Acoustic Characterization of Magnetic Fluids

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Introduction

Determine the acoustic sound speed behaviors of ferro fluids as functions of magnetic field, field orientation and acoustic frequencies. Previous investigations in June 2011 and May 2013 concerned the acoustic characterizations of magnetorheological fluids.

Experimental

Cell 4 in the National High Magnetic Field Laboratory at Florida State University was utilized for all of the experiments due to its high magnetic field capacity and relatively large size of the opening bore that can accommodate the acoustic test chamber in both normal and orthogonal orientations. The January 2014 experiments began with a water-filled magnetic fluid chamber as the water was used for calibration with or without a magnetic field presence. Initial test runs were conducted in the orthogonal direction from 0 to 2 T and back to 0 T in 0.05 T steps which was later changed to 0.1 T steps. These tests were repeated for the normal direction. A second series of tests were conducted for both orientations from 0 to -2 T and back to 0 T. We wanted to repeat the lower magnetic field experiments that we did in June 2011 and May 2013 with magnetorheological (MR) fluid to see if the sound speed, and hence bulk moduli, varies as functions of magnetic field intensities and field orientation. The magnetic fluids tested included a MR fluid from Lord Corporation and a Ferrofluid from Ferrotec where the manufacturer's properties of both fluids are provided in Table I.

Table I: Magnetic fluid properties

Fluid	MR Fluid	Ferrofluid
Manufacturer	LORD Corporation	Ferrotec
Fluid Name	MRF-117_AX	EMG 900
Particle Material	Iron	Magnetite
Mean particle diameter	5.6 μm	10 nm
Volume Fraction	.17	.18
Carrier Liquid	Hydrocarbon Oil	Hydrocarbon Oil
Viscosity	35	60 mPa-s
Density	1.99 x 10^3 kg/m^3	1.74 x 10^3 kg/m^3

Results and Discussion

The MR fluid had a greater velocity in the normal (∥) orientation than the orthogonal orientation (⊥) while the Ferrofluid showed minimal change due to the orientation and increase in magnetic field intensity. The measured data showed that in the MR fluid that as the magnetic field increases the sound speed of the fluid also increases for both orientations. This behavior is attributed to the alignment of the iron particles with the magnetic field lines. As the magnetic field increases the amount of clustering along the field lines increases causing the fluid to become stiffer and act more like a solid. While the agglomeration was not expected, a hysteresis was observed for both fluids. However, the Ferrofluid showed little change as functions of magnetic field or orientation.
The MR fluid reached saturation at about 2 Tesla but when the magnetic field was decreased the hysteresis effect could be seen. For both orientations the velocities did not decrease as the field was decreased. This suggests that in the MR fluid the iron particles maintained its alignment as the field is removed. While the ferrofluid showed negligible anisotropy, the MR fluid reached a level of 9 % anisotropy at 2 T. The level of anisotropy between the two orientations remained consistent as the magnetic field was removed. There was also negligible frequency dependence of the speed of sound for either fluid in both orientations.

Acknowledgements

This work was supported by a NAVSEA Division Newport ILIR. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy