

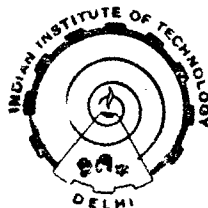
SOME STUDIES ON BALANCING OF FLEXIBLE ROTORS

by

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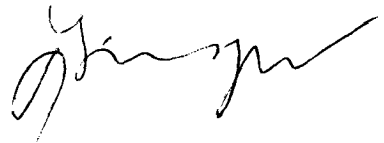
**Thesis submitted in fulfilment of the requirement
for the Degree of
DOCTOR OF PHILOSOPHY**



**to the
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CERTIFICATE

This is to certify that the thesis entitled, "SOME STUDIES ON BALANCING OF FLEXIBLE ROTORS" submitted by Mr. Jagbir Singh to the Indian Institute of Technology, Delhi, in fulfilment of the requirement for the award of the Degree of Doctor of Philosophy' is a record of the bonafide research work carried out by him under my guidance and supervision. The results contained in the thesis have not been submitted in part or full to any other University or Institute for the award of any degree/diploma.



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A B S T R A C T

In recent years, the trend in design of rotating machinery has been towards reduced weight and increased operating speed. These designs result in increased rotor flexibility. Some rotors may have operating speed below which two or three modes of vibration exist. Since the imperfections in rotor manufacture and assembly can not be avoided, it results in rotor mass unbalance. The rotor starts vibrating with large amplitudes in the neighbourhood of the critical speeds due to this unbalance. Thus, it is necessary to balance the flexible rotor by mounting balancing masses at suitable places for its smooth operation throughout its operating range.

Various methods for balancing flexible rotors have been invented. They have their inherent advantages and disadvantages. Therefore, a comparative evaluation study for their balancing effectiveness was carried out for the benefit of the user. For this purpose, two rotor models were considered; one had rigid supports whereas the other had highly flexible supports. These rotors were balanced by each of the four well known methods (N-plane method, (N+2)-plane method, influence coefficient method and unified balancing approach). The residual vibration has been determined in each case and it has been found that some of the methods are very sensitive to the plane location whereas others are less. A brief guide has been provided for the selection of the method. It has

also been observed that flexible supports result in lesser residual vibration for the flexible rotor.

The N-plane method and (N+2)-plane method use mode shapes corresponding to rigid support but in reality supports have finite stiffness. Therefore, a study was carried out to find influence of modal variation. The influence of modal variation is more on N-plane method and use of actual mode shape results in better balancing of the flexible rotor. The modal variation has practically no influence on (N+2)-plane method and results indicate that it tends to balance the flexible rotor independent of the change in support conditions (universal state of balance).

The universal state of balance for the flexible rotor is desirable. The studies have been conducted in this direction also. Ballo's method has been studied by considering a better support model. The detailed balancing studies have been conducted considering different combinations of bearing and pedestal. Results indicate that Ballo's method provides universal state of balance to the flexible rotor.

To validate the theoretical results of some of the above mentioned studies, a test rig was designed and fabricated. The test rotor was initially balanced for the entire range of speed to attain zero rotor condition. Then, the balancing studies were performed with known arbitrary unbalance. Ballo's method has been used for this purpose. The balancing studies have also been

performed by varying flexibility of supports. The flexibility of supports has been changed by using flexible pads. The results indicate that Ballo's method provides universal state of balance

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