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APPLICATION OF EXPERIMENTAL STRESS ANALYSIS TECHNIQUES TO SPEED BALL BEARINGS

Final Technical Report

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PROGRAM OBJECTIVE

Aircraft gas turbine engine rotor bearings currently operate in the range from 1.5 to 2 million DN (bearing bore in mm times shaft speed in rpm). It is estimated that engine designs of the next decade will require bearings to operate at DN values of 3 to 4 million. In this DN range, the reduction in bearing fatigue life due to the high centrifugal forces developed between the rolling elements and outer race becomes prohibitive.

To solve the problem of reduced fatigue life in high-speed ball bearings, various methods of decreasing ball mass to reduce the centrifugal force have been proposed. Spherically hollow balls, fabricated by welding hemispherical shells together, offer a possible solution. Full-scale bearing tests with hollow balls, operating at a 280,000 psi maximum Hertz stress, have indicated that the balls failed in flexural fatigue after relatively short operating times.

Another method of reducing ball mass is to machine a concentric hole through the ball. Full-scale bearing tests with cylindrically hollow ball bearings have demonstrated that operation at speeds to 3 million DN is possible. Fracture of cylindrically hollow balls has also been experienced during the operation of full-scale bearings.

Analysis of the failures experienced, and the effect of changes in ball characteristics at high speeds has been handicapped by the lack of an adequate theory to predict the stresses existing in the balls under bearing loads and centrifugal forces.

The object of the project was to determine experimentally the stress distribution in cylindrically hollow and spherically hollow balls.

Ball models several times actual bearing ball size were fabricated. Strain gage rosettes will be mounted on the outside and inside surfaces of the models at specific locations and orientations. The models were subjected to a range of static loads simulating actual ball-race contact loads experienced in high-speed bearings operating at DN values from 2 to 4 million. The strain gages were read, and the principal strains determined for each load setting. Principal stresses were calculated and dimensionless stress coefficients determined to permit the evaluation of stresses in hollow balls of any size and load of geometrically similar configuration.

FINDINGS AND PUBLICATIONS

Four investigations were undertaken. The first investigations resulted in NASA CR-2439 "Experimental Evaluation of Stresses in Cylindrically Hollow (Drilled)Balls," August, 1974, by L. J. Nypan; NASA CR-2445 "Experimental Evaluation of Stresses in Spherically Hollow Balls," August, 1974 by L. J. Nypan; and a paper accepted for publication in the ASME Journal of Lubrication Technology, "An Experimental Evaluation of Stresses in Drilled Balls," ASME paper 74-Lub-17 presented at the joint ASME-ASLE Lubrication Conference, Montreal, Canada, October 8 - 10, 1974, by L. J. Nypan, H. H. Coe, and H. W. Scibbe.

The third investigation has resulted in a report, "An Experimental Evaluation of Stresses in a Webbed Ball," by L. J. Nypan, submitted to NASA Lewis Research Center, February 1975.

The fourth investigation has resulted in a report, "The Effect of a Conforming Contact Geometry on Bending Stresses in Cylindrically and Spherically Hollow Balls," by L. J. Nypan, submitted to NASA Lewis Research Center, February 1975.