Smart Dampers for Turbomachinery Applications

CONTINUATION PROPOSAL

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Introduction

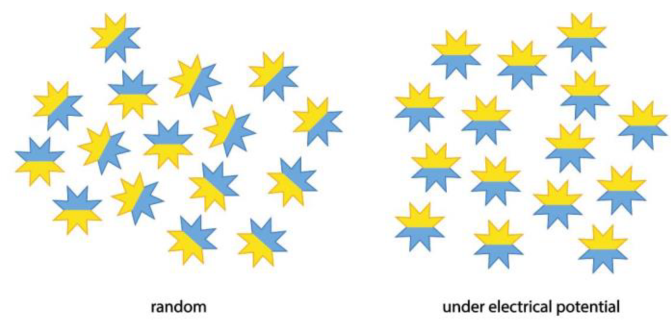

Figure 1. An electrical field aligns functionalized nanoparticles to create a rapid change in viscosity.

Electrorheological (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. 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.

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. Current HSFD designs produce frequency dependent damping, resulting in a reduction in available damping at higher frequencies. ER fluids enable damping to be increased at high frequencies without geometric modification to the damper. This concept is illustrated Figure 2.

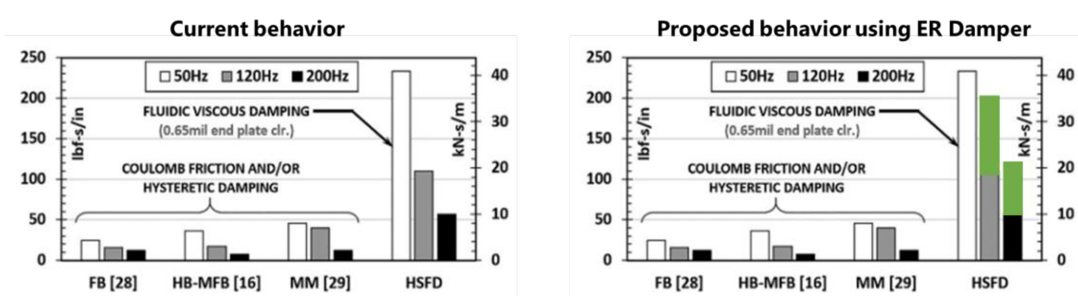

Figure 2. Increased damping performance at higher frequency compared to previous HSFD testing[1]

Status

In the first year, the damper fluid with charged 2D nanoparticles capable of alignment when subjected to an electric field was developed. This functionality was evaluated and validated with basic laboratory tests. In the second year, a hermetically sealed damper design was developed with the capability of applying a voltage potential while directly leveraging the benefits of variable fluid properties to enhance its dynamic response. An external wiring system utilizing an amplifier is also developed to control the voltage applied to the fluid, shown in Figure 4. The damper prototype develops fluidic stiffness and damping making it a prime candidate for active control. The prototype is also capable of controlling the developed fluid, observed through a change in damping and stiffness. Although minimal, the change highlights the future capabilities of this concept.

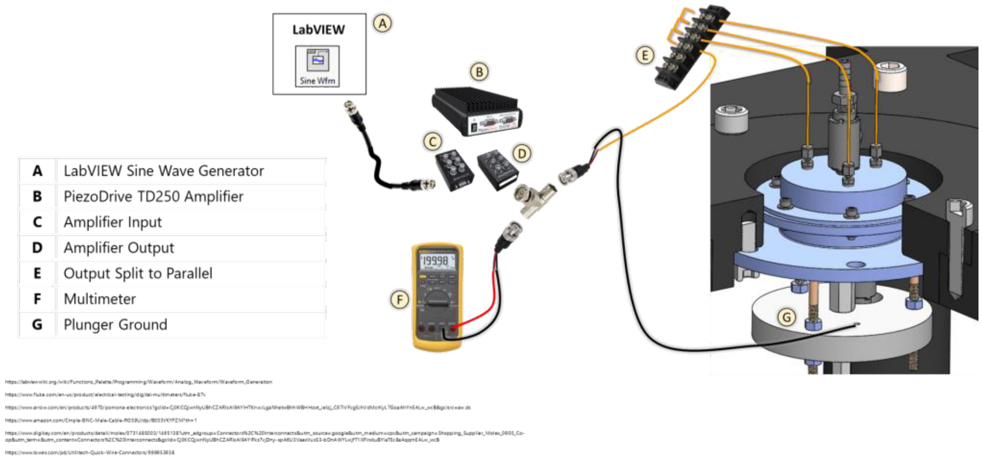

Figure 3: Current system wiring diagram electrifying the electrorheological fluid

Proposed work

The third phase of the project will consist of modifying current electrode design and increasing fluid compatibility with the nanoparticles. Dynamic performance is characterized in a controlled-motion test rig. 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.

Budget	
Graduate Student Payroll, 12 months @ $2250/month	$ 27,000
Fringe Benefits	$ 3,093
Tuition and fees	$ 17,349
Lab supplies	$ 2,558
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.