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Rotordynamic Analysis of a Rotating System

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Abstract- *Rotating machines are extensively used in mechanical engineering applications. Rotor- disc- bearing assembly is one of the most interesting fields of study in the research area. The unbalance excitation of rotor, stability analysis of rotor or vibration control of rotor receives significant research importance over the decades. By means of static, dynamic and rotor dynamic analysis the rotor bearing system can be efficiently monitored. This review paper attempts to collect researchers' different contributions on this field. Further to perform the rotordynamic analysis, the needed data, detailed procedure is detailed in this paper.*

Keywords: *Rotor Bearing, static analysis, dynamic analysis, Rotor dynamic analysis*

INTRODUCTION

Rotor dynamics is specialized branch in which study includes the lateral and torsional vibration of rotating shaft. The basic component of rotor dynamics is shaft or rotor. It also includes disc and the bearings which supports the rotor. As the rotating speed increases the amplitude of vibration also increases and it passes through a speed where it matches with the natural frequency that is called critical speed. Rotating part produce the vibration depending upon the mechanism used and if any fault is present in machine then it increases the vibration. Analysis in rotating system involves study of critical speed, unbalance loads, deflection of shaft. Bearing also plays an important role in controlling the vibration in which it acts as a damper. The stability of rotor and critical speed is mainly controlled by the stiffness properties and peak amplitude response of the bearing. In a rotating system assembly the static, dynamic, harmonic and rotordynamic analysis plays a significant role in determining the pertinent information of the system. The following sections of this paper discusses about the analysis procedure to be done for a rotating system.

Static Analysis

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring the inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads, and time varying loads that can be approximated as static equivalent loads. Static analysis determines the displacements, stresses, strain and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading response conditions are assumed that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis includes externally applied forces and pressures, Steady state inertia forces, Imposed displacements, Temperature, Fluencies

The procedure for a static analysis consists of these tasks: Building the model, setting the solution, setting up of additional solution, applying the loads and solving the analysis

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Dynamic Analysis

The dynamic analysis is a technique used to determine the dynamic response of a structure under the action of any general time dependent loads. This type of analysis is used to determine the time varying displacements, strain, stresses and forces in structures as it responds to any combination of static, transient and harmonic loads. The time scale of the loading is such that the inertia or damping effects are considered to be important. The basic equation of motion solved by a dynamic analysis is

(M)(u”) + (C)(u’) + (K)(u) = (F(t))

Where,

(M) = mass matrix
(C) = damping matrix
(K) = stiffness matrix
(u”) = nodal acceleration vector
(u’) =nodal displacement vector
(F(t)) = load vector

The procedure for a dynamic analysis consists of the following procedure:

1. Build the model
2. Establish initial condition
3. Set solution controls
4. Set additional solution options
5. Apply the loads
6. Save the load configuration for the current load step
7. Repeat step 3-6 for each load step
8. Save a backup copy of the database
9. Start the transient solution
10. Exit the solution processor
11. Review the results

Harmonic Analysis

Harmonic analysis is a technique used to determine the steady state response of a linear structure to loads that vary sinusoidally harmonically with time. The idea is to calculate the structure’s response at several frequencies and obtain a graph of some response quantity versus frequency. “Peak” responses are then identified on the graph and stresses reviewed at those peak frequencies. This analysis technique calculates only the steady state, forced vibrations of structure. The transient vibrations, which occur at the beginning of the excitation, are not accounted for in a harmonic response analysis.

Rotordynamic Analysis

Rotor dynamics is the branch of engineering that studies the lateral and torsional vibrations of rotating shafts, with the objective of predicting the rotor vibrations and containing the vibration level under an acceptable limit. The principal components of a rotor-dynamic system are the shaft or rotor with disk, the bearings, and the seals. The shaft or rotor is the rotating component of the system. Many industrial applications have flexible rotors, where the shaft is designed in a relatively long and thin geometry to maximize the space available for components such as impellers and seals. Additionally, machines are operated at high rotor speeds in order to maximize the power output. The main components of rotor-dynamic systems are the bearings and the seals. The bearings support the rotating components of the system and provide the additional damping needed to stabilize the system and contain the rotor vibration. Seals, on the other hand, prevent undesired leakage flows inside the machines of the processing or lubricating fluids, however they have rotor-dynamic properties that can cause large rotor vibrations when interacting with the rotor.The basic equation of motion in generalized matrix form for an axially symmetric rotor rotating at a constant spin speed Ω is,

M q(t) + (C+G)q(t) +(K+N)q(t) = f(t)

