World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Production, Microstructure and Properties of Carbonyl Iron Powder Magnetorheological Elastomers

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Abstract: In this paper studies on carbonyl-iron powder magnetorheological elastomers (MREs) microstructure in respect to their magnetic and mechanical properties are reported. MREs were obtained from a mixture of polyurethane gel and carbonyl-iron particles cured in a magnetic field of 300 m. T. Three - dimensional digital microscope was used to observe the formation process of micro-particle chain column structure of magnetorheological elastomer.
Keywords: Magnetorheological elastomers, microstructure, Shear modulus.

1. INTRODUCTION

Magnetorheological elastomers (MREs) are materials with rheological properties which can be changed continuously, rapidly and reversibly by an applied magnetic field. They are solid analogs of magnetorheological fluids (MRFs) and consist mainly of magnetic particles and a matrix. The magnetic particles were uniformly dispersed in the matrix, and a certain amount of catalyst was added to prepare the MRE. Based on the characteristics of the carbonyl iron powder, carbonyl iron powder was selected as the MRE magnetic particles. The matrix mainly refers to polymer materials, including natural silicone rubber and synthetic silicone rubber. A strong external magnetic field is applied before the curing process of the polymer [1-4]. The field induces dipole moments within the particles, which seek minimum energy states, Chains of particles with collinear dipole moments are formed and curing of the polymeric matrix material locks the chains in place [1]. In this orientation, the particles can form separate chains in three-dimensional simple lattice structures or even more complicated. The advantage of MREs is that ferrous particles are not subject to sedimentation. The thermal stability of MREs is greater than for MRFs and their resistance to degradation is higher. Structures, where particles have multiple interaction points. This is the main difference between MRE and MRF structures which results in their elevated properties [5].

2. MATERIALS AND MEASUREMENT METHODS

The magnetorheological elastomer matrix material used in this experiment is 184 silicone rubber from Dow corning co., ltd., as shown in figure 1. 184 silicone rubber is a suite of two compounds consisting of high temperature vulcanized composite, including matrix and active agent (catalyst), according to the mass ratio of 10: 1. 184 silicone rubber is cured in the temperature range of 25 ~ 150 ℃ without secondary curing. The widest operating temperature range is - 55 ~ 200 ℃. The silicone rubber also has low toxicity, no heat release during curing, no need of special ventilation conditions, no corrosion, excellent anti-oxidation aging, light aging and other properties, long service life of silicone rubber products, and long-term storage.

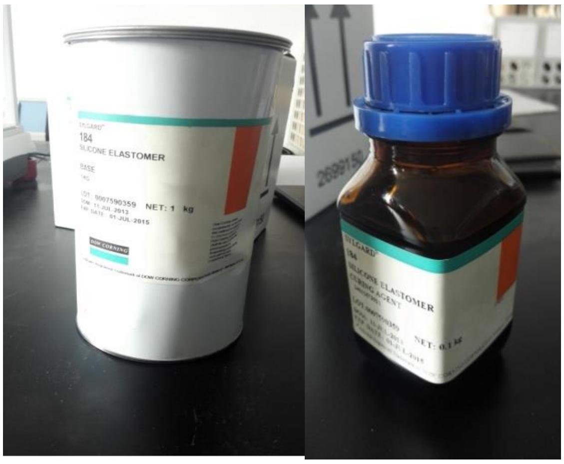


Fig. 1 184 silicone rubber

Fig. 2 magnetorheological elastomers

MRE is mainly composed of magnetic particles and matrix. The magnetic particles were uniformly dispersed in the matrix, and a certain amount of catalyst was added to prepare MRE. Firstly, using the balance to take the appropriate quality of carbonyl iron powder and 184 silicone rubber, into the mortar by mixing and mixing for 10min, the mixture into the vacuum oven, the extraction of air for 10min, filter out the air in the mixture; Then,add 10% of the catalyst with a volume ratio of 184 silicone rubber to the kneaded mixture. The mixture was stirred for 10 min. The kneaded mixture was placed in a vacuum oven again, the air was taken for 10 min, and the air in the agitator was filtered again. Finally, the mold was cleaned using an ultrasonic cleaner, and then the mixture was poured into a mold and placed in a homemade magnetic field device. The whole apparatus was placed in a vacuum oven and heated to a temperature of 120 ° C for 1.5 h to prepare MRE.As shown in Figure 2.

