Behavior of Magneto-Rheological Fluids Subject to Impact and Shock Loading

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Abstract

Investigations on the design of controllable magnetorheological (MR) fluid devices have focused heavily on low velocity and frequency applications. The extensive work in this area has led to a good understanding of MR fluid properties at low velocities and frequencies. However, the issues concerning MR fluid behavior in impact and shock applications are relatively unknown.

To investigate MR fluid properties in this regime, MR dampers were subjected to impulsive loads. A drop-tower test facility was developed to simulate the impact events. The design includes a guided drop-mass released from variable heights to achieve different impact energies. The nominal drop-mass is 55 lbs and additional weight may be added to reach a maximum of 500 lbs. Throughout this study, however, the nominal drop-mass of 55 lbs was used. Five drop-heights were investigated, 12, 24, 48, 72 and 96 inches, corresponding to actual impact velocities of 86, 127, 182, 224 and 260 in/s.

Two fundamental MR damper configurations were tested, a double-ended piston design and a mono-tube with nitrogen accumulator. To separate the dynamics of the MR fluid from the dynamics of the current source, each damper received a constant supply current before the impact event. A total of five supply currents were investigated for each impact velocity.

After reviewing the results, it was concluded that the effect of energizing the MR fluid only leads to "controllability" below a certain fluid velocity for the double-ended design. In other words, until the fluid velocity dropped below some threshold, the MR fluid behaved as if it was not energized, regardless of the strength of the magnetic field. Controllability was defined when greater supply currents yielded larger damping forces.

For the mono-tube design, it was not possible to estimate the fluid velocity due to the dynamics of the accumulator. It was shown that the MR fluid was unable to travel through the gap fast enough during the initial impact, resulting in the damper piston and accumulator piston traveling in unison. Once the accumulator bottomed out, the fluid was forced through the gap. However, due to the energy stored in the accumulator and the probable fluid vaporization, it was impossible to determine the fluid velocity and in many cases the damper did not appear to become controllable.

In conclusion, the two designs were compared and general recommendations on designing MR dampers for impulsive loading were made. Possible directions for future research were presented as well.