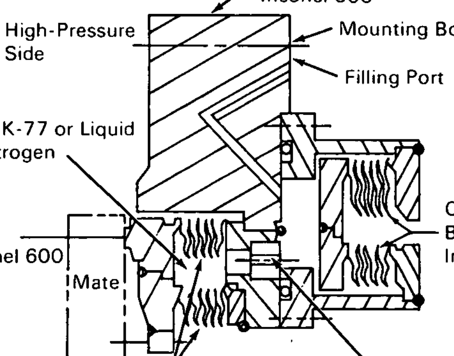
NASA TECH BRIEF

Investigation of Positive Shaft Seals



Orifice Damped Seal Design

Advances in the design of turbomachinery have required the development of new shaft seal technology to cope with the extremes of temperature and speed. Although seal engineering technology has progressed significantly, turbomachinery performance demands have also increased, particularly in the areas of high speed, high pressure, wide speed range, and extended life. The static portion of the mechanical seal, referred to as the secondary seal, must maintain its integrity while accepting axial shaft displacements caused by elastic deformations, fluid pressure pulsations, and vibrations.

The secondary seal having the greatest number of advantages is the welded metal bellows. The metal bellows design provides the most positive method of preventing secondary seal leakage with a minimum number of potential leak paths. A high performance seal can be obtained if a method is provided for controlling the potentially unstable seal-face movements induced by mechanical vibrations and fluid pressure pulsations. The ability of the bellows to function as a stable secondary portion of the mechanical seal plays a major part in controlling leakage and extending the life of the sealing faces.

In addition to normal quality control inspections, application of the welded metal bellows concept required test programs: (1) to study the effects of bellows vibration dampers to ensure that the damping did not impair the normal operation of the bellows, with reference to primary seal separation and bellows life; (2) to observe bellows integrity and seal performance by axial cycling of the bellows, both mechanically and through pressure pulsations; (3) to determine bellows response and recovery rate by accelerating the mating ring away from the bellows carrier; (4) to observe the reaction of the bellows to vibration; and (5) to analyze the total seal-face loading.

Four seal designs were selected from a potential seventeen for detailed investigation and possible fabrication: (1) piston-damped seal; (2) purged double-lip seal; (3) orifice-damped seal (shown in the figure); and (4) particle-damped seal. The piston-damped seal was eliminated because of restricted use; the purged double-lip seal was eliminated because of temperature limitations and susceptibility to contamination.

Orifice-Damped Seal

The orifice-damped seal utilizes viscous friction to absorb imposed axial vibration. The design consists of two cavities, formed by two pairs of radially stacked, welded bellows and separated by an orifice plate. The end fitting of one bellows cavity has a sealing surface which mates with an adjacent, rotating sealing surface. The end fitting on the other bellows cavity closes the system. Both cavities are filled with a liquid metal or a cryogenic fluid as the temperature environment dictates. As the seal face is subjected to

(continued overleaf)

axial movements, the damping fluid contained in the bellows cavity is forced through the orifices, creating viscous forces to absorb energy. The rear bellows cavity, or compensator assembly, accumulates the fluid forced through the orifices and also acts to increase or decrease the total volume due to fluid temperature/density change.

For a cryogenic application, the fluid to be sealed also acts as the damping medium. However, analog computer calculations have indicated that, due to the relatively small displacements of this seal, little damping may be obtained with a gaseous medium. To obtain significant damping, a high density fluid must be used. Nonetheless, the orifice-damped seal is suited to high temperature uses, because the bellows cavities can be filled with a damping medium that is different from the fluid to be sealed. For the purpose of this study, the cavities were filled with liquid sodium-potassium metal (NaK).

The application of this design is apparently feasible for temperature environments other than cryogenic. However, further research and detail-design refinements are necessary before the orifice-damped seal can be considered a practical reality.

Particle-Damped Seal

The particle-damped seal consists of a conventional bellows seal design, using a stationary bellows welded to a sealing face and pressed against an adjacent, rotating seal. In addition, a series of 24 cylinders is welded to a radial extension of the sealing surface, placing the cylinders at the outside diameter of the bellows. The cylinders are filled to an effective level with spherical particles of molybdenum. The spherical particles react to vibration inputs by absorbing displacement energy through inertia and friction of the particles on the inside surfaces of the cylinders.

Vibration data taken during testing of the particle-damped seal indicate effective damping of nonrotating seal parts, with the potential advantages of increased carbon sealface life and improved leakage characteristics.

Notes:

1. The prime advantages of the methods described over conventional vibration damping devices (such as spring-loaded frictional devices) are simplicity of design, greater reliability, and less risk of contamination or fire when in the proximity of solvents. In addition, effective damping can be obtained over a wide range of temperatures, from cryogenic to gas-turbine environments.
2. The following documentation may be obtained from:

   Clearinghouse for Federal Scientific
   and Technical Information
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.65)

   Reference:
   NASA-CR-97143 (N68-36254), Investigation of Positive-Type Shaft Seals

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