SESSION VI. ROTORDYNAMICS

LUKE A. SCHUTZENHOFER
SYSTEMS DYNAMICS LABORATORY
NASA, MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE. ALABMA 35812 USA

INTRODUCTION

In rotational systems that operate at high speeds, i.e., in excess of their critical speeds, and where the tolerances between rotating members are close, careful consideration must be given to rotordynamic design. In the design and development phase of the SSME, some of the rotordynamic design considerations were bearing loads, whirl instability, excessive deflections that result in rubbing, unbalance, deadband, sideforce, transmission of dynamic loads, rotor stack buildup/shift (internal rotor friction), etc. The purpose of rotordynamic design is to minimize all detrimental effects; this usually results in optimizing all of the aforementioned effects with respect to each other and with respect to system performance and life.

The rotordynamic analyses that are required to support the SSME design while sophisticated with respect to the present state-of-the-art still require additional advances because of the far reaching SSME operational conditions. The goal of the rotordynamic working group is to plan generic, but SSME related, research activities that ultimately lead to optimum rotordynamic design. Specifically, the plan is to improve the description and analysis methods pertaining to rotordynamic loads and response, to define more accurately and completely the significant rotordynamic forces, and to define design requirements that influence rotordynamic loads, deflections and stability. Consistent with this plan, tasks have been defined to: (1) develop new analysis and simulation techniques, (2) define forces which result from the rotor and surroundings, (3) determine the effect of rubbing, (4) improve balancing, (5) develop damping methods, i.e., eddy-current and damping seals, (6) develop methods to quantify internal friction, and (7) develop supporting test apparatus.

The papers that have been presented during this session illustrate some of the accomplishments achieved under the aforementioned plan. The activities related to deadband by J. R. Glaese and A. P. Bukley have extended previous work to illustrate the nonlinear effects on loads and stability in addition to developing a limit cycle algorithm. The model applied by J. R. Glaese and A. P. Bukley was a generic model while in the paper presented by Dara W. Childs, a nonlinear multiple degree-of-freedom model was utilized. D. W. Childs' results showed that (1) a reduction in whirl frequency could result from bearing clearances, (2) the computed whirl frequency matches test data, (3) damping seals are effective toward suppressing subsynchronous whirl, and (4) under certain conditions synchronous bearing loads were more important than subsynchronous bearing loads.

Results of activities related to improved balancing were presented by M. J. Hine, C. E. Landis, and R. F. Beatty. The significant results achieved in this activity include the (1) definition of HPOTP and HPFTP balance sensitivity, (2) effectiveness of low speed multiplane balancing, (3) demonstration of potential improvements due to rotor stiffness, (4) definition of nonlinear deadband effects, (5) interrelationship between balance planes, balance runs and speed, and (6) modeling of time dependent unbalance changes for analysis of self-enhanced unbalance. E. S. Zorzi and J. Walton also presented results related to unbalance. Their results showed (1) multiplane/multispeed balancing can decrease machine vibrations, (2) low speed single plane trim balancing does not allow control for high speed vibration suppression, (3) a low speed balancing approach may be acceptable provided sufficient balance planes are available, and (4) effects of bearing tilt were shown to minimally effect rotor unbalance response.

Results related to damping seals were presented by G. L. von Pragenau. These seals are a new technology and the results are encouraging in that these seals are retrofittable in machines beset with whirl instability. At the present time, damping seals are being tested in the SSME program. An apparatus to test damping seals is discussed in the paper presented by K. L. Cappel. This apparatus has been designed and fabrication is in progress. It will operate at speeds up to 37,000 rpm with various flow rates up to 300 gpm and pressures up to 2,300 psi. R. E. Cunningham, also addressed seals; however, his approach consisted of developing an eddy-current damper test rig. Results from the eddy-current damper program are as follows: (1) damping potential was demonstrated on a vibrating beam in liquid N_2, (2) computer codes were developed to characterize eddy-current dampers at cyrogenic temperatures, (3) a 12,000 rpm rotating apparatus for testing several eddy-current dampers in liquid N_2 was developed and tested, and (4) an eddy-current test rig that will operate to 36,000 rpm in liquid H_2 was designed.

In summary, some of the papers presented in this session focused attention upon understanding loads, response and whirl instability utilizing rotordynamic computational methods. Other papers emphasized activities related to unbalance with their end goal being to reduce the unbalance loads and consequential vibrations at high speed operations. A new method to suppress whirl instability with retrofittable damping seals was presented along with the development of a test apparatus to test damping seals at conditions similar to SSME operating condition. Finally, the test results related to eddy-current dampers were presented.