STUDY CONCERNING THE IMPLEMENTATION OF SOME KINDS OF ULTRASONIC MOTORS IN POSITIONING SYSTEMS OF SOLAR PANELS

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Rezumat. Lucrarea îşi propune studierea, modelarea şi experimentarea unor modele de motoare rotative şi liniare ce utilizează unde ultraacustice pentru realizarea deplasării. Motoarele studiate sunt caracterizate prin precizie de poziţionare, inerţie mică, domeniu larg de reglaj al vitezei (nu necesită angrenaje şi reductoare), control uşor, cuplu ridicat pe unitatea de greutate, miniaturizare, structură simplă, zgomot redus, caracteristică descrescătoare moment – viteză. Tema are caracter transdiciplinar, abordând elemente din domeniul maşinilor şi electronicii, materialelor electrotehnice, mecanicii, undelor, informaticii şi metodelor numerice, al modelării sistemelor electromecanice.

Cuvinte cheie: motor ultrasonic, efect piezoelectric, unde acustice

Abstract. This paper aims the studying, modeling and testing of models of linear motors which use ultrasonic waves to achieve the movement. The studied motors are characterized by the positioning accuracy, small inertia, wide speed control (does not require gears and gearboxes), easy control, high torque per unit weight, miniaturization, simple structure, low noise, decreasing time-speed characteristic. Theme is nature trans-disciplinary work, addressing elements of the electrical machines and electronics, electrical materials, mechanics, waves, computer and numerical methods, modeling of electromechanical systems.

Keywords: ultrasonic motor, piezoelectric effect, acustic waves

1. INTRODUCTION

Piezoelectric effect was described in 1880 by Curie and wife and consists in the occurrence of polarized electric charges on the faces of crystalline materials when mechanical action exerted on them. The direct phenomenon is accompanied by the opposite phenomenon, deduced mathematically by Lippmann in 1881 based on fundamental principles of thermodynamics. This phenomenon consists in the generation of mechanical tension or movement when an electric field is applied to a piezoelectric material. If this is an alternating electric field, the material vibrates with a certain frequency and amplitude.

The advantages of the piezoelectric actuators and motors are:

- sub-micron positioning accuracy;
- quick time response of the microseconds order ;
- energy efficiency around 50%;
- extended range of the input electrical signals (1 mV to 1 kV);
- large forces;
- possibility of miniaturization and integration in terms of energy and information;
- clearly defined dependence between applied voltage and changing the length of the active elements, not being required the equipping with sensors and transducers;
- insensitive to the operating environment;
- silent in operation;

Among the disadvantages are: the fragility of the piezoelectric materials, wear and fatigue caused by operational shocks and the need to transform the high frequency vibrations into continuous or intermittent motion.

Linear or rotary piezoelectric actuators with continuous or step-by-step motion can have in their structure one or more active elements. They can take the form of bars, strips, tubes or plates. Their controlled deformation can be used to drive the mobile element. Also, the mobile element can be driven by a traveling-wave, the movement being taken over by contact or shape. In this case, the overlapping of several stationary waves generated through control, inside the active element arises a traveling-wave that causes an elliptical movement of the contact points with the mobile element. Deformation of active elements can be perpendicular or parallel to the polarization axis.

If there are known the physical principles of operation of piezoelectric systems and relations expressing the acoustic wave propagation in solid mediums and at the interface between them, is relatively easy to build a piezoelectric transducer which is based on two-directional vibration and which is on the base of the ultrasonic motor operation. The two vibratory components havs the role to ensure the energy source necessary to act the rotor and to control the friction force through that the torque is transmitted. It can achieve an equivalent circuit to analyze the formation of the two oscillating components and to model numerically the phenomena that occur between stator and rotor. This model allows the understanding of the mechanism which makes the motor to operate and helps the design activity. The design consists mainly of determining the parameters of the vibratory system, parameters which will determine the motor's characteristics (maximum torque and maximum rotational speed).

2. THE PIEZOELECTRIC EFFECT

The operating principle of piezoelectric linear motors PILine Piezo is based on a patented unit which generates ultrasounds. In the center of system is a rectangular monolithic piezoceramic plate (the stator), segmented on one side by two electrodes. Depending on the desired direction of movement, the left or right electrode of the piezoceramic plate is supplied with high frequency signals of hundreds of kilohertz from the electronic control system.

Direct or inverse piezoelectric effect is determined by the internal structure of materials. One of the necessary conditions for occurrence of the phenomenon of piezoelectricity is the lack of a center of symmetry which makes these materials to be anisotropic. The piezoelectric materials can be divided into:

- crystals: quartz, Rochelle salt (of the 36 crystal classes, 20 have this property);
- sintered ceramics: barium titanate (BaTiO3), lead zircotitanate (PbTiZrO3 - PZT), PXE – polycrystalline structure based on PbTiZrO3;
- polymers: polytetrafluororethylene (PVDF).

