

VIBROMOTORS BASED ON MAGNETOSTRICTION EFFECT

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REZUMAT. Unul din cele mai performante materiale magnetostrictive la ora actuală este TERFENOL-D, cu aplicabilitate atât la construcția actuatorilor cât și ca senzori, pentru controlul vibrațiilor. Datorită proprietăților pe care le are acest material poate fi utilizat și la construcția motoarelor neconvenționale, mai exact a vibromotoarelor.

Cuvinte cheie: vibromotoare, materiale magnetostrictive, TERFENOL-D

ABSTRACT. One of the most performing magnetostrictive materials is currently TERFENOL-D, which is use in construction of the actuators and as sensors for vibration control. Due of their properties this material can be used also to build of unconventional motors, namely the vibromotors.

Keywords: vibromotors, magnetostrictive materials, TERFENOL-D

1. INTRODUCTION

The vibromotors are unconvetional motors which operate on the principle of conversion of the vibrations motion in a continuous motion (rotary or linear). The first studies of vibromotors have shown their exceptional properties: a high resolution of displacement, a wide temperature range and absence of parasitic magnetic or electrical (in particular, radiation) fields. A particular characteristic of this vibromotors is that they can be designed without metallic parts (besides power supply cables), thus allowing application in precision magnetic and geodetic instruments. But the main features of vibromotors is their dynamic quality in transient motion conditions (i.e., in start-stop and stepping regimes), because vibrating element becomes a brake at the moment of switching off of the power supply.

Aother characteristic of the vibromotors, compared to other electric motors, is that the rotor is in direct contact with the stator.

In many fields of application, vibromotors solve the problems of positioning and uniform high-speed displacements, and execute prescribed motions. Mechanism with controllable structure and mechanisms with controllable parameters are also very effective. Vibromotors will be of great importance in designing precision microrobots-devices capable of manipulating objects of small mass in a limited space but with very high accuracy.

2. MAGNETOSTRICTIVE MATERIAL TERFENOL-D

In the 60s it was observed that two actinides, terbium (Tb) and dysprosium (Dy) have the huge magnetostrictive deformations by two to four orders of magnitude higher than nickel alloys. Because these deformations appear only at low temperatures, the phenomenon could not be exploited in applications at that time. Later it was found that by combining the terbium and dysprosium with iron are obtained intermetallic compounds TbFe₂ and DyFe₂ which have magnetostriction at the ambient temperature, but requires very high magnetic fields applied. Finally, in the mid-'70s, the former Naval Ordnance Laboratory (now Naval Surface Warfare Center) in Silver Spring, Maryland, USA (in the same place where it was found and Nitinol) by combining the two components above is obtained material with highest performance of magnetostrictive deformation in present, called TERFENOL-D. This name is after terbium (TER), iron (FE), initials of the laboratory old name (NOL) and and the D from dysprosium. The Terfenol-D is an alloy that expands and contracts when exposed to magnetic fields more than any other alloy (the deformation Δl can reach values of up to 2000 $\mu\text{m} / \text{m}$). Stoichiometric formula of Terfenol-D is Tb_{1-x}Dy_xFe_y, where $x = 0,27-0,3$ and $y = 1,9-2$. [95], [117] The technology for manufacturing the material efficiently was developed in the 1980s at Ames

Laboratory under a U.S. Navy funded program. As applicability, the magnetostrictive materials are used both as actuators and as sensors for vibration control. [1]

Magnetostrictive actuators have also been considered for use in fuel injectors for diesel engines because of the high stresses that can be produced. For improve the method of actuating an electronic fuel injector is provided using magnetostrictive transduction. For that, the rod, which has ferro-magnetic magnetostrictive properties, is operatively coupled with a fuel injector needle valve. Application of a magnetic field to the ferro-magnetic rod generates strain in the rod and corresponding motion in the needle valve, thereby actuating the fuel injector. [2]

In [1] is presented some specific characteristics of terfenol, as follows:

- usual the magnetostrictive deformations, in order of 0.15% (1500 μ m/m), are obtained at relatively low magnetic fields applied (about 100 A / m);
- millisecond response times;
- possibility of developing forces hundreds of N;
- operating temperature lies between -50 °C and 71 °C.

The above characteristics are considered average values and corresponding "normal" external parameters (pressure, temperature). For example, increasing the applied magnetic field up to about 200 kA/m it can obtain a magnetostrictive strain of 0.2% (2000 μ m/m). So, the magnetostrictive deformation increases with the applied magnetic field, but an influence in this respect has the applied mechanical tension, as noted in Fig. 1.

