Materials Science and Engineering B 166 (2010) 94–98

Contents lists available at ScienceDirect

Materials Science and Engineering B

journal homepage: www.elsevier.com/locate/mseb

Magnetorheological elastomer-based quadrupolar element of electric circuits

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ARTICLE INFO

Article history:
Received 3 July 2009
Received in revised form 12 October 2009
Accepted 15 October 2009

Keywords:
Quadrupole
Magnetorheological elastomer (MRE)
Control current
Outlet voltage
Transverse magnetic field

ABSTRACT

The author of this paper describes a quadrupolar electric circuit element (*Q*) based on electroconductive magnetorheological elastomer. It is shown by means of the experimental setup presented in the paper, that the electrical resistances, measured at the gates of *Q*, decrease with the increase of the strength *H* of the transverse magnetic field. But, for intensities of the control current (I_c = const.) injected into *Q* along the direction normal to $\vec{H}$, the voltage at the outlet of *Q* decreases as the strength of the magnetic field increases. The as-obtained experimental results are presented and discussed.

1. Introduction

Magnetorheological elastomers (MREs), alongside of magnetorheological suspensions (MRSs) [1,2], belong to the category of materials called magnetically active materials in Ref. [3]. Their physical, in general, and viscoelastic properties, in particular, are influenced by an externally applied magnetic field [3–7]. This latter property of the MREs is used in achieving various types of attenuators of vibrations and mechanical shocks [7–10] (working, however, on a different physical basis, compared to those using the effect known as magnetomechanical damping [11]).

It has been shown recently [12] that MRE can be used as dielectrical material in devising electrical condensers whose capacity can be modified under a magnetic field, due to the magnetostrictive effect [13]. It is shown in Refs. [14–18] that MRSs with additives are electroconductive. The electrical conductivity of these MRSs depends on the composition and intensity of the magnetic field applied. This property of MRSs can be used in devising magnetoresistors [19], Hall sensors [20], thermosensors [21], etc.

It has been recently shown that MRSs modify their conductivity by compression [22,23], heating [24], under the influence of an external magnetic field [25].

Taking further this line of research, the following part of this paper shows that electroconductive MREs can be used in devising magnetoresistors and/or generators of steady voltages controlled by a transverse magnetic field.

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doi:10.1016/j.mseb.2009.10.020

2. Description and structure

The quadrupolar element of electric circuit (*Q*) based on magnetorheological elastomer is achieved from a parallelipipedic (80 mm × 15 mm × 6 mm) body, formed of electroconductive MRE, provided at its ends, with two electrodes (called control electrodes) and, lengthwise, with another two electrodes, called outlet electrodes. A longitudinal section through *Q* is shown in Fig. 1.

The distance between the electrodes 5 is of 80 mm ± 10%, while the distance between the electrodes 6 is of 6 mm ± 10%.

3. Magnetorheological elastomer (MRE)

MRE is produced by using the procedure described in Ref. [25]. It contains (in vol.%) 40% silicone rubber (RTV 3325-Bluestar Silicones SAS), 5% catalyst (C, 60R Rhône-Poulenc), 20% iron microparticles (IMs), 20% graphite microparticles, and 15% silicone oil (SO, Merck). The IMs were obtained by thermal decomposition in SO of iron carbonyl particles (Merck, diameters ranging between 4.5 and 5.4 μm and Fe content exceeding 97%), according to the procedure described in Ref. [26].

The particles obtained by thermal decomposition of iron carbonyl were studied with Olympus optic equipment (Fig. 2).

We can say that 65% of diameter ranges between 0.35 and 0.60 μm. The mean diameter of the iron microparticles is of 0.260 μm. Graphite microparticles (G's) are obtained by grinding, graphite electrodes (Kahler, Bratislava) in a mill with palettes. Fine particles having the diameter ranging between 30 and 40 μm resulted after sieving.

The mixture consisting of SR, C, I, G and SO was introduced in the quadrupolar element cavity (position 1 in Fig. 1); a parallelipipedic

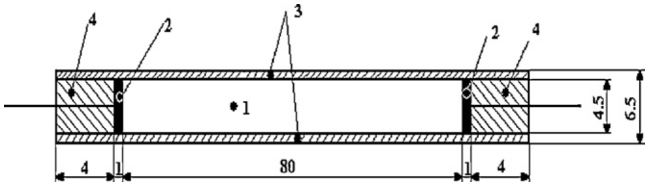

Fig. 1. Quadrupolar element of electric circuit based on MRE (longitudinal section): 1 and 2, control terminals; 3 and 4, outlet terminals; 5, control electrodes (10 mm × 0.5 mm); 6, outlet electrodes (5 mm × 6 mm); 7, cavity (80 mm × 15 mm × 6 mm) with electroconductive MRS; p_1 and p_2, plexiglass plates (100 mm × 20 mm × 1 mm); d_1 and d_2, plexiglass distancers (25 mm × 5 mm × 6 mm).

elastic body, with magnetic and electroconductive properties was obtained in 24 h.

4. Experimental device

The experimental device for the study of the electric circuit quadrupolar element (*Q*) is shown in:

- Fig. 3a, for the case in which *Q* fulfils the function of quadrupolar magnetoresistor, and in
- Fig. 3b, for the case in which *Q* is an active element of electric circuit.

It includes (Fig. 3a) an electromagnet, consisting of a core A and a coil B, between whose poles *Q* is fixed. An ohmeter Ω is connected to each of the terminals 1 and 2 and 3 and 4 of *Q*.

According to Fig. 3b, the device *Q* was disconnected from the ohmeter Ω. The current source S_c is connected to terminals 1 and 2. But the terminals 3 and 4 are connected to the voltmeter *V*. The value *H* of the magnetic field strength is measured function of I_e, generated by the source S_e, with the gaussmeter GM-04 (not represented).

