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ELECTROMECHANICAL CONVERTOR WITH MAGNETS - EXPERIMENTAL WORK -

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ABSTRACT
Experimental investigations performed with an electromechanical device based on magnets and ferrofluid were carried out to estimate possible applications as a current to displacement convenor, a displacement transducer or a vibrator. The results obtained using the experimental laboratory model (built with available technical means) suggest some methods for the improving its performances in practical applications. These improvements concern both the choice of the electromagnetic system configuration and the material characteristics of its component (magnets, ferrofluid).
Keywords: electromechanical device, ferrofluid, displacement converter.

1. INTRODUCTION
The device principle and the dynamic model of electromechanical converter presented in [1], constitute the necessary basis for experimental work of the variants intended to specific applications. The ensemble formed by movable magnet ferrofluid, rod and diaphragm is elastic suspended by means of magnetic field created of the two magnets and by elastic diaphragm (Figure I). The ideal behaviour of the system is close to that of a dynamic second order element, according to eq. 2 [1], overdamping (damping coefficient $\zeta > 1$) because of the ferrofluid magnetic-viscosity effect.

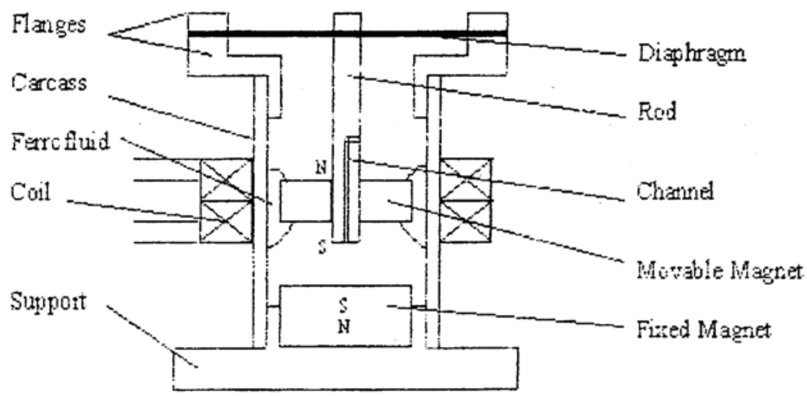

Figure 1. Schematic diagran of electromechanical convertor [1]

The experimental tests conducted using the device represented schematically in Figure 1, working as a current to displacement convertor, a displacement transducer or a vibrator are presented in the next sections.

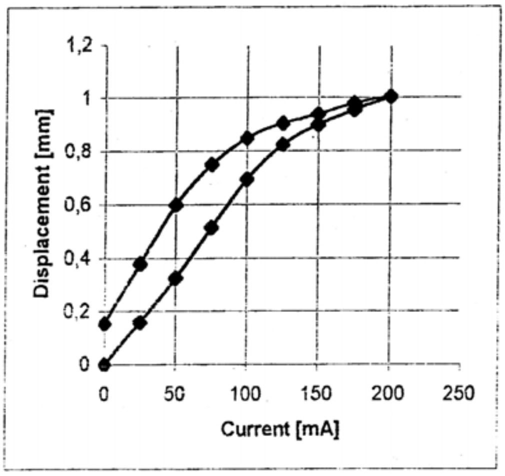

Figure 2. Displacement versus current characteristic

2. CURRENT TO DISPLACEMENT CONVENOR

The experimental device in Figure 1 consists of: two ferrite ring magnets (type FB-2-06, I.F. Urziceni) with the dimensions, outside diameter x inner diameter x height = 18.3 x 5.4 x 8.3 mm^3, a non-rnetallic diaphragm having the outside diameter of 50 mm, a coil with two identically windings which have each 400 turns and a ferrofluid based on kerosene having following characteristics: saturation magnetisation M_s= 25 kA/m, initial susceptibility % = 0.6, dynamic viscosity η = =0.01kg/ms, kinematic viscosity υ =10^{-5} m/s.

Two windings of the coil were connected additionally. By a proper choice of the d.c. current direction the magnetic field produced by the coil will either increase or decrease the magnetic field produced by the movable magnet, which in turn will move the mobile ensemble either upwards or downwards.

In the case of the upwards movement the displacement versus current characteristic (Figure 2) exhibits a strong hysteresis effect. The displacement variation may be considered linear for the command current in the ranges 0 - 100 mA and 125 - 200 mA. Obviously, for small current variations the characteristic non-linearity and hysteresis effect are much more reduced. The hysteresis effect is due to the diaphragm and (the mostly) to die friction force between the ferrofluid surrounding the movable magnet and the carcass wall. The friction force in ferrofluid-carcass wall contact region depends of the relation between ferrofluid-magnet and ferrofluid-wall adhesion forces. The wall friction is minimum near the magnet circular edges where the ferrofluid is strongly attracted to the magnet due the intense magnetic field. As a result the followina three conditions must be imposed in order to reduce the friction: decrease the ferrofluid volume using flat ling magnets (made of high-energy magnetic materials); create a high magnetic field at the interface with the walJ; reduce the contribution of the friction force with respect to the total balancing weight of the mobile ensemble, by increasing the elasticity constant k. These three essential conditions may be accomplished by building the current - displacement convertor according to the schematic principle in Figure 3. The two movable magnets are fixed with so that facing poles have the same polarity and the two coil windings will be connected differentially this time. Supplementary upper fixed magnet contributes to increasing equivalent elastic constant k.