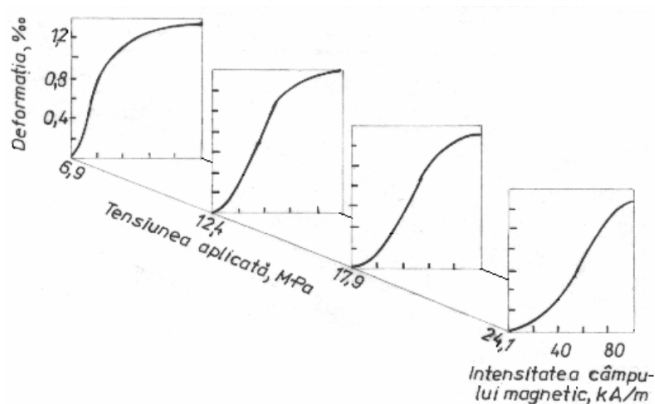


Fig. 1. Influence of magnetic field and mechanical tension applied to the magnetostrictive strain terfenolului (taken from [1]).

3. VIBROMOTORS BASED ON MAGNETOSTRICTION EFFECT

In Fig. 2 is illustrated a solution of vibromotor based on the magnetostriction effect. This vibromotor is consist mainly of a shaft 1, mounted by means of two bearings 1' and 1' and solidarity with a rotor 2 in the form of a disk which is attached a friction ring 3, made of a plastic material. [3]

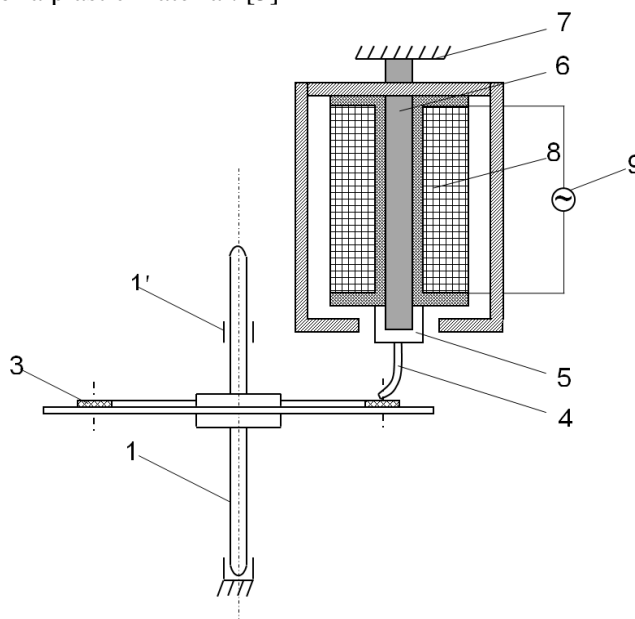


Fig. 2. Operating principle diagram of magnetostrictive vibromotor.

On the friction surface ring drives a spur 4 made from a flexible blade, slightly tilted in the direction of rotation. The spur 4 is fixed through a metallic armature 5 to the free end of a terfenol bar 6, which is fixed with the other end to a fixed support 7.

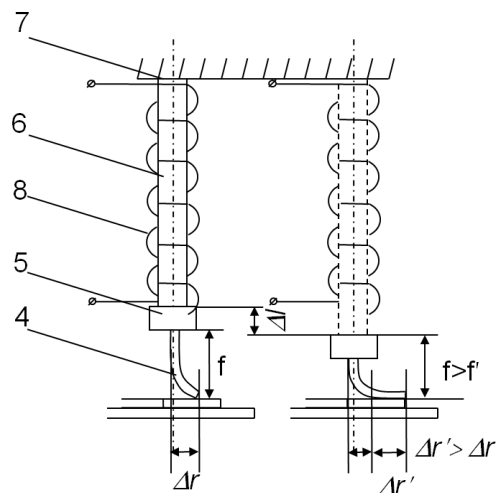


Fig. 3. Conversion principle of vibration motion in continuous rotating movement (taken from [3]).

The full length of terfenol bar is under action of alternating magnetic field generated by an electromagnet whose coil 8 is supplied from a AC source 9. The operation and performance of electric motor is achieved due to material which is made the bar 6. So, when the coil 8 is energized the terfenol bar 6 generally expands $\Delta l = 1500 \mu\text{m/m}$. If the coil 8 is powered from AC sources the terfenol bar 6 will expand and contract in a magnetic field, which perform a movement of on the spur 4 as shown in figure 3.