When a ceramic material is subjected to the action of a magnetic field near the Curie temperature (TC), the dipoles are aligned by the field direction. Under the action of an electric field near TC, the polarization (P) of dipoles increases with applied electric field strength (E). To align the regions is necessary to overcome energy thresholds, depending on their size and internal tensions. Exceeding gradually these thresholds and increasing the number of aligned regions has as result a hysteresis phenomenon. Material cooling up to the ambient temperature, under the action of the electric field, leaves the most dipoles aligned, the material remains in a remanent state, the deformation having a permanent character. Subjecting the metal to mechanical stress, the dipoles stretch or shrink, and the crystal lattice deforms. This interaction between the dipoles and the electric field produces the effect of piezoelectricity. By proper connection of electrodes it can measure the piezoelectric effect. External compressive force generates between the electrodes a voltage of the same polarity as the polarization voltage. If the material is stretched, the polarity is changed.

In case of the reverse piezoelectric effect, applying a voltage with the polarity opposite to the polarization voltage, leads to material "compressing", while a voltage of same polarity leads to the material "lengthen". Quantitatively, this behavior is characterized by piezoelectric charge constants d31, d33 and voltage constants g31, g33. [5]

The advantages of piezoelectric ceramics are given by the possibility to control their properties through their chemical composition, by the high dielectric rigidity and by the geometric configuration flexibility, which meant that now is the material used to achieve piezoelectric actuators.

In the table 1. are shown comparatively some characteristics of piezoelectric materials. [5]

Table 1

Material	**Density**	**Dielectric constant**	**Piezolecetric constants**		**Pyroelectric coefficient**	**Coupling factor**
	[g cm-3]		*D [pC/N]*	*G 10-3 [Vn/N]*	*P [µC/m2K]*	*k [%]*
PVDF	1.76	1	20 (d31)	20 (g31)	40	16
PVF	1.38	5	1 (d31)	20 (g31)	10	3
PZT-5	7.75	1700	171 (d31)	20 (g31)	60 – 500	34
BaTiO3	5.7	1700	78 (d31)	20 (g31)	200	21
Cuarț	2.66	4.5	2 (d11)	20 (g11)	…	9
TGS	1.7	50	-	-	350	…

Table 2

Material characteristics of PZT type ceramics with trade name PIC [5]

Characteristic name	PIC 140	PIC 151	PIC 155	PIC 255
Density [g/cm3]	7.6	7.8	7.5	7.8
Curie temperature [ºC]	330	250	345	350
Dielectric constant □T33 / □0	1200	2100	1500	1750
Dielectric constant □T11 / □0	680	1980	1400	-
Dielectric loss (tanδ [x10-3])	10	15	20	15
Resistivity [Ωm]	1010	1011	1011	-
Coupling factors				
kp	0.50	0.62	0.62	0.62
k33	0.60	0.69	0.69	0.35
k31	0.25	0.34	0.35	0.69
Mechanical constant Q	250	120	80	80
Frequency constants [Kzm]				
NP	2200	2100	1950	2000
N1	1680	1500	1430	1420
N3	1800	1680	-	-
Nt	2100	1950	1985	2000
Load constants [×10-12 m/V]				
d31	-60	-210	-165	-180
d33	200	450	360	400
d15	265	580	520	560
Voltage constants [×10-3 V/m]				
g31	-8.5	-11.5	-12.4	-11.3
g33	28.2	22.8	27.0	25.1
Elasticity constants [×10-12 m2/N]				
S11E	11.7	15.0	15.6	16.1
S33E	11.7	17.0	19.7	20.7
Ageing rate [%]				
Cf	0.3	0.2	0.15	0.13
Ck	-1	-2	-2	-1

In terms of current trends in the field of piezoelectric materials used in the structure of ultrasonic engines should be noted:

- Considering that piezoelectric effect can not occur in any dielectric non-uniform in terms of relative permittivity and modulus of elasticity, have developed new materials with piezoelectric properties (e.g. double layer material which comprises a polyurethane layer and one of polypropylene).
- In mechatronics are used more often materials which have not only piezo-electric effect but also piezo-optic effect (refractive index change under the action of an outside unified effort), piezo-magnetic effect (dependence of the unit effort by magnetic properties) and piezo-resistive effect.
- There were developed methods of obtaining composite materials having in their structure active piezo-electric elements with superior functional characteristics.

Directions of study:

- developing experimental and teaching models of ultrasonic motors;
- identifying methods to increase the reliability of these engines;
- identifying methods to command and control the operating of such engines, used for precise positioning or for intermittent operation;
- implementation of ultrasonic actuators in industrial systems involving fine-tuning;
- identifying new applicability areas for the ultrasonic motors, based on their advantages.

3. EXPERIMENTAL DATA

The control of motor was achieved using a control software, for various time intervals, that allows the accurate determination of time to generate the control signal demonstrate proper orientation with an angle of the Sun diurne movement.