5. Experimental results and discussion

The setup shown in Fig. 3a is achieved. The resistance R_T between the terminals 1 and 2 of *Q* and the resistance R_L between the terminals 3 and 4 are measured as a function of the magnetic field strength ($0 \le H \le 150$ kA/m). The results are plotted in Fig. 4.

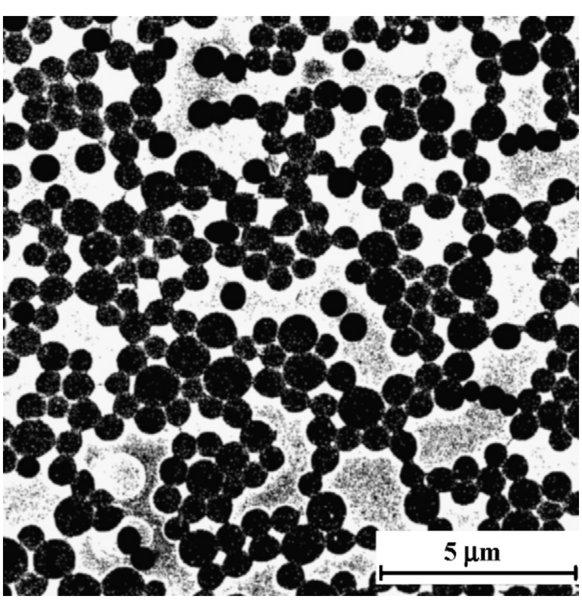

Fig. 2. Optical micrograph of the as-resulted IMs.

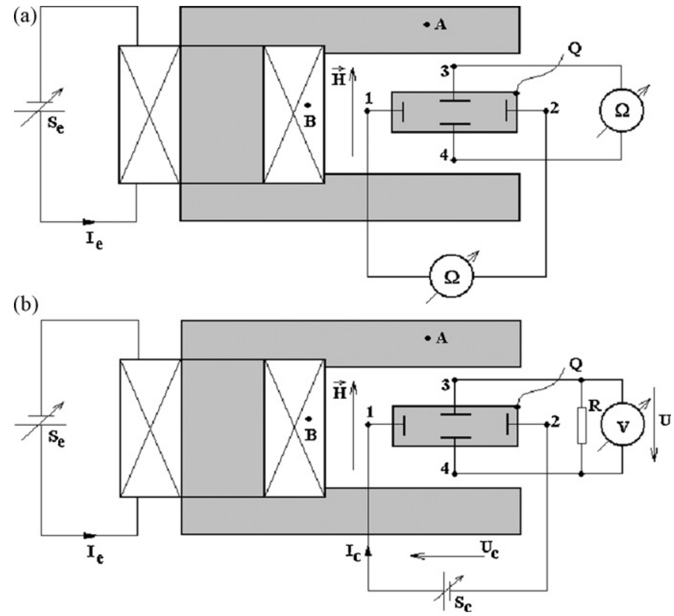

Fig. 3. Experimental device (the general operational layout) for *Q* having the function of: (a) quadrupolar magnetoresistor and (b) active electric circuit element. A, magnetic core; B, coil; S_e, dc voltage supply (max. 30 V); Ω, ohmmeter (UT-70A); S_c, dc current source (max. 1 A); *V*, electronic voltmeter (UT-70B), I_e, I_c, electric currents; *Q*, quadrupole element; *H*, magnetic field strength; *U*, outlet voltage; U_c, control voltage; *R* = 10 kΩ-electric resistance.

5.1. Denoting

$$\beta_{\mathrm{ex}} = \frac{R_{\mathrm{T}}}{R_{\mathrm{L}}}, \tag{1}$$

from Fig. 4 results that for *H* = 0, this ratio is close to 63.

The resistances R_T and R_L are assimilated to a linear resistor. Then, $R_T = \rho L/s$ and $R_L = \rho l/s$ where ρ (assumed constant) is the resistivity of the MRE, *L* is the distance between the electrodes 5 (Fig. 1), *S* is the surface area of the electrodes 5, *l* is the distance between the electrodes 6 (Fig. 1) and *s* is the area of their surface; at *H* = 0, L_0 = 80 mm, l_0 = 6 mm, S_0 = 1.5 mm × 0.5 mm

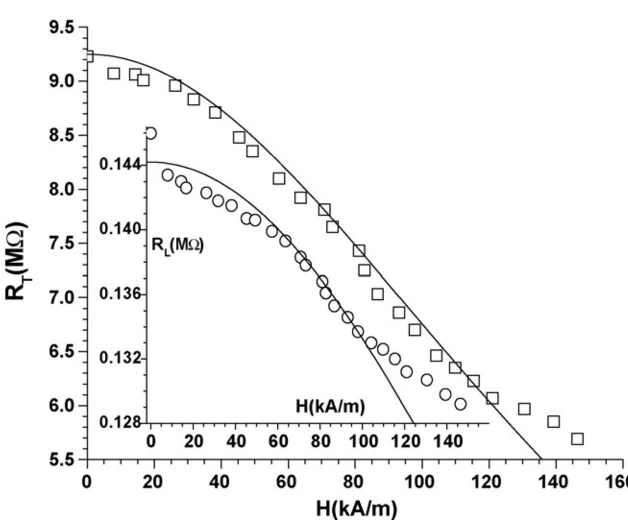

Fig. 4. The electric resistances R_T and R_L of *Q* as a function of the strength *H* of the transverse magnetic field; symbols (□, ○) – experimental values, solid line – theoretical values.