Spur 4 actuates in a similar manner "ratchet wheel", which the rotor moves like a stepper motor. Rotor speed depends on elongation Δl of a terfenol bar and the frequency of current that flows through the coil 8. Figure 4 shows an experimental model of vibromotor presented in in figure 2.

This model, presented above, has some disadvantage as follow:

- is not able to change the direction of rotation,
- don't offer possibility to adjust of the speed,
- the torque is small at low speed.

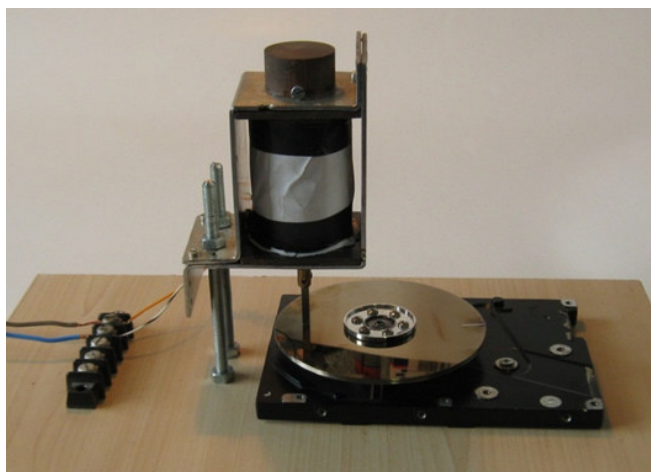


Fig. 4. Experimental model of magnetostrictive vibromotor.

A solution of for make the magnetostrictive vibromotor to has reversible direction of rotation is shown in figure 5.a. In this case is use a device *P1* that changes the inclination of the actuating spur for reversing the direction of rotation of the viromotor rotor. In figure 5.b is illustrated a detail on the implementation of specified device *P1*. This is consist of a support rod 13 which slides on two guides 14 and 14'. On one side, the rod is equipped with two rollers 15 and 15', spaced between them where is paced the friction spur 5. One of the rolls, 15 deviates the inclination of the spur to the right and the other, 15', deviating inclination spur "left", causing rotation of the rotor in the same direction. The support rod 13 is provided at both ends with a ferromagnetic armature 16

and 16', each located, as appropriate, under the action of electromagnetic field produced by a coil 17, respectively 17', powered from the same power source via pushbuttons 18, 18' [4].

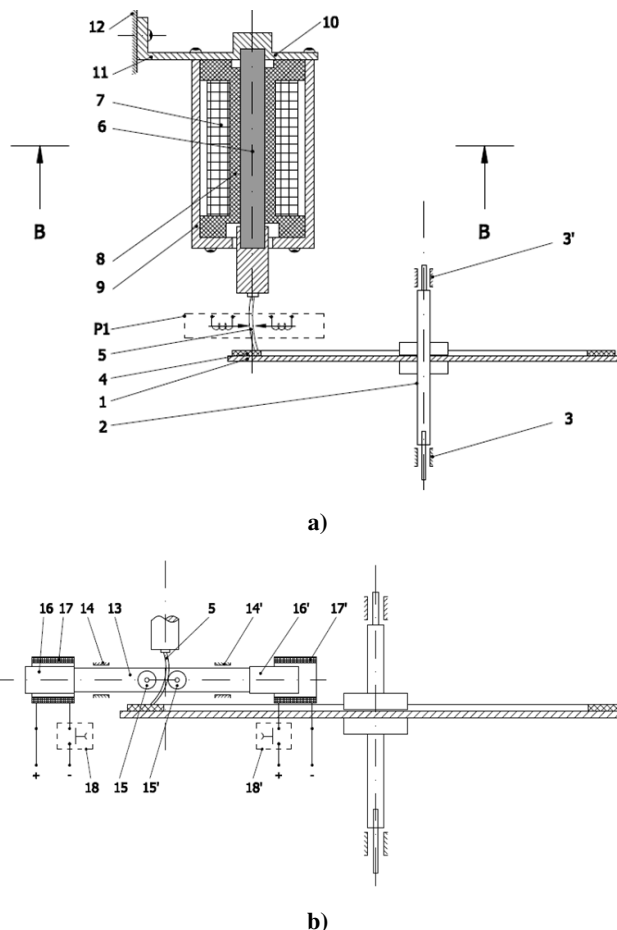


Fig. 5. Solution for reverse of rotation direction.

