Generic summary

Magnetorheological (MR) fluids are non-Newtonian fluids consisting of ferromagnetic particles in a carrier/base oil. The randomly dispersed particles in the base oil become ordered in the presence of magnetic field of sufficient strength. That leads to a formation of ordered chain-like structures within the fluid. By principle and considering the manner in which the material is utilized in controllable semi-active devices, MR fluid based hardware can be classified into the following four categories: flow-mode, shear mode, squeeze mode and gradient pinch mode. While flow- and shear-modes have been extensively researched, studied and commercialized (BWI/Delphi's automotive MagneRide controlled chassis system that utilizes flow-mode MR dampers is one classic example of the commercialization of the technology), the remaining two modes (squeeze mode and gradient pinch mode) are less documented, and in the case of the gradient pinch (GP) mode the available knowledge is next to none. Of the four modes the gradient pinch mode is to be fundamentally different in the underlying principle. Carlson and Goncalves (2009) in their paper "An alternate operation mode for MR fluids — Magnetic Gradient Pinch " (MGP) revealed a novel variable orifice-like valve. The fundamental principle of this valve was to energize only a small portion of the fluid volume near surfaces of the magnetic poles, thus solidifying the fluid in these areas. Thus, the device was operated in a manner similar to that of a variable area orifice rather than a "classic" MR valve. In typical MR valves their performance relies on the ability to energize the entire volume of fluid in a flow channel in order to develop a yield stress in the material upon the development of a magnetic flux in the control gap in the direction perpendicular to fluid flow. The inventors indicated a potential of the pressure-driven mode by highlighting pressure vs. flow rate characteristics that differ from those of flow-mode and speculating the research on pinch mode would lead to high turn-up ratio devices. The authors wish to examine this hypothesis.

There is no doubt that the knowledge on pinch mode (or magnetic gradient pinch mode) is scarce incl. available references (4 published research papers). The mechanism behind pinch mode requires thorough studies in terms of both experimental work and modeling. It is necessary as poor knowledge in this area will definitely lead to errors and mistakes in the development of future pinch mode devices if any. Therefore, the authors indent to perform a number of experimental studies followed by extensive CFD-FEM (CFD – Computational Fluid Dynamics, FEM – Finite Element Method) modeling in order to arrive at a math-based description of the mechanism. It is planned then that the first part of the experimental series will lead to the confirmation of the mechanism followed by parametric studies to identify key variables governing the pinch mode physics. On the theoretical side, this project requires the application of interdisciplinary tools/methods such as CFD (Computational Fluid Dynamics) and FE (finite-element) electromagnetics for resolving fluid and magnetic field domains as well as to provide guidelines for a GP prototype valve and means for developing a lumped parameter model of the fluid flow in this mode. In the classic 2009 paper Carlson and Goncalves highlighted a simple 1D model of a GP valve that was based on the modified Wuest equation and utilized the equivalent and field dependent hydraulic diameter concept. Limitations of this model are not known nor the equivalent diameter estimation method.

The project topic is novel. Novel aspects of this project involve delivery of means (experimental results and math models) for providing an insight into the pinch mode governing physics and mechanisms. Moreover, the research project outcome may provide guideline for the development of a new category of semi-active pinch mode MR devices with a high turn-up ratio as well as fluid formulations.