NASA TECH BRIEF

Study of High-Speed Angular-Contact Ball Bearings Under Dynamic Load

A research program has been conducted to investigate the behavior of specific high-speed, angular-contact ball bearings. The program was a continuation of the effort to isolate several probable causes of ball-bearing "failure" in a specific gyro wheel. The present program was aimed specifically at detailed investigation of two of these potential causes, namely, the ball-separator behavior, and lubrication surface-finish effects. The ball separator has been investigated with respect to dynamic behavior, materials, and geometric design. The effects and functions of lubrication and raceway finish have been studied from the viewpoint of lubricant-film generation, lubricant flow, and traction forces. In addition, the bearing-dynamics-analysis program, which was previously developed, has been extended through development of a companion program for analysis of ball and separator dynamics. Both of these programs were used for extended studies of the dynamic effects on precision bearings due to the presence of the ball separator.

Experimental measurements of gyro-bearing lubricant-film thickness and traction characteristics were performed in the rolling-disk configuration to verify lubrication models for calculations of bearing dynamics. Values of rheological model parameters were determined that fit the experimental data for the load and contact-residence time conditions of interest in the gyro-bearing configuration. Mathematical techniques and approximations were developed to efficiently calculate the total tractive force and moment at a ball/race contact in the analysis of bearing dynamics.

Verifying experiments were also conducted for models of the tractive force between the ball and the ball separator. A gyro-bearing-scale-traction apparatus was developed with a measuring sensitivity of ±0.01 gm force. Measurements of traction in the range of 0.2 to 1.0 gm force were obtained for speeds ranging from 24,000 to 36,000 rpm and loads ranging from 2 to 10 gm force. Results were in reasonable agreement with the theory when meagerness of the lubricant was accounted for.

Theoretical analyses and rolling-disk experiments were performed to assess the effects of roughened surfaces on elastohydrodynamic lubrication. Average film thicknesses found for transverse and circumferential roughness lay were higher than those for smooth surfaces. Significant reductions in traction were found for the circumferential roughness lay in the gyro-bearing operating range of conditions.

Lubrication models for each of the types of bearing contact were incorporated into the bearing-dynamics analysis program. This digital computer program provides a numerical solution of the complete set of equations of motion for the moving elements of an angular-contact ball bearing. Analyses of the current gyro wheel geometry were performed using the program for the conditions of an oversize ball and race misalignment. Several interesting general features of ball and separator motion in high-speed bearing operation were noted that have not previously been calculated. Results also revealed a separator/race contact drive mechanism for the ball-separator-whirl instability.

Several potential ball-separator material and geometry improvements have been conceived. Relatively new high-temperature polymers, such as Polyimide and Pyrrones, were found to offer several potential advantages over Synthane and Nylasint. Geometry changes in the pocket and at the outer race contact

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were conceived which may offer improved separator stability and lower torque and associated frictional heating.

Experimental measurements of ball/race lubricant-film thickness were obtained from operating gyro-wheels to assess the effects of raceway-surface apparatus were improved and experimental results are believed to be more reliable quantitatively than in previous research. Results showed considerable differences in film-thickness behavior between the smooth and the roughened race; however, theory and rolling-disk data explain the differences in the intermediate and high speed ranges fairly well. It now appears that the surface-finish theory and experiments can be used to design a surface that will provide lower ball/race traction with adequate minimum film thickness.

Notes:

1. It is believed that the state of theoretical prediction of lubrication processes and dynamic behavior in gyro bearings has progressed to the point that significant improvements in bearing performance can now be realized. Future research tasks should be conducted in the areas of ball-separator geometry, ball-separator material, and raceway surface finish. Modifications in geometry suggested by analyses must be checked for practicality and then further analyzed using the bearing dynamics analysis program.
2. Documentation is available from:
   Clearinghouse for Federal Scientific
   and Technical Information
   Springfield, Virginia 22151
   Price $3.00
   Reference: TSP69-10367

Patent status:

No patent action is contemplated by NASA.

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