3. MICROSTRUCTURE OF MAGNETORHEOLOGICAL MATERIALS

Experimental observations of MRE chaining were carried out using a keyence microscope, which is a microscope system integrated by a 5400 megapixel 3c CD camera, 100 - 5000 times enlarger lens, and a 15 - inch high definition LCD display, as shown in figure 3.

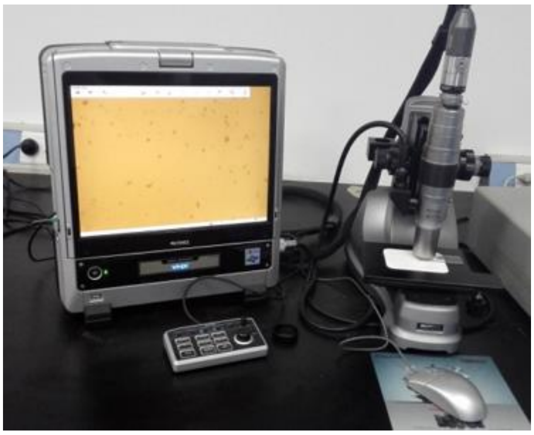
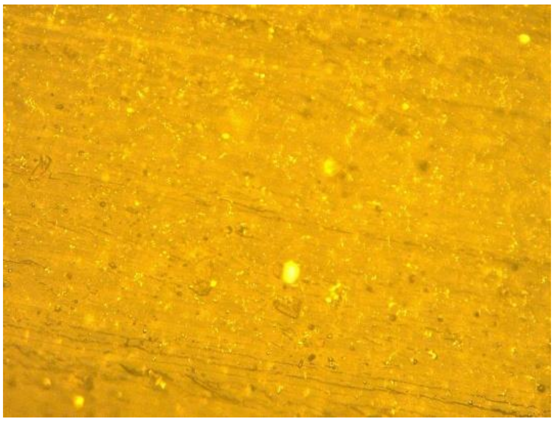
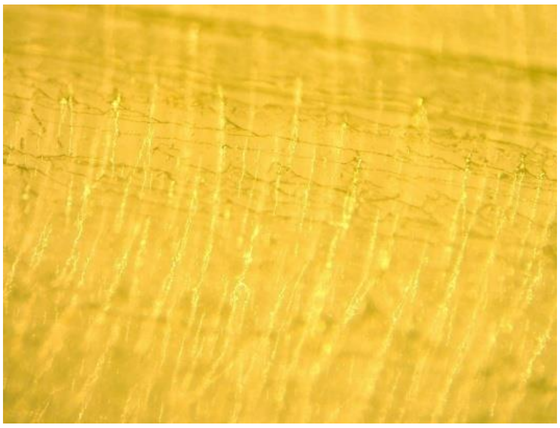


Fig. 3 Digital microscope

The solidified MRE was cut into longitudinal sections along the direction of grain chain formation. The structure of grain chain column of MRE was observed by three-dimensional digital microscope, and the magnification was set to 500 times. The microscopic particle structure of MRE is shown in fig. 4 below. Fig. 4 (a) is a graph of the internal microscopic particles of MRE in a zero field environment, from which it is obtained that the magnetic particles inside the MRE are distributed as single particles. Fig. 4 (b) is a graph of microscopic particle chain formation of MRE under magnetic field environment, from which it is obtained that magnetic particles in MRE under magnetic field environment condense into a chain column structure.