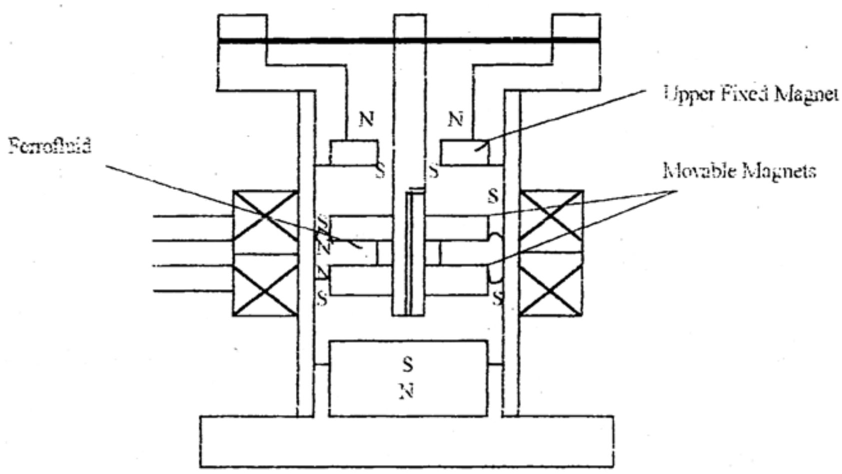

Figure 3. Schematic diagram of the improved current to displacement convertor.

The tests, shown a high settling time of the system. In order to detennine the causes for this effect an analysis of the time constants that appear in the step response of the system was made, using equations (2). .(6) [1]. Since a non-periodic overdamping response was obtained (ζ > 1), the time domain expression of the response function exhibits two time constants, T_1 and T_2 ($T_1 > T_2$), that directly influence the system response time:

$$T_{1,2} = \frac{1}{2\pi f_n(\xi \pm \sqrt{\xi^2 - 1})}, \xi > 1 \tag{1}$$

If ζ = 1 critical non-periodic response is obtained giving the smallest response time:

$$Tc = \frac{1}{2\pi f_n} = \sqrt{\frac{m}{k}} \tag{2}$$

The largest time constant, T_1, with overwhelming influence in the time response, has the expression:

$$T_1 = \frac{c + \sqrt{c^2 - 4km}}{2k} \tag{3}$$

The bottom limit for T_1 is $T_1 = T_2 = T_c$. Relations (2) and (3) show that in order to reduce the system response time, the ratio m/k and above all the damping coefficient c, must be reduced. Figure 2 presents an improved device that ensure both a reduction in the ratio m/k and a decrease in the coefficient c by using a smaller amount of ferrofluid. Other ways of diminishing the friction due to the magnetic fluid consist in choice of a carrier liquid with a smaller viscosity and in diluting the magnetic fluid; the latter solution leads to a decrease in magnetisation and thus in reducing the elastic separation effect between the magnet and the case according to rel. (1) [1].

3. DISPLACEMENT TRANSDUCER

The device presented in the previous sections (Fig. 1) may be also used as a displacement transducer. The movable magnet is placed in the centre of the coil whose windings are connected additionally, same as for the current to displacement converter. A small shift at the top of the rod causes the movable magnet to modify the initially equal magnetic fluxes in the two windings. The inductances of the two coils, which were initially equal will have opposite and equal variations, depending on the magnet displacement. The calibrating plot of the transducer presented in Figure 4 is near to a straight line. The tests showed almost the complete absence of the hysteresis effect. The calibration was performed using an electronic micro-comparator type N 2201, made in Romania. The two windings of the transducer coil were connected in two measuring bridge branches of this apparatus.

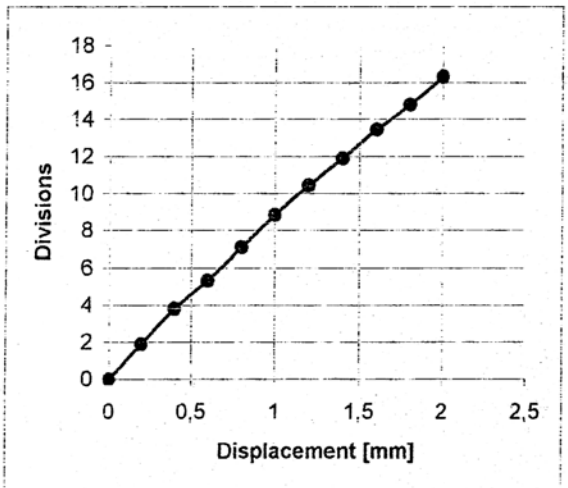

Figure4. Calibrating plot for displacement transducer

4. VIBRATOR

The device was tested as a vibration generator. The largest amplitude vibrations were obtained for an additional connection of the two windings. The experiments conducted using an adjustable frequency sinusoidal voltage generator showed that the amplitude of vibration is almost constant in the range 0-28 Hz, reaching a small maximum around 28 Hz; above this frequency the amplitude exhibits an important decrease.

5. CONCLUSIONS

The electromechanical magnet convenor was tested in the laboratory for three types of working conditions: current lo displacement convenor, displacement transducer and vibrator. In working as a current to displacement converter two main disadvantages appear: large hysteresis effect and large response time. In order to reduce these disadvantages a structure using two high-energy magnets is proposed for the mobile part; the magnets must be small weight and retain a small quantity of ferro fluid while moving with respect to the device case.

The displacement transducer presents in the domain 0-2 mm a near to a straight-line transfer characteristic.

When working as a vibrator the device generated almost constant amplitude vibrations in the frequency range 0-28 Hz, above this frequency the amplitude showing an important decrease. In order to expand the working domain, the critical time T_c must be reduced (the ratio k/m must be increased), which may be also accomplished with the device in Figure 3.

We anticipate that the device built according to the schematic pimciple presented in Figure 1 or Figure 3 may detect the vibrations applied to the device support or to the top of the elastic ensemble rod, although no experiment were made in this respect.

6. REFERENCES

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