ABSTRACT

The expansion turbine constitutes the most critical component of a large number of cryogenic process plants – air separation units, helium and hydrogen liquefiers, and low temperature refrigerators. Turbines in typical cryogenic refrigerators run at speeds between 1,00,000 and 5,00,000 r/min. These operating conditions impose stringent constraints on the bearing designer. By the use of process gas as the lubricant, gas bearings often provide the best answer to this problem. The work presented in this dissertation, attempts to study, analyse and test various feasible gas bearing options for supporting cryogenic turboexpanders. The thesis has two major objectives - the analysis and design of gas bearings, and fabrication and testing of prototype bearings in operation of a turboexpander.

The work presented here can be broadly classified into three parts. The first part is the genesis that builds up the problem and gives a comprehensive review of gas bearing literature. The plain aerostatic bearing and its various modifications, the tilting pad journal bearing, the grooved journal and thrust bearings and the foil bearings are covered in the review. A chronology of development of gas bearings for cryogenic turboexpanders is also included.

The second part deals with the theoretical analysis of different types of gas bearings with a potential to be applied in cryogenic turboexpanders. The bearings include the aerostatic double thrust bearing, the rubber stabilised aerostatic journal bearing and pivot-less tilting pad journal bearing. Double thrust bearings are often provided as a check against accidental thrust reversals. For an inherently orifice compensated aerostatic thrust plate, a comparison is given between the simple radial flow model and a more accurate 2-D flow model. The O-rings provide flexibility to the plain aerostatic journal bush and enable it to pass over the half speed whirl limiting speed. The pivot-less pads, having excellent high-speed stability properties, serve a very good alternative to aerostatic journal bearings. The absence of pivots frees the pads from alignment problems. A step-by-step design procedure is given for all the bearings analysed.

The third and the last part of the thesis deals with the fabrication of the prototype gas bearings and associated components, as well as performance of the rotor-bearing system in operation of the turboexpander. To start with, aerostatic journal and thrust bearings have been built and an unbalanced rotor is operated to test the efficacy of the bearings. Satisfactory operation, up to a duration of about 40 hours, is achieved with a speed of around 80,000 r/min. Multiple start-stops is possible without encountering any problem. Unbalance response and critical speeds for the prototype rotor is computed using the transfer matrix method; computed critical speeds are compared with those obtained from theory. Fabrication details of an alternative system based on pivot-less pad journal bearing and aerostatic thrust bearing have also been provided.

Keywords: Cryogenics, Gas bearings, Thrust bearing, Journal bearing, Inherent compensation, Aerostatic bearing, Rubber stabilised bearing, Pivot-less tilting pad bearing, Critical speed, Unbalance response, Transfer matrix method