(a) Particle distribution in zero field environment



(b) Particle structure in magnetic field environment

Fig. 4 Microstructure of MRE

4. EXPERIMENT AND ANALYSIS OF SHEAR PROPERTIES OF MAGNETORHEOLOGICAL ELASTOMERS

As shown in fig. 5, MRE is placed between the guide rod and the shear frame, which are made of aluminum material to prevent the influence of the magnetic field force of the magnet. The shear modulus was measured by fixing the shear frame to the moving platform of the press, fixing the guide rod to the pressure sensor, and fixing the pressure sensor to the frame of the press. The press is driven by an electric motor to move up and down, and a shearing force is apply to that MRE by the up and down movement of the press. The relevant values measured by the sensor are transmitted into the acquisition card, and the measurement values are directly displayed on the display screen of the acquisition card. MRE is 20 mm in diameter and 5 mm in thickness. During the experiment, the magnetic field of MRE is changed by changing the relative position of magnet, and the magnitude of magnetic induction intensity of MRE is measured by Tesla meter. The direction of the magnetic induction intensity is the same as the direction in which the magnetic particles form chains inside the MRE. The moving speed of the press is 0.052 mm/s and the maximum compression displacement is 0.5 mm, i.e. the maximum shear strain of MRE is 10 %.

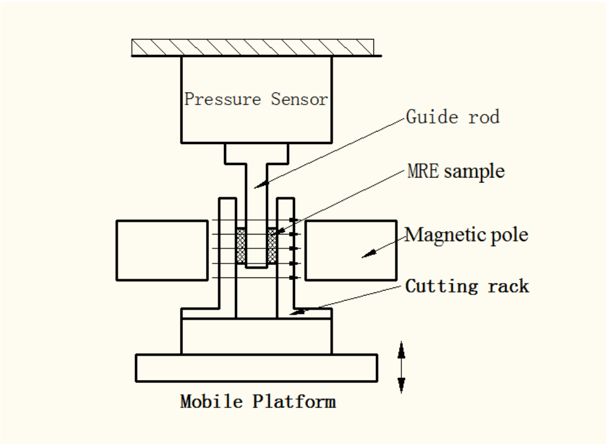


Fig. 5 Shear device structure

The change of shear modulus of MRE is shown in fig. 6 when the magnetic induction intensity is different. As can be seen from fig. 6, the value of the shear modulus of MRE in the zero-field environment is 0.43 MPa, and the shear modulus of MRE increases approximately linearly with the increase of the magnetic induction strength. When the magnetic induction strength is 300 mt, the shear modulus of the material is 0.65 MPa, and the increase amount of the shear modulus is 51 % with respect to the zero-field environment.

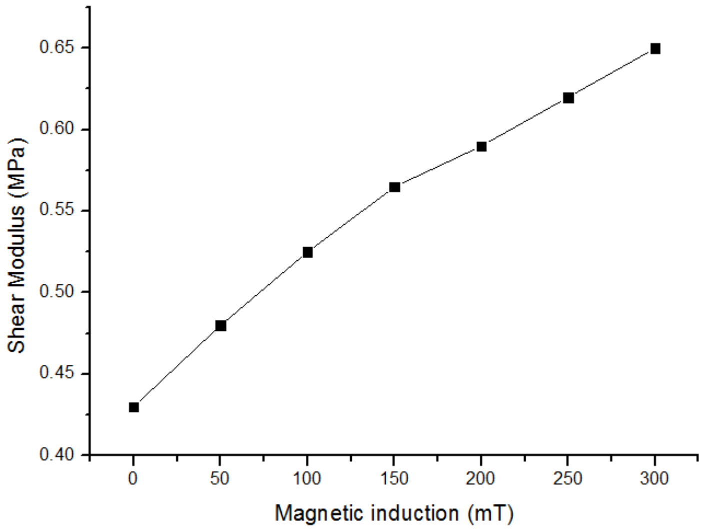


Fig. 6 Dependence of shear modulus on magnetic field

5. CONCLUSION

The preparation process of MRE was established according to the properties of MRE elastomer. MRE was prepared with carbonyl iron powder and silicone rubber as main components, and the particle chain column structure of magnetorheological elastomer was observed by microscope. The mechanical properties of MRE were tested and analyzed. The results show that MRE can change its shear modulus by applying magnetic field.

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