STUDIES ON DYNAMICS OF RIGIDLY/FLEXIBLY COUPLED PNEUMATIC FREE PISTON MACHINES

by

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To my mother and wife

CERTIFICATE

This is to certify that the thesis entitled "**Studies on Dynamics of Rigidly/Flexibly Coupled Pneumatic Free-Piston Machines**" being submitted by Mr. Bakshi Lal Sachdeva to the Indian Institute of Technology, Delhi, for the award of the Degree of 'Doctor of Philosophy' in Mechanical Engineering is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis.

The results contained in this Thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The present dissertation reports the theoretical and experimental investigations carried out for the dynamic analysis of a free-piston pneumatic compressor driven by a Stirling engine or a cam mechanism. The drive system is considered as if imparting a sinusoidal or harmonic motion to the compressor cylinder. The cyclic variation of gas pressure in cylinders gives rise to non-linear differential gas force characteristic and hysteresis damping in the system, and thus it has led to the formulation of non-linear equations of motion. Method of Krylov and Bogoliubov or Ritz averaging method with the approximation of only first harmonic terms has been used to find out the steady-state solution to these equations.

For the dynamic analysis two versions of the system have been considered. In the first version the free-piston pneumatic machine is considered to be coupled to the drive system rigidly, while in the second version it is connected flexibly. The former version has resulted into a single-degree-of-freedom system, while the latter to a two-degree-of-freedom system, but both having non-linearity due to the presence of hysteresis damping and non-linear gas force characteristic.

A detailed theoretical study has been carried out on the first version of the system to obtain steady-state solutions by using method of Krylov and Bogoliubov, Ritz averaging method, equivalent linearization technique and

numerical integration technique. With the help of first two methods expression for response of the system has been obtained in dimensionless form. Effect of variation of different parameters on the response has been studied and discussed. The numerical integration technique has shown that the response of the system is fairly harmonic and thus it has supported the approximation of first harmonic terms in the Ritz averaging method.

For validation of the results, an experimental rig has been designed, fabricated and developed. Experimental results have been obtained for different values of parameters like pressure ratio, inertial mass, spring stiffness and cam rise. These results are then compared and discussed in the light of theoretical results obtained.

In the second version of the system two variations have been considered. In the variation-I, cylinder motion of the pneumatic machine is unrestrained, while in the variation-II its motion is restrained by a spring. Steady-state solutions have been obtained in both cases by using the method of Krylov and Bogoliubov. Results are presented in dimensionless form. Effect of coupling stiffness and cylinder mass on response of the system are then studied and discussed.

General conclusions drawn from the whole study are listed at the end. Suggestions for future work are also indicated.

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