Experimental Determination of Preswirl Effects on Damping Seal Performance

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The interactions and phase relations between a rotor's elastic and inertial forces can lead to subsynchronous whirl, a type of self-excited vibration at frequencies near the lowest critical frequency of the rotor. This potentially destructive phenomenon imposes limits on turbomachinery performance. As an example, subsynchronous whirl caused serious development problems on the space shuttle main engine's high-pressure fuel turbopump. Early in the development program, the speed of the turbopump was limited to 22,000 r/min because of destructive subsynchronous whirl. Stiffening the ball-bearing carriers and introducing smooth interstage seals enabled the turbopump to reach its design speed of 36,000 r/min. However, the whirl persisted, although the amplitude was considered acceptable. To combat the problem, MSFC engineer George L. von Pragenau invented the damping seal. Upon replacement of the smooth interstage seals with damping seals, subsynchronous whirl was eliminated from the high-pressure fuel turbopump.

MSFC-developed computer codes have shown that damping seals inhibit subsynchronous whirl by providing more damping than whirl forces. In most applications, fluid comes out of the impeller with very high tangential velocities and enters the damping seal; MSFC's codes indicate this fluid preswirl degrades the damping seal's stabilizing capacity. Unfortunately, no high-Reynolds-number damping seal test data with known preswirl are available to verify this important analytical result.

The subject program objective is to assess (experimentally) the effect of preswirl on damping seal performance. An existing test rig will be used to compare the performance of a smooth seal and a damping seal with two different fluid preswirls. The performance of each seal will be measured with a smooth test rig shaft and fluid preswirl of one-tenth the shaft speed. Tests will be performed in water at 5,000, 10,000, and 20,000 r/min, and 1,000, 1,500, and 2,000 lb/in^2 delta pressure. The test series will then be repeated with a new shaft with paddles to increase the fluid preswirl to the shaft speed. Present analyses predict this will greatly degrade the stabilizing capacity of each seal. Resulting data will be compared to computer code predictions, and anchored computer codes will then be used to design new turbomachinery.

Subsynchronous vibration is a potentially destructive phenomenon that imposes limits on turbomachinery performance. Damping seals have been shown to inhibit subsynchronous whirl by providing more damping than whirl forces. This project will provide the requisite data to relate the stabilizing capacity of the damping seal to the amount of preswirl in the fluid entering the seal.

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