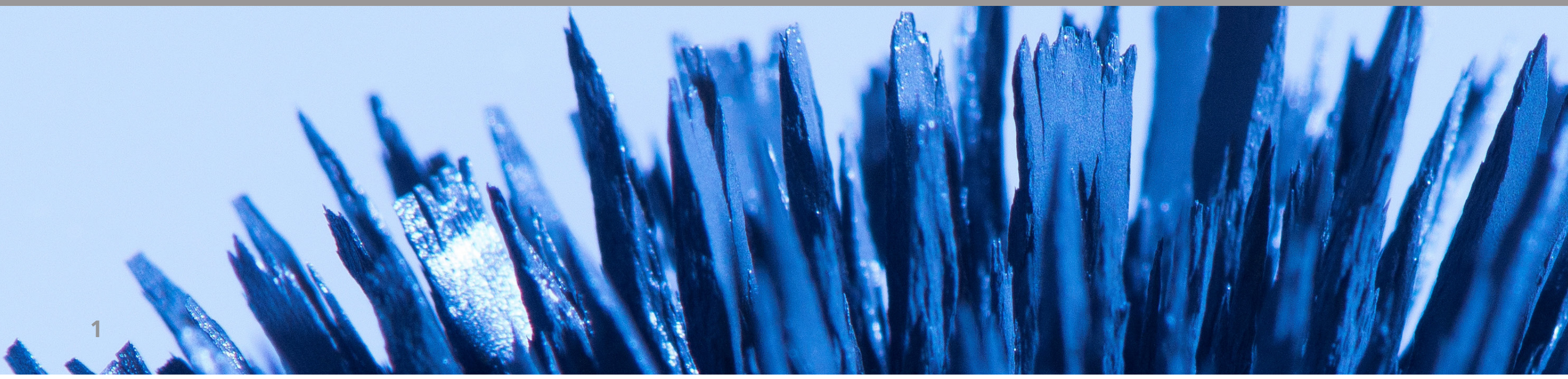
FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH ISC



1 *Magnetorheological fluid MRF © Fraunhofer ISC*

ADAPTIVE VIBRATION DAMPING WITH MAGNETORHEOLOGICAL FLUIDS

Fraunhofer-Institut für Silicatforschung ISC
Neunerplatz 2
97082 Würzburg
Germany

Contact
Center Smart Materials CeSMa

Dr. Holger Böse
Phone +49 931 4100-203
holger.boese@isc.fraunhofer.de

www.isc.fraunhofer.de
www.cesma.de

The problem

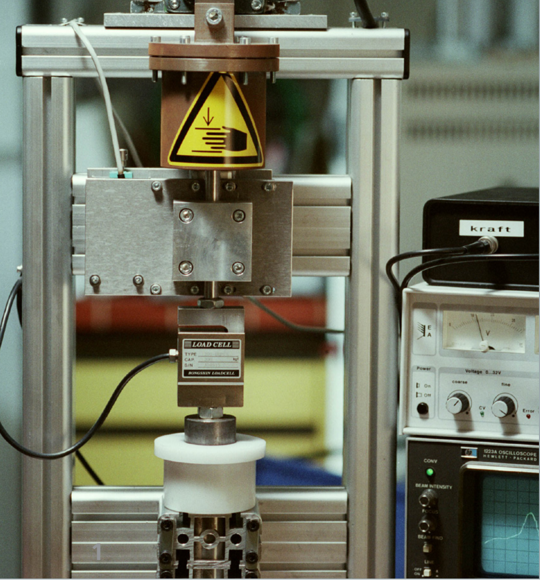
Vibrations occur in many technical systems. They vary in strength according to the operational status of the system and are experienced as unpleasant. This is particularly the case in transportation technology, for instance in cars or rail vehicles, but it also happens on bridges. Other vibrating systems can be found in machine tools and in buildings. Vibrations may cause damage, as they subject the materials to increased wear and tear, and at worst they can cause destruction or failure of the system. They also constitute a source of annoyance for machine operators and of reduced comfort for the occupants of vehicles.

The passive dampers that are normally used can only remove vibrations in certain operating conditions. In many cases, however, different damping forces are needed in different operating conditions. A high damping factor is required for a vibrating system that excites resonance, for instance, whereas damping should be as low as possible when the vibration frequency deviates widely from the resonance frequency.

