Acoustic Characterization of Magnetorheological Fluids

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Introduction

Determine the acoustic sound speed behaviors of magnetorheological (MR) and ferro fluids as functions of magnetic field, field orientation and acoustic frequencies.

Experimental

The May 2013 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 (same type of magnetorheological (MR) fluid but not the same fluid used in the first experiments). After we had conducted the first set of experiments in 2011, we found that some data discrepancies as it appeared that we likely over drove the magnetic field such that the iron particles clamped themselves together and separated from the host fluid. For our May 2013 tests, the MR fluid in the acoustic chamber was changed out between each direction change in order to ensure that the iron particles stayed in solution.

Results and Discussion

There appears to be a unit shift in the normal direction responses at 0.7 T in the increasing magnetic field while the decreasing field from 2 T to 0 shows very little change in sound speed which suggests that the MR fluid stayed solid with the decreasing field instead of returning to a pure fluid state. The 0 to –2 T response shows the variation that we have been seeking over the magnetic field strength as the sound speed varied from 1300 m/s at – 2 T to 1050 m/s at –0.1-0.2 T. However the return response from –2 T back to 0 T, shows a relatively constant sound speed until –1.3 T when the response abruptly drops from 1300 m/s to 1200 m/s. There also appears to be more differences in the individual frequency responses in each of the four radial direction measurements than expected as the frequency should remain constant regardless of the magnetic field. In the 0 to 2 T orthogonal direction response, the sound speed has an initial drop from 1400 m/s to 1080 m/s with a 0.1 T field which slowly rises to 1125 m/s at 2 T. However the 2 T to 0 T response appears to maintain the 1125 m/s sound speed which again suggests that the MR fluid has remained stiff. The 0 to –2T response shows the same initial decrease from 1400 m/s without a magnetic field to 1060 m/s and slowly rising to 1100 m/s with the return from – 2 T to 0 remaining fairly constant at 1100 m/s.

Conclusions

The measured results do show that the sound speed is faster in the normal (radial) direction than in the orthogonal direction. In fact the ratio of the sound speed for the two directions is on the order of magnitude desired for acoustic metamaterial applications.

Undesirably, it appears that a residual magnetic field condition exists when returning back to a lower magnetic field such that it is not possible to “dial in” a desired sound speed at a specific applied magnetic field. It appears that there is a magnetic hysteresis in the MR fluid after the field is decreased.

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