BALANCING OF FLEXIBLE ROTORS

SYNOPSIS

Rotors running at supercritical speeds are most commonly used now-a-days in steam and gas turbines, jet engines, pumps, compressors and power transmission shafts of helicopters. If they operate below the first flexural critical speed, they may be considered as "rigid" rotors and can be balanced in conventional manner by inserting calculated correction masses in any two conveniently selected balancing planes.

Rotors of the type mentioned above, however, operate mostly beyond first flexural critical speed. Such rotors are called "flexible" rotors. Two-plane balancing is not sufficient to balance these flexible rotors and multiplane balancing is mandatory.

Presently there are four commonly used methods of balancing flexible rotors. They are

1) Modal Balancing Method,
2) Comprehensive Modal Balancing Method,
3) Influence Coefficient Method and
4) Unified Balancing Approach.

All these methods involve the use of trial mass insertion in selected balancing planes to determine the

sensitivity of the rotor and may need some skill and experience in their use. Insertion of trial masses involves a large number of runs and hence increases the total time needed for balancing.

It has, therefore, become necessary either to perfect these methods or to evolve a new method which will avoid trial mass runs. The work reported in this thesis is aimed at the latter proposition.

In the first phase, the work is concentrated on the development of a sound analytical basis for the dynamics of flexible rotors. Differential equations governing the response of flexible rotors are derived using Hamilton's principle. Most of these equations are compared with those already available in the literature and thus the validity of the analytical basis is first established. Analysis is then extended to include effects of those parameters that are of importance for the supercritical rotors.

In the second phase, the work is focussed on the development of a new method of balancing of flexible rotors, named as "Collomode" method, by using Collocation technique. The governing equation of rotor response is solved to yield the unbalance eccentricities at selected planes on the rotor. The correction masses and their phase angles are then computed with the help of the computer program COBAL developed for this method. Input to this program is the vibration of rotor due to inherent unbalance collected at the measuring planes.

This collomode method is analytically verified by considering a simple rotor model with triangular shaped unbalance eccentricity distribution. Typically residual vibration level predicted by this method is 0.06 μm compared to 11.00 μm as per Modal Balancing method, 17.37 μm as per Federn's Comprehensive Modal Balancing method and 0.54 μm as per Influence Coefficient method.

In the third phase, a second method, named "Multimode" method is developed and a computer program MOBAL is prepared. This method consists of expressing the vibration amplitudes in terms of known approximating functions corresponding to the modes of an "ideal" rotor supported on "ideal" bearings. It is theoretically verified and compared with all the conventional existing methods and Collomode method. The Table of comparision shows that this Multimode method is superior to all the existing methods.

In the fourth phase, the Multimode method is refined and adapted to suit the requirements of practical

flexible rotors. A complete flow chart of balancing of flexible rotors is developed for this method. Major advantages of this practical Multimode method are

- It eliminates the use of trial masses and trial runs and hence minimizes the number of starts and stops, in contrast to the Influence Coefficient Method which requires a large number of trial runs.
- It requires only approximating functions simulating the mode shapes, in contrast to the (unknown) exact modes required by the Modal Balancing Method. The exact modes are very difficult to obtain accurately in practice.
- It does not assume that the response near any critical speed is dominated by the adjacent mode shape.

In the last phase, this Multimode method is applied to balance a test rotor in the Laboratory. The results of the test are encouraging and indicate that this method has great potential as a practical method of balancing flexible rotors, both for large-volume shop-floor balancing and low-volume or single-rotor balancing.