Where,

M is the symmetric mass matrix
C is the symmetric damping matrix
G is the skew-symmetric gyroscopic matrix
K is the symmetric bearing or seal stiffness matrix

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N is the gyroscopic matrix of deflection for inclusion of e.g., centrifugal elements
q is the generalized coordinates of the rotor in inertial coordinates
f is a forcing function

Application

- For preparation of results file for a subsequent Campbell diagram of a prestressed structure.
- Specifications of the rotational velocity of an element component about a user defined rotational axis.
- Applies the gyroscopic effect to a rotating structure and also applies the rotating damping effect
- Specifies the rotational velocity of the structure about global Cartesian coordinates.
- Specifies whether the excitation frequency is synchronous or asynchronous with the rotational velocity of a structure in a harmonic analysis.
- Produces animations of time harmonic results or complex mode shapes.
- Plotting of Campbell diagram data.
- For displaying the orbital motion.
- Prints the Campbell diagram data as well as critical speeds.

Resonance

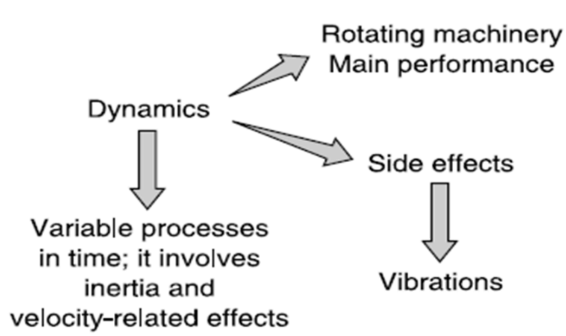
Resonances are a concern because small excitations can be amplified to yield very large vibrations. Strictly Speaking, a resonance condition occurs when an excitation's frequency nearly coincides with a system Natural frequency. An opera singer breaking a wine glass is a classic example of resonance, where the Singer's pitch nearly equals the natural frequency of the glass. Even though the force of the sound waves is very small, their frequency causes large vibrations in the glass that eventually cause it to crack. Just like wine glasses, guitar strings and tuning forks, shafts and machine structures have frequencies. Where they naturally prefer to oscillate when excited. These natural frequencies are dependent on various Properties of the system.

$$\omega_n = \sqrt{\frac{k}{m}}$$

Where k is the spring's stiffness and m is the weight's mass.

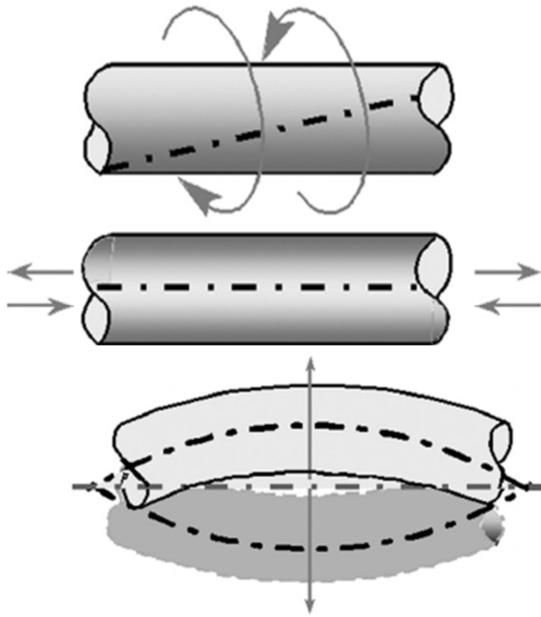
Energy Flow in Rotors

The rotational energy has a potential for serious leaks and can easily be transformed into other forms of energy such as heat. In addition, in rotors there exist additional sources of energy leaks, transforming the rotor rotational energy into other forms of mechanical energy



Various Mode of Vibration

Due to several factors, which contribute to the energy transfer - from rotation to other forms of motion - the rotor rotation may be accompanied by various modes of vibrations. There exists also a third category of vibrations in physical systems, known as self-excited vibrations. These vibrations are steady, usually with constant amplitude, phase, and frequency. They are sustained by a constant source of energy, which may be external, or is a part of the system. In this type of vibrations, through the feedback mechanism, the constant energy is ''portioned'' by the oscillatory motion. The frequency of self-excited vibrations is close to one of the system natural frequencies. Well known are aerodynamic flutter vibrations of wings or blades, or transmission lines sustained by unidirectional wind.



Conclusion

Thus the basic and advanced analysis procedure in relations to a rotating system is discussed in this paper. This paper discusses the necessity of the analysis in briefly. The importance of the analysis procedures is listed in this paper.

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