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Original Research Article

Test setup for examination of magneto-mechanical properties of magnetorheological elastomers with use of a novel approach

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ABSTRACT

This paper presents an experimental setup aiming at evaluating the magneto-mechanical and damping properties of the thermoplastic magnetorheological elastomer (MRE). The idea of the system is to create controllable conditions similar to those present in a vehicles and other mechanical constructions and to make it possible to determine parameters only relating to the MRE material itself. The test stand is based on four samples stimulated with highly effective Halbach arrays. The upper plate of the test stand is excited with use of a modal shaker to assure a constant impact force value during each test. This enables control of impact character and allows automation of the test stand. The last section of this paper presents preliminary test conducted to find the resonance frequency dependence on the impact force of the system for a constant value of magnetic field. The results indicate non-linear behavior of the material and therefore exclude use of the simple Kelvin-Voight model based approach for damping properties determination, that is a commonly used model for description of different materials.

1. Introduction

Magnetorheological elastomer (MRE) is a material presented more than 30 years ago [1] as a development of the magnetorheological fluid. It is called smart material as its properties can be changed by application of an external magnetic field that reversibly modifies its mechanical and rheological properties. The material is usually made out of three main components: ferromagnetic particles, non-magnetic elastomer matrix and additives (i.e. plasticizers, sol–gels covers for ferromagnetic particles and other components modifying structure of the MRE). Particles can have from few to few hundred micrometers in diameter and various shape like sphere, flake, nugget, etc. [2–8]. The matrix can be made out of natural rubber, silicone rubber or thermoplastic elastomer with additives, for example paraffin oil [2,7–11]. The particles inside the matrix can be randomly dispersed or the material can be polarized to obtain a structure of particles oriented parallel to the direction of magnetic field direction. Polarized material, also

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called anisotropic MRE, is characterized by higher magnetorheological effect under magnetic stimulation than in case of an isotropic one, but only in the direction of polarization [12].

Magnetorheological elastomers can operate in a wider range of frequencies than MR fluids and may transfer large shear deformations [13]. Also they have response time counted in milliseconds [14]. Effectiveness of MRE as a damping material for vibration isolation of structures was presented in paper [15]. There have been many proposals on possible application of the MRE, most of them concern vibration absorbers, insulators, sensing devices and other similar solutions. MRE is applied in those devices as controllable semi-active element, for example in adaptive tuned vibration absorbers (ATVAs) [16–18], dynamic vibration absorbers for multiple story building structures [19–21], vehicle seat vibration isolator [22] and engine vibration isolator [23]. It was determined that devices like those mentioned can increase the natural frequency of the system more than two times [24].

The test stand presented in this paper is based on the idea and setup described in papers [25,26], where the setup was constructed to present a method for determining the usefulness of MRE in active suspension systems. The idea of the test stand was a two degree of freedom setup where examined material worked as a suspension for the excited mass. Such system allowed determination of material properties through analysis of frequency response function (FRF) obtained from force peak and acceleration of the system. Magnetic stimulation was achieved through double circular dipolar Halbach arrays that were 7 mm high and could generate a magnetic field of 50 up to 150 mT. Excitation was obtained with a manually operated modal hammer. Similar construction, a vibration isolator, is designed for vibration absorption in buildings [27,21].

In this paper, the new test stand for determining the usefulness of the magnetorheological elastomers is describe and theoretically and experimentally investigated. Elements of the previously developed test stand were used as a base for development of a new version. Modifications of the test stand focused on the magnetic field generators, sensors, method of excitation and software. Finally new software for control and data processing was prepared to enable live data analysis, inspection and control of the system. In the paper preliminary results are shown to present possible use of the test stand. Further results, their analysis and discussion will be published in a separate paper. This division is dictated by the need to separate analysis of the test stand and the magnetorheological elastomer which can be tested with use of presented system.

2. Test setup

2.1. *Idea of the test stand*

The idea of the test stand is a two degree of freedom system. Mass M_1 is suspended with use of the MRE, mass M_2, relatively bigger than M_1, is suspended on the spring K. It is done to obtain separate resonance frequencies for both of masses.

This idea is visualized in Fig. 1, where M_1 is excited mass, MRE is tested material dependent from magnetic field B, M_2 is base of the test stand suspended on spring K. The system is excited with force F.

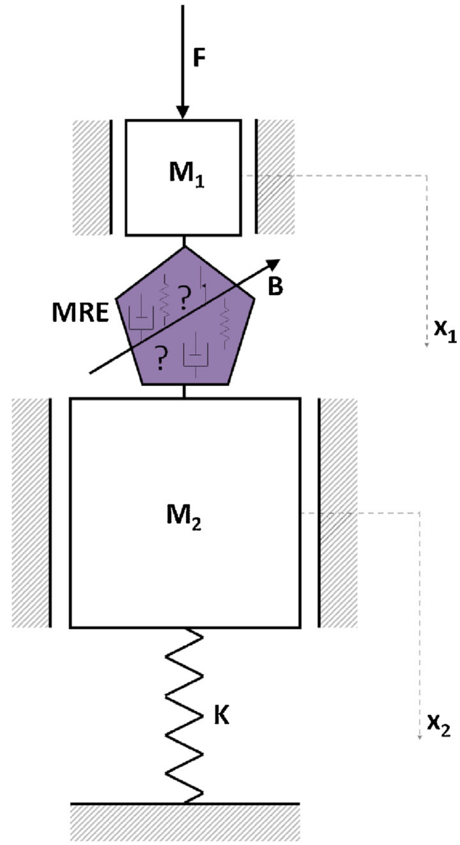

Fig. 1 – Idea of the test stand.

Scheme presented in Fig. 2 shows practical realization of the idea from Fig. 1. The piece of MRE is being sheared between two plates, as the upper one is excited with force impulse. It can be seen that the applied force is perpendicular to the axis of the setup and therefore it can be considered that shearing with no bending or any other similar phenomenons occur. Samples are shared between upper and base plates, mass M_1 and M_2. During the experiment acceleration of the upper and base plates, and excitation force have to be recorded. Displacement on the upper plate relative to the base one can be recorded. On the basis of those signals the damping of the system can be determined. Also frequency response function can be obtained that can be used for determination of further parameters.

Test stand is thought to work with four samples located symmetrically on the test stand to ensure linear movement of the mass M_1 in the direction of excitation. First of all, four samples are used to ensure stability of the upper plate. Otherwise the mass M_1 would have a rocking possibility during the experiment which would introduce additional loading to

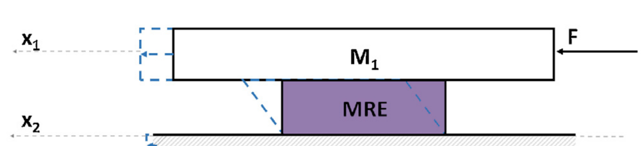

Fig. 2 – Idea of working principles of the test stand.