FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH ISC

Magnetorheological Elastomer (MRE) disc on a solenoid MRE-valve in the opened 1 and closed 2 state

MAGNETORHEOLOGICAL ELASTOMERS WITH CONTINUALLY ADJUSTABLE HARDNESS

Elastomers are soft polymers with high expansibility, widely used in numerous technical applications including gaskets and vibration-damping bearings. One of the key properties of elastomer materials is their hardness, which can be adapted to the specific application. The hardness can be adjusted through the choice of material and the degree of chemical crosslinking.

In many cases, it would be of great benefit to be able to control the mechanical properties of the elastomer during the application. For instance, the vibration-mitigating effect of the material could be adapted to varying conditions. This is important when vibrations vary in frequency.

Another example relates to the haptic sensation on touching a surface. Selectively modifying the hardness of an elastomer surface makes it possible to change the feel of the surface.

Behavior like this can be achieved with magnetorheological elastomers (MREs). In this novel class of materials, mechanical properties such as the storage and loss modulus can be extensively controlled via a magnetic field. MREs are composite materials that consist of an elastomer matrix and magnetizable particles.

When a magnetic field is applied, the magnetic particles are polarized and exert forces on one another that cause the material to stiffen. When the magnetic field is switched off, the MRE returns to its original, softer state.

Soft MREs also exhibit a shape memory effect. A shaped body made of this material can be deformed by the magnetic field or an external force in the field, and resumes its original shape when the field is deactivated. This effect can be put to use in actuators, for example.

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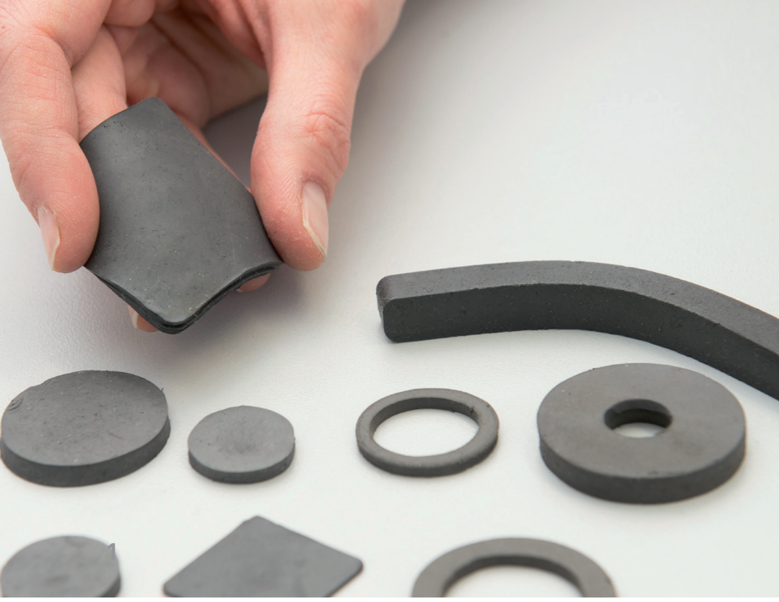


It is also possible to influence the microstructure of the MRE by applying a magnetic field during the chemical crosslinking of the elastomer. This produces a material with anisotropic mechanical properties. Anisotropy also affects the modification of the mechanical properties during technical applications of the MRE.

The magneto-mechanical properties of the composite material can moreover be adjusted by the choice of component materials (magnetizable particles, matrix elastomer, additives) and the manufacturing process. MREs based on a variety of component materials have been developed at the Fraunhofer ISC. Silicone is a preferred material for the elastomer matrix, while iron is usually chosen as the particle material.

MRE components can be shaped to various geometries to meet requirements. The decisive factor for practical application is to integrate the shaped body in a magnetic circuit so that a sufficiently strong magnetic field can be produced in the MRE.

The elastic and viscous (damping) properties of MRE in terms of the storage and loss modulus, respectively, can be controlled by the magnetic field strength. This stiffening effect may be exploited for variable damping and also for haptic applications.

The other fascinating materials effect is the actuation capability of the MRE. Controlled by the strength of the magnetic field, the MRE expands or shrinks. This electrically switched deformation can be used in novel valves. For this purpose, a ring-shaped MRE body is inserted in the magnetic circuit. Such valves can perform more complex motions than conventional valves. The MRE ring expands radially in the magnetic field.

Another possible application of MRE is a haptic actuator. When a magnetic field is applied, the MRE plate is deformed. This strong deformation is sensitively perceived by the finger touching the MRE plate. This material-based technology can be used as a base for new human-machine interfaces (HMI).

Areas of application

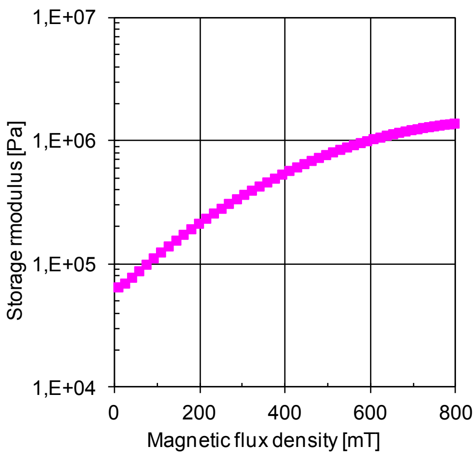
The reversible stiffening of MREs in a magnetic field can be put to use for technical applications such as the following:

- Flexible bearings with adjustable hardness
- Adaptive dampers for use in vehicles, industrial machinery, etc.
- Controllable gaskets, valves
- Haptic interfaces and devices (force feedback)
- Surfaces providing variable tactile feedback
- Artificial muscles, actuators

Different applications require the MRE to have different property profiles. This can be achieved by modifying the composition of the composite material.

Fraunhofer ISC areas of competence

- Development of magnetorheological elastomers for specific customer applications
- Characterization of application relevant material properties
- Assistance with system development of new products



Increase of storage modulus of MRE with magnetic flux density

1 Shaped MRE parts of various geometries 2 Magnetorheological Elastomer (MRE) disc on a solenoid MRE-valve in the opened state