Smart Dampers for Turbomachinery Applications

NEW PROPOSAL

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Introduction

Electro-rheological (ER) fluids have made possible new developments that include smart clutches, fast-acting hydraulic valves, shock absorbers, brakes, and many others. Unlike magnetorheological fluids, ER fluids can operate at higher temperatures and do not require complex arrangements to create magnetic fields. A key factor in the application of ER fluids is the speed of its response to alternating current. However, despite this unique characteristic, the change in viscosity of today's ER fluids has not met the demanding requirements of many modern applications. Achieving a controlled change in viscosity and concomitant speed has been a challenge and the understanding of active fluids has not been fully achieved. This research aims to create a novel approach to generate controllable nanofluids and to develop and evaluate active and controllable novel damper prototypes for turbomachinery applications. The proposed approach uses functionalized nanoparticles (NPs) as additives that incorporate charged molecules. When an electrical field is applied to the resulting ER fluid, the NPs align together so as to change its viscosity. The high responsive rate is achieved by the elimination of diffusion and because of the size of nanoparticles, they simply rotate for alignment. This concept is illustrated in Figure 1. The rotation of NPs changes viscosity. The changing rate speed can be increased due to rotation and localized alignment.

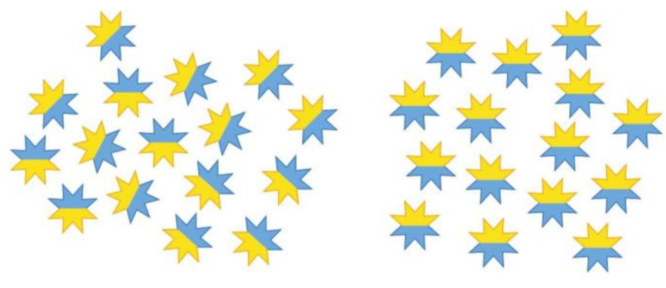

Figure 1 An electrical field aligns functionalized nanoparticles to create a rapid change in viscosity.

The use of the nanofluids with active control would represent the disruptive solution to allow new damper concepts, such as the hermetically-sealed damper HSFDs[1], achieve the required damping entitlement of oil-lubricated bearings. The enhanced HSFD can pave the way for the development of oil-free MW-range turbomachinery and serve as a unique energy dissipation device for any type of support (oil-lubricated or rolling element bearings) in high-speed machinery. There are two main classes of open-flow SFD, 2π SFD and the segmented SFD (Figure 2). The ISFD is classified as a "segmented" damper that uses centering spring partitions to block flow in the circumferential direction and therefore directing flow solely through the end seal clearances. This approach, in contrast to a 2π damper configuration, generates linear damping coefficients that are amplitude and frequency independent while exhibiting linear stiffness coefficients from the structural centering springs. Similar to the ISFD, the HSFD leverages the concept of segmentation within the damper land and controlling flow resistance through a restrictive clearance that is not a function of vibratory motion or the static equilibrium position of the system. Unlike traditional dashpot dampers, the HSFD uses a "face" damper rather than an "orifice" damper and possesses an integral plunger submersed in an incompressible damper fluid bounded by a single flexible member. Integrating the plunger to the housing using centering springs (like an ISFD) allows for the HSFD to be packaged in designs that have aggressive space envelope requirements. As vibration x(t) is imposed on the plunger through a rod located outside the damper fluid, there is a change in upper and lower cavity fluid volumes with respect to time (V1(t) and V2(t)). These time-dependent changes in volume are accompanied by time-varying dynamic pressures (P1(t) and P2(t)) that create the Poiseuille flow-driven damping force [1].

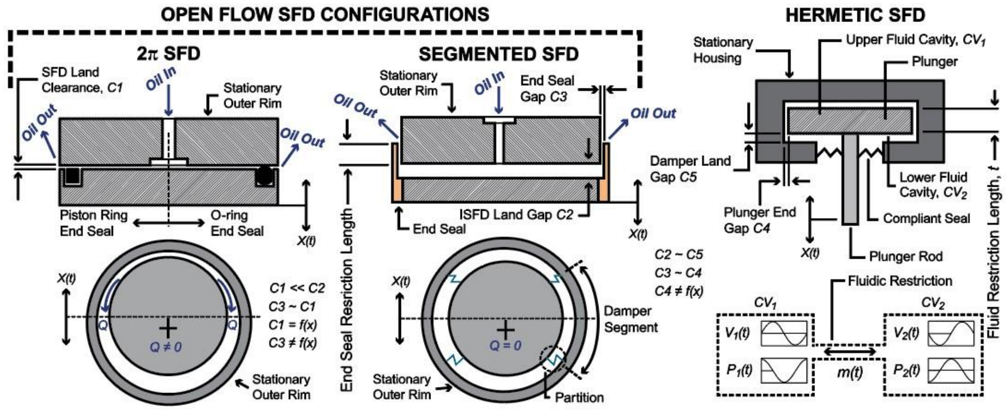

Figure 2. Turbomachinery open flow squeeze film damper configurations and hermetic damper concept [1]

Proposed work

The first year of this project will focused on developing a damper fluid with charged 2D nanoparticles capable of fast rotation and alignment when subjected to an electric field. This functionality will be evaluated and validated with basic laboratory tests. In parallel, a damper design will be developed with the capability of applying a voltage potential while directly leveraging the benefits of variable fluid properties to enhance its dynamic response. The second phase of the project will consist of building the damper prototype and characterizing its dynamic performance in a controlled-motion test rig shown in Figure 3. These tests, following well-established parameter identification methodologies, will provide the full set of force coefficients (stiffness *K*, damping *C*, virtual mass *M*) characterizing the damper dynamic load performance. The testing will include multiple frequency excitations to produce physical parameters (*K*, *C*, *M*) as a function of frequency of the damper with and without active control.

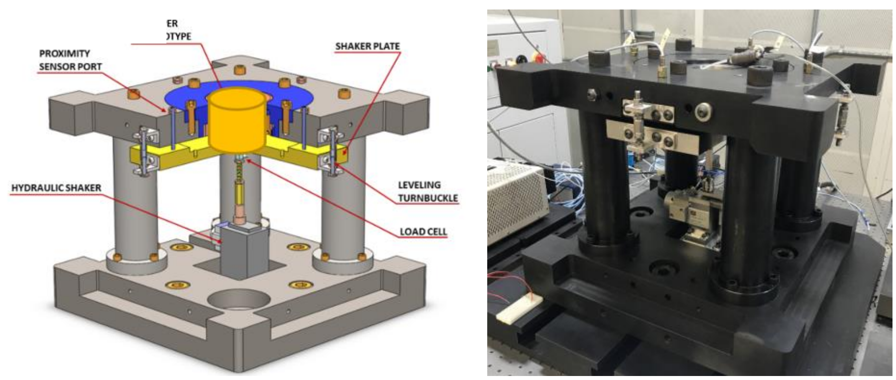

Figure 3. Picture and 3D Model of controlled-motion test rig including sensor locations and detailing main components.

Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 5,755
Tuition and fees	$ 13,275
Lab supplies	$ 4,570
Total	$ 50,000

References

[1] Ertas, B., and Delgado, A., Hermetically Sealed Squeeze Film Damper for Operation in Oil-Free Environments. ASME. *J. Eng. Gas Turbines Power* **2019**, 141, 022503-022513.