Possible solutions

Magnetorheological fluids (MRFs) are suspensions of fine magnetically polarizable particles in a carrier liquid. The consistency of an MRF is changed dramatically, rapidly and reversibly when exposed to a magnetic field. Materials of this kind thus provide the ideal basis for adaptive vibration damping. The drastic change in the rheological properties of the MRF can be utilized for adaptive vibration damping in various ways.

In shear mode, the MR fluid is sheared between two parallel plates, the shear force being affected by the magnetic field. In flow mode, the flow resistance of the MR fluid is controlled via the magnetic field as it flows through a channel. Finally, squeeze mode produces a damper in which the MR



fluid is extruded from the gap between two plates. In this case, too, the damping force is influenced by the strength of the applied magnetic field.

Commonly the damping force of a MRF damper is controlled by the magnetic field generated by an electromagnet. This operation principle requires a continuous supply of electric energy for all elevated damping forces. In case of a power failure the damper returns to the lowest damping force. An improved fail-safe behavior is achieved by the advanced MRF damper. Its magnetic circuit contains a permanent magnet beside the electromagnet. The permanent magnet generates a magnetic field without any electric energy supply. The magnetic field is optionally increased or decreased by the electromagnet. The damping force exerted in the piston motion cycle which is controlled correspondingly is exhibited in Figure 4.

Another novel MRF damper mechanism is realized with a switchable hard magnet in the magnetic circuit integrated in the piston. The magnetization of the switchable hard magnet is controlled by short current pulses in the coil of the electromagnet. The magnetization of the hard magnet and the corresponding damping force are maintained until the next current pulse. This mechanism is very energy-efficient because electric energy must be supplied only for the change of the damping state.
An adaptive MRF damper is a mechatronic system. To produce the desired effect with this system, it is particularly important to achieve the best possible balance between the magnetorheological fluid and the other system components such as the damper design, the magnetic circuit and the control unit. Commonly the damping force of a MRF damper is controlled by the magnetic field generated by an electromagnet. This operation principle requires a continuous supply of electric energy for all elevated damping forces. In case of a power failure the damper returns to the lowest damping force. An improved fail-safe behavior is achieved by the advanced MRF damper shown in Figure 1. Its magnetic circuit contains a permanent magnet beside the electromagnet. The permanent magnet generates a magnetic field without any electric energy supply. The magnetic field is optionally increased or decreased by the electromagnet. The damping force exerted in the piston motion cycle which is controlled correspondingly is exhibited in Figure 2.

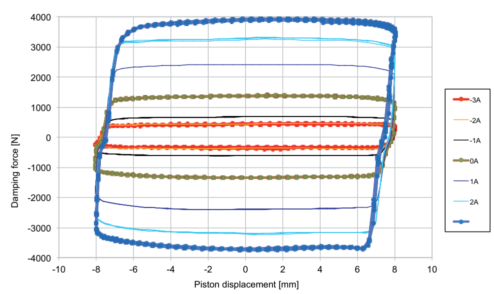
Another novel MRF damper mechanism is realized with a switchable hard magnet in the magnetic circuit integrated in the piston (Figure 3). The magnetization of the switchable hard magnet is controlled by short current pulses in the coil of the electromagnet. The magnetization of the hard magnet and the corresponding damping force are maintained until the next current pulse. This mechanism is very energy-efficient because electric energy must be supplied only for the change of the damping state. Figure 4 shows the complete MRF damper.

The operational properties of the MR fluid can be extensively modified and adapted to requirements by altering its design and the basic materials selected.

The essential properties of the MRF are its flow behavior without a magnetic field and the shear stress that can be achieved in a field of a certain strength. A further factor to be taken into account, to avoid any incompatibility with construction materials, is the selection of carrier liquid. MR fluids with a variety of the carrier liquids as their basis have been developed at the ISC. They exhibit substantially enhanced shear stress in the magnetic field (see Figure 4), along with high sedimentation stability and good redispersibility.

ISC areas of competence

- Development of adaptive vibratio dampers up to functional models
- Support during the ensuing product-development phase
- Development of adapted MR fluids for specific customer applications



Damping force of the MRF damper with permanent magnet at various coil currents

1 *MRF damper in squeeze mode*
2 *Modular MRF damper*
3 *MRF absorber with integrated permanent magnet*