Stress along the shaft profile is found to be maximum of the Structural Steel material profile with shaft diameter 70-100 mm and 80-100 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 70-100 mm and 80-100 mm.

- 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.
- In a comparison with the gray cast iron, stainless steel, structural steel and titanium alloy material resulted in higher Normal stress characteristics close to the end of the shaft for a different shaft diameter profile. The critical speeds are maximum for structural steel and minimum for gray cast iron at less Normal Stress on same RPM

IV. FUTURE SCOPE

□□□Solid shaft and hollow shaft could be used to analyze critical speed for different dimensions.

□□Different materials can be used for analyzing frequency and critical speed for different types of shaft.

□□Different masses could be also analyzed for different RPM to predict critical speed for shaft for save design.

□□Stiffness of bearing should be changed and also with damping coefficient for study of shaft system on Campbell diagram.

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