ABSTRACT

Vibration in rotor shaft system is of major concern to the designers. Both transverse and torsional vibrations take place in a rotor shaft system but in this work attention has been paid to the transverse vibration. Two reasons viz. a) external excitations and b) loss of stability may be accounted for high transverse response. External excitations may be caused by unbalance in the rotor, mismatch in the coupling, bends in the shaft, defects in the bearings etc. but the survey of literature shows that unbalance in the rotor happens to be the most common source of excitation that causes resonance. Hence resonance has been considered to be the chief cause of high transverse response in this work. Loss of stability is caused when the characteristics of the system under certain conditions excite the system internally resulting in self- excitation. Presence of these excitations puts limits on the operating speed of the rotors. Good design, meticulous manufacturing and assembly processes as well as balancing techniques may at best mitigate the aforementioned defects but may at the same time prove costly. Researchers showed that providing damping at the supports is very helpful and is a viable means for achieving substantial reduction of vibration as the excess vibratory energy is dissipated through the damping at the support causing reduction in response and widening of the stability limit speed. They also observed at the same time that the selection of proper supports for a particular rotor shaft system is the most important part. Therefore design of proper support characteristics forms the central theme of this work.

Support as conceived by many researchers as well as conceptualized in this work is a member between the bearing and the bearing housing and is considered to be stationary with respect to the frame housing the rotor. This is modeled to have both stiffness and damping characteristics. Squeeze film damper is one such example where damping in the fluid ensures stability of the rotor shaft system.

Recently polymeric materials gained much importance in containing vibration levels in different mechanical systems primarily because of the high

damping characteristics of these materials. Further these materials are inexpensive and are found to have many mechanical as well as operational advantages. Recently researchers have also ensured the synthesis of polymers according to desired mechanical properties. With these recent developments in view, polymeric materials have been chosen as supports in this work. Polymeric materials exhibit a unique property that the stiffness and the loss factors are functions of frequencies when these materials are subjected to harmonic excitations as the elastic modulii are functions of operator of time unlike constants for metals. This property has been seen to influence the natural frequency of the system when such materials are used. For rotor shaft systems theoretical studies showed the scope for avoiding resonance through proper prediction of support properties. Therefore prediction of support properties has been the main aim of the present work. Response amplitude and the stability limit speed of the rotor shaft system have been considered as the two indices for designing the support of a rotor shaft system. Prediction of support characteristics has therefore been taken up with two objectives in view viz. 1) minimization of the transverse response amplitude caused by rotor unbalance considered to be one of the chief causes of high transverse response and 2) the maximization of the stability limit speed of the rotor shaft system. Another objective has been the analysis of sensitivity of the optimum values of support characteristics as it is important for the designer to know the amount of deviation of the dynamic performance of the system in case the actual support characteristics deviate from the optimum ones. Yet another viewpoint to the issue of sensitivity is the knowledge of any critical frequency where the performance of the system may be very sensitive to the deviation of the support characteristics from the respective optima. In short the present work aims to present the optimum frequency dependent support characteristics for a rotor shaft system and the sensitivity of the optimum support characteristics.

With these objectives fixed, support characteristics have been predicted for systems having single and multiple rotors, subjected to both internal and external damping forces. Whereas the internal damping has been chosen to be primarily of viscous type as has been used by some researchers, the external damping has been considered primarily when oil-journal bearings are considered. In practice, rolling element bearings give rise to restoring forces varying nonlinearly with the deformation of the bearing elements. A linearization technique for such bearings as obtained from the literature has been effectively used to handle the problem of non-linearity. The case of preloaded rolling element bearings has been considered in this context.

Classical methods as well as finite element method of modeling the rotor shaft system have been done depending upon the degree of complicacy. Parameters of the system have been non-dimensionalized wherever possible. This renders the applicability of the results to any system.

The major conclusions held are as follows

1. The minimization of unbalanced response alone can be used as the criterion for finding the support characteristics when the instability is caused principally by the internal damping but the conditions of simultaneous minimization of transverse response and as well as maximization of the stability limit speed gives better support characteristics when external source of instabilities are also present. However the latter is more time consuming.

2. Optimality calculations may land up with prescribing support characteristics changing suddenly with the frequencies. This pattern of frequency dependence is not achievable for any real support material. Therefore a constraint on the variation of the slope of the support characteristics was used and found very useful as this gives smoothly varying support characteristics.

3. Comparison of results with published work in this line shows that the process presented in this work gives better results.