It can observe the character of the graphs obtained for the same load of the motor, but making steps of differing duration, and also the polynomial function that approximates the displacements obtained.

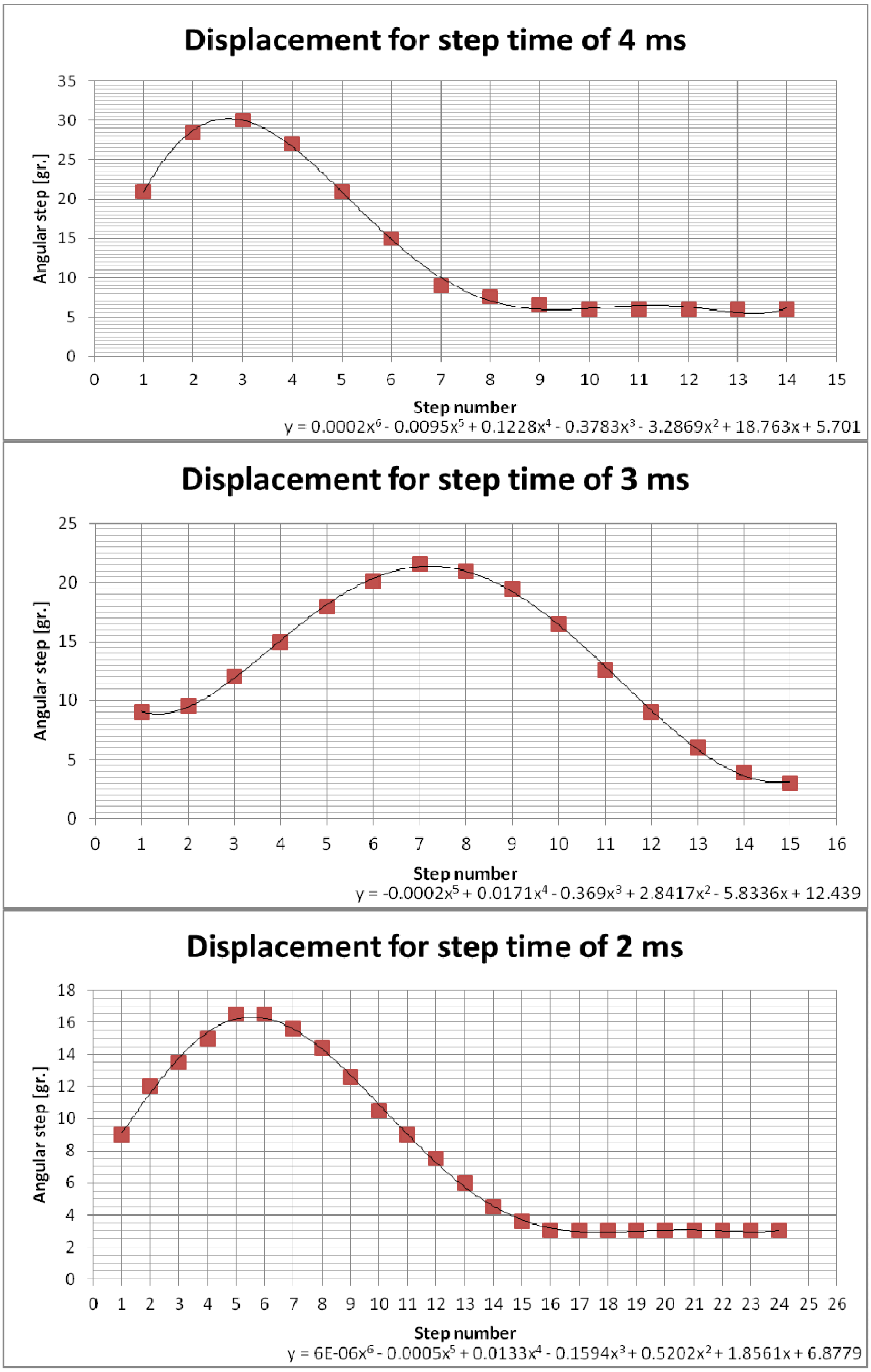

Fig. 1. Experimental data

4. CONCLUSIONS

The ultrasonic motor used in the actuation of the solar systems has several advantages:

- possibility of movement with small angular velocity in the aim of fine orientation of the solar device
- the motor enables the accurate positioning without the need for speed and torque mechanical reducing
- maintaining a high torque also during the time when the motor is not powered
- easy motor controling

The main disadvantage lies in nonlinear characteristic as seen in figure 1. To compensate the positioning deviations is recommended, for the control, a microsystem in which to be implemented, by software, the relationships of the interpolation functions deduced in the previous chapter.

ACKNOWLEDGMENT

This paper was supported by the project „Progress and development through post-doctoral research and innovation in engineering and applied sciences– PRiDE - Contract no. POSDRU/89/1.5 /S/57083", project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

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