Elastic Capsule Filled with Magnetic Fluid in an Alternative Magnetic Field

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The realization of locomotion systems using deformation of magnetizable materials (a magnetic fluid in a elastic capsule or a magnetizable polymer) in an applied magnetic field is a new interesting problem. In [1-3], the theory of a flow of layers of magnetizable fluids in a traveling magnetic field is discussed. It is shown, that the traveling magnetic field can create the rate of flow in the fluid layers. In [4], the theory of the behavior of a locomotion system using periodic deformation of a magnetizable polymer, when an alternate magnetic field operates, is discussed. The average velocity of such locomotion systems is proportional to the difference of the friction coefficients between the system and the substrate, which depends on directions of motion. In [5] the motion of a chain of spherical elastic balls filled with magnetic fluid in a cylindrical channel is experimentally studied. Such a chain moves in a magnetic field created by two permanent magnets, which are moved along the channel. In [6] the deformation and the motion of a cylindrical body (a body made by a magnetizable polymer) in an alternate magnetic field are experimentally studied. The cylindrical body, which is located in a cylindrical channel, is considered. It is found that there is an undulation of the body in a periodic magnetic field of special structure and the body moves along the channel. The theoretical estimation of the deformation of the body in an applied magnetic field and the body velocity is done [6]. In experiments the body velocity reaches 6 cm/sec [6]. The initiator of the motion is an alternate magnetic field, which forms to exterior sources (a electromagnetic system [6]). Such device has some characteristics, which allow to use this device in medicine and biology. For example, it does not contain solid details contacting with a surrounding medium.

In the present paper a motion of an elastic cylindrical capsule filled with a magnetic fluid in an alternate magnetic field is studied.

Experimental results

In our experiments an elastic cylindrical capsule filled with a magnetic fluid is located inside a cylindrical channel. The channel and the capsule diameters are 11 mm and 4.5 mm. The length of the capsule filled with a magnetic fluid is 75 mm.

An electromagnetic system contains coils which are along the channel. The axes of the coils are in a horizontal plane, L is the distance between the adjacent axes ($L=25$ mm). The coils are placed at the left and right sides of the channel. A magnetic field is created by three coils simultaneously. The axis of the middle coil is the symmetry axis of the magnetic field. These three adjacent coils are turned on at the same moment. Periodically the left coil is turned off and the next coil (fourth) is turned on. Thus the magnetic field travels to right along the channel. The maximum value of the magnetic field on the channel axis is about 300 Oe. The parameter n is the number of the coil switches per a second. We call n as a frequency. In our experiments the frequency changes from 2 s^{-1} to 100 s^{-1}, here-

with the capsule velocity changes from 0.05 cm/s to 2.5 cm/s.
It is found that there is an undulation of the capsule in a periodic travelling magnetic field of special structure and the capsule moves along the channel. The phases of motion and the deformation of the capsule are shown in Fig. 1.

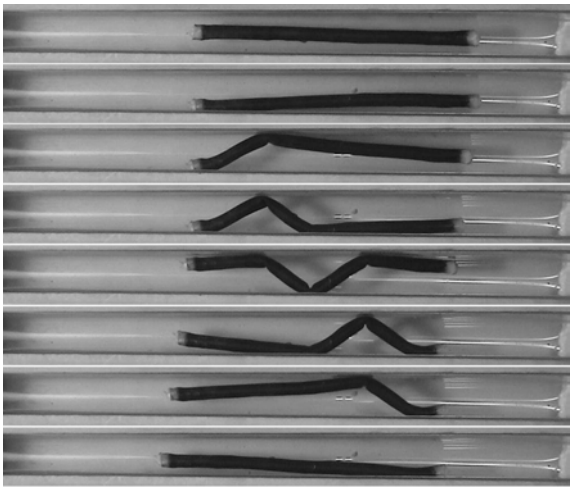

Figure 1: The form of the capsule at different moments during a cycle of a deformation in the traveling magnetic field.

Conclusion

It is shown experimentally that in a specially structured periodic traveling magnetic field the elastic cylindrical capsule filled with a magnetic fluid moves along the channel. Direction of the capsule motion is opposite to the direction of the traveling magnetic field. The maximal obtained capsule velocity is 2.5 cm/s. For the frequency n <100 s^{-1} the theoretical estimations of the velocity of the capsule agree with the experiments. The optimum geometrical sizes of the capsule and the channel are discussed.

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