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MAGNETIC FLUID BRIDGE BETWEEN TWO CONES AND A CYLINDER IN THE MAGNETIC FIELD OF A CURRENT-CARRYING WIRE

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A magnetic fluid (MF) changes its surface shape in the magnetic field of a wire while the current is slowly changing. In [1] the spreading of a MF drop along a wire is studied theoretically and observed in the experiment. A MF drop on a wire with limiting conical surfaces is studied in [2]. In the present paper, we propose to study a MF bridge to open or close the channel of special geometry by imposing the magnetic field of a wire. The use of MF in microvalves is one of actuation methods in microfluidics. In [3] it is shown that a level of pressure in the range of decades of millibar can be expected from a MF. Different magnetic fields could be used to actuate the MF: for example, external magnets [4] and a microcoil [5].

We consider a heavy, incompressible, homogenous, isothermal MF (Fig 1) between two conical surfaces with different apex angles α_1, α_2 and a cylinder of the radius R_c. There is a wire of the radius r_0 with the current I on the axis of these surfaces. It should be noted that a MF bridge between coaxial cylinders [6] cannot sustain any pressure drop in contrast to this problem where there is the pressure drop $\Delta p = p_1 - p_2$. The MF is immersed in a non-magnetic liquid with the same density. We use the Langevin law to describe a MF magnetization. We get the general analytical solution for any axially symmetric MF surface shape in the magnetic field of a wire from the hydrostatic equation and the boundary condition on the MF surface. Numerical modeling of the MF valve behavior for different values of MF volumes and currents based on this analytical solution is done in the computing environment Maple.

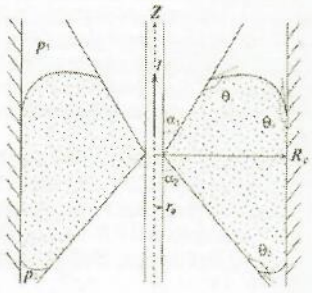

Fig. 1. Magnetic fluid bridge between coaxial conical and cylindrical surfaces in the magnetic field of a wire under a pressure drop in case of non-wetting.

It is shown that the presence of limiting conical surfaces allows the MF to sustain the pressure drop, which is much bigger in case of non-wetting ($90° < \theta_1, \theta_2, \theta_3 \le 180°$) than in case of wetting ($0° \le \theta_1, \theta_2, \theta_3 \le 90°$). In case of wetting the MF cannot sustain any pressure drop for small currents in the wire, but in case of non-wetting the MF bridge can do it even for zero current. Spasmodic and hysteresis phenomena are possible for some values of MF volumes and currents. Presence or absence of these phenomena should be taken into account in the design of microvalves with controlled MF volumes, in which the magnetic field is changed periodically.

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