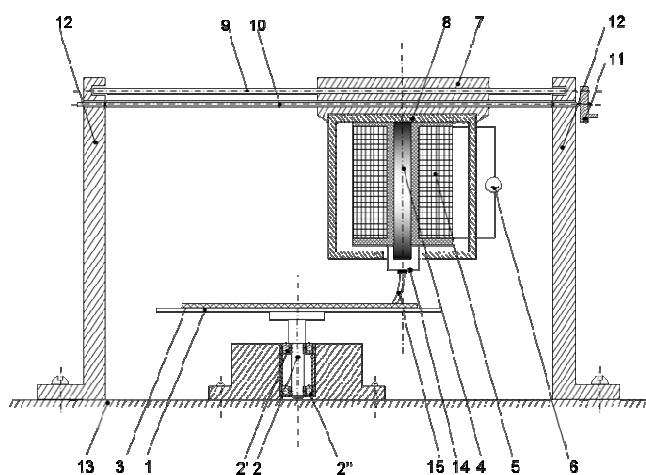


Fig. 6. Solution for adjust of the speed.

In figure 6 is presented a solution which permit to adjust of vibromotor rotor speed. The magnetostrictive

module slides on a guide rod 9 and a threaded axle 10 provided with a drive arm 11 [5].

The speed of the disc 1 is according to distance from the axis of rotation 2 of the friction spur 15.

In many cases requires an motor which develops produce the high torque at low speed of the rotor. Such a variant of motor is the one shown in figure 7.a, which represent a magnetostrictive micromotor with rolling rotor. It consists of a circular stator in which is mounted concentrically a flexible rolling rotor. The stator of motor consists of several magnetostrictive vibrators, grouped two by two, A1 - A1', B1 - B1', C1 - C1' and mounted on a circular 2 diametrically opposed positions. The rotor deformation sequence is shown in figure 7.b [6].

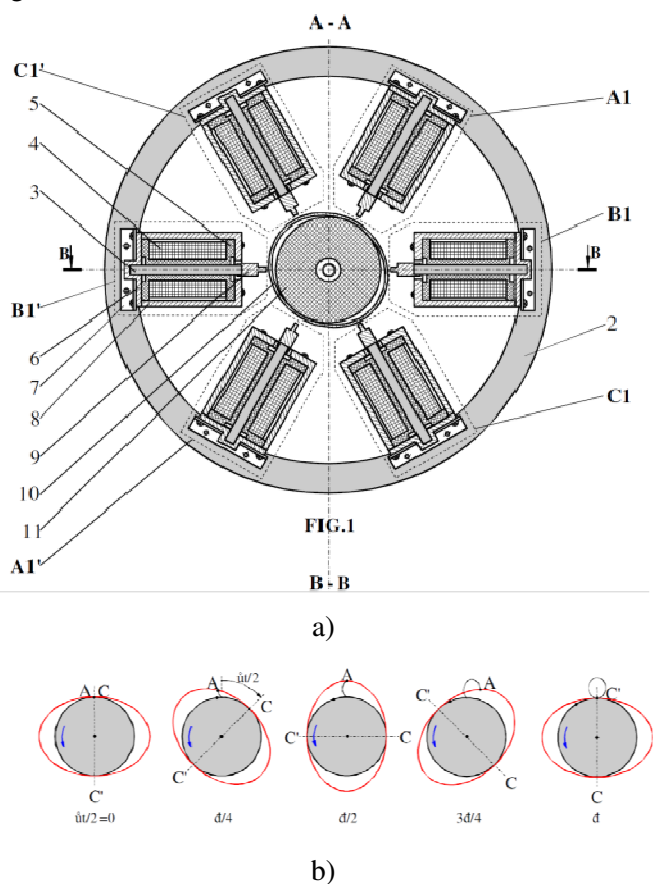


Fig. 6. Magnetostrictive micromotor with rolling.

4. CONCLUSIONS

In the mid-'70s, the former Naval Ordnance Laboratory by combining the two components TbFe₂ and DyFe₂ is obtained a material with highest

performance of magnetostrictive deformation in present, called TERFENOL-D. As applicability, the magnetostrictive materials are used mainly both as actuators and as sensors for vibration control. In addition, this material finds application in automotive, and in the construction of electric motors. In addition, this material finds utility in automotive domain, and in the construction of unconventional motors.

In this paper has been presented some constructive variants of magnetostrictive vibromotors which permit to reverse speed direction, to adjust the rotor speed and improve the torque at low speed.

The magnetostrictive vibromotors have the following advantages:

- constructive simplicity;
- reduced overall dimensions;
- low noise.

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