SOME STUDIES ON BALANCING OF FLEXIBLE ROTORS

by

JAGBIR SINGH

INDUSTRIAL TRIBOLOGY, MACHINE DYNAMICS & MAINTENANCE ENGINEERING CENTRE

(ITMMEC)

Thesis submitted in fulfilment of the requirement for the Degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

June 1989

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.

(K.N. Gupta Dr.Ing.)

Professor, Department of Mechanical Engineering and ITMMEC, Indian Institute of Technology, Delhi

A C K N O W L E D G E M E N T S

The author expresses his deep sense of gratitude to his thes supervisor Prof. K.N. Gupta. He feels indebted to him f suggesting the present work, his expert guidance and unfaili encouragement throughout the course of study.

Prof. B.C. Nakra, Prof. A. Sethuramiah and Prof. O.P. Chawla : their capacity as head of ITMMEC, made available variou facilities of the centre. Dr. K. Gupta in his capacity a incharge of Vibration Laboratory in Mech. Engg. Deptt. made available all the facilities of the laboratory. The author i highly obliged to all of them. Thanks are due to Prof. M.I Mandal, Principal and Prof. P.L. Ballaney, Head of Mech. Engg Deptt., Delhi College of Engg. for sponsoring the author unde quality improvement programme to I.I.T. Delhi. Thanks are als due to Prof. Y.V.S.R. Sastri for his encouragement in thi course of study.

The author also wishes to acknowledge the valuable help of Dr B.K. Gupta, Sh. Brahm Prakash, Sh. Naresh Tandon, Dr. S Chandrasekaran, Dr. N.K. Garg, Dr. K. Athre, Dr. M.K Aggarwal, Sh. A.K. Saluja and several other colleagues in the form of useful discussions and encouragement.

Thanks are also due to Ashok, Sh. Sharma, Madhusudnam, Avtar and other staff of laboratories and workshops of ITMMEC, IDDC and

Mech. Engg. Department. Thanks are also due to Dilbagh Sing Delhi College of Engg. for tracing the curves, Mrs. B.S. Chaw for typing the manuscript neatly and Mr. Samsheer Singh, Frien Computer Centre for printing the thesis.

The author would be failing in his duty, if he did not expre his gratitude to his wife and other family members who ha borne many domestic problems with him patiently during the cour of the investigation.

Above all, the author feels that the grace bestowed upon him Sat Guru has been instrumental in successful completion of t project.

(JAGBIR SINGH)

A B S T R A C T

n recent years, the trend in design of rotating machinery has een towards reduced weight and increased operating speed. These esigns result in increased rotor flexibility. Some rotors may ave operating speed below which two or three modes of vibration xist. Since the imperfections in rotor manufacture and assembly an not be avoided, it results in rotor mass unbalance. The rotor tarts vibrating with large amplitudes in the neighbourhood of he critical speeds due to this unbalance. Thus, it is necessary o balance the flexible rotor by mounting balancing masses at uitable places for its smooth operation throughout its operating ange.

arious methods for balancing flexible rotors have been invented. hey have their inherent advantages and disadvantages. Therefore, comparative evaluation study for their balancing effectiveness as carried out for the benefit of the user. For this purpose, wo rotor models were considered; one had rigid supports whereas ther had highly flexible supports. These rotors were balanced by ach of the four well known methods (N-plane method, (N+2)-plane ethod, influence coefficient method and unified balancing pproach). The residual vibration has been determined in each ase and it has been found that some of the methods are very ensitive to the plane location whereas others are less. A brief uide has been provided for the selection of the method. It has

.so been observed that flexible supports result in lesser ›sidual vibration for the flexible rotor.

ıe N-plane method and (N+2)-plane method use mode shapes ›rresponding to rigid support but in reality supports have .nite stiffness. Therefore, a study was carried out to find ıfluence of modal variation. The influence of modal variation is ›re on N-plane method and use of actual mode shape results in ›tter balancing of the flexible rotor. The modal variation has 'actically no influence on (N+2)-plane method and results ıdicate that it tends to balance the flexible rotor independent the change in support conditions (universal state of balance).

ıe universal state of balance for the flexible rotor is ›sirable. The studies have been conducted in this direction .so. Ballo's method has been studied by considering a better ıpport model. The detailed balancing studies have been conducted considering different combinations of bearing and pedestal. ›sults indicate that Ballo's method provides universal state of .lance to the flexible rotor.

ı validate the theoretical results of some of the above ›ntioned studies, a test rig was designed and fabricated. The st rotor was initially balanced for the entire range of speed attain zero rotor condition. Then, the balancing studies were rformed with known arbitrary unbalance. Ballo's method has been ed for this purpose. The balancing studies have also been performed by varying flexibility of supports. The flexibilit of supports has been changed by using flexible pads. The result indicate that Ballo's method provides universal state of balance

CONTENTS