6TH INTERNATIONAL CONFERENCE ON ELECTROMECHANICAL AND POWER SYSTEMS
October 4-6, 2007 - Chişinău, Rep.Moldova

THERMAL CONDITIONS FOR USR30-S3 TRAVELLING WAVE ULTRASONIC MOTOR

Ilie PRISACARIU

„Ştefan cel Mare” University, Suceava

Abstract **– This paper presents a study about thermal conditions for USR30-S3 traveling-wave ultrasonic motor (TWUM). It is known that the largest problem in ultrasonic motors is heat generation and causes a serious degradation of the motor characteristics. The author has analyzed the heating process at the surface of the TWUM using a numerical thermometer with temperature sensor. Analyze of the thermal conditions for USR30-S3 TWUM in load and no-load cases has took place in a laboratory and the temperature of the ambient medium was constantly while testing. The heating curves were drawn at different values of speed of the TWUM in load and no-load conditions. The experimental stand for the TWUM is also presented in this paper. First, it was observed that the speed of the TWUM modifies in time in no-load conditions because of the temperature's increasing process of stator's piezoelectric material. The monitoring of the temperature's increasing process for others TWUM types and also for the main elements of those are the future directions of research of the author.**

Keywords: *ultrasonic motor, traveling-wave motor, thermal conditions.*

1. INTRODUCTION

Piezoelectric motors perform a two-step energy conversion. In the first stage, electrical energy is converted into mechanical vibrations of the stator.

In the second stage, high frequency oscillatory vibrations of the stator are transformed into unidirectional macroscopic motion of the rotor.

Piezoelectric motors work by converting small amplitude, high frequency vibration (of 10 kHz and higher) of a stator with piezoelectric elements into unidirectional linear or rotary motion using friction.

An important application of these motors is at micropositioning stages.

These micropositioning stages can be used in: life science, medicine, biology semiconductors, microelectronics data storage, optics, photonics, fiber optics metrology and measuring technology precision mechanics and mechanical engineering.

The advantages of piezoelectric motor over the conventional electromagnetic motor are: silent drive due to the ultrasonic, no gear mechanism (suitable to video cameras with microphones); thin motor design leading to space saving. Also other advantages of piezoelectric motors can be mentioned: low speed and high torque; quick response; hard brake and no backlash: excellent controllability; fine position resolution; light weight, simple structure and easy production process; negligible effect from external magnetic or radioactive fields and also no generation of these fields.

The disadvantages of piezoelectric motors are: necessity for a high frequency power supply; less durability due to frictional drive; drooping torque-speed characteristics and the costs of piezoelectric elements.

The study of rotating piezoelectric motors leads to technical understating of their function and also allows the observation of his function at many apllications or in „aggresive” mediums, making easy the choice of product when buying it. Compact miniaturised actuators and with low energy consumption are needed, for example at some types of robots used in planetary exploration [1] and also at high-precision devices. [2]

The rotating travelling-wave ultrasonic motors fulfies these conditions and this is the reason of the interest for their fonction in mediums like vacuum, criogenia, umidity or with higher temperatures. Generally, the main scope for testing the piezoelectric motors is the understanding of the stator-rotor interface phenomenon folowed by the conception of new optimized models.

The utilization of traveling wave ultrasonic micromotors is present especially at high-precision systems and in robotics.

Nowadays, the main development direction is not lightening up the problems about the secure thermal conditions but increase their difficulties. The future developments based on miniaturisation can create problems regarding the thermal conditions, that's why is needed a thorough research about the heating transfer.

In many cases, the travelling-wave ultrasonic micromotors and also the liniar types must have cooling systems.

It is possible that once the piezoelectric material is heated excesively it may appear the pyroelectric effect(which may cause serious problems to the motor's stator).

There are cases when the temperature of stator's piezoelectric material is increasing at values between 100°-120°C. That is the reason for using

piezoelectric materials with higher values for mechanical quality factor *Q*.
The determination of the value of stator's temperature can be achieved using a transducer placed on his surface (thermoresistence, diode) to obtain a higher precision of measure.
It is known the transducer method for the determination of the temperature values in inaccessible points, after the realisation of micromotor [4].
In the case of travelling-wave ultrasonic motor, the implementation of a thermal transducer is possible and after the manufacturing of micromachine.
In order to determinate a series of specifical values for travelling-wave ultrasonic micromotor and also the variation of them, the author has performed the aquisition and tested the USR30-S3 type machine [3].

Figure 1: USR30-S3-type traveling-wave ultrasonic motor.

2. THE TEST WORKBENCH.

In the case of USR30-30-type micromotor [5] which is presented in figure 1, it has been used as cooling system a radiator made from aluminiyum. Knowing the aplicability domains for rotating travelling-wave ultrasonic micromotor, it can be asserted that the function of machine has a specifically short-time period. The analyses of heating process was realized in a laboratory where the temperature of ambient medium was maintained constantly while testing.
On the testing bench dedicated to TWUM has been used a digital thermometer fixed in order to determine the temperature at the surface of motor's case and the machine was fixed on a support with radiator (2700 mm^2).
The testing workbench, presented in figure 7, was made for the study of travelling-wave ultrasonic micromotor's function when is heating up in load and no-load conditions.

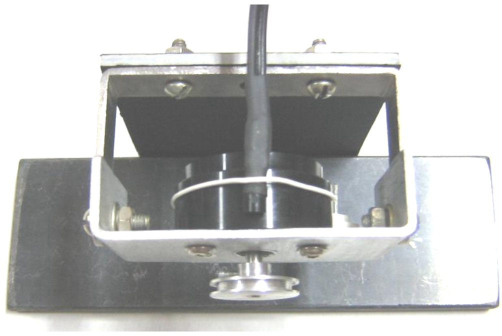

Figura 2: The mounting of USR30-S3-type TWUM on a support with radiator and of the thermal sensor.

Generally, the TWUM is used in apllications for short periods of time(1-3 minutes). Even if the function time periods are short, the temperature of piezoceramic stator is increasing very much, and as a result, the micromotor is heating up. It must be mentioned that the heating of the piezoceramic stator and the other mechanical parts happens fast.
First, it was made a no-load test for the travelling-wave ultrasonic micromotor. The speed of TWUM was established at a minimun value *n*=60 rpm.
Thus, analizing the obtained graphic (figure 3) it is observed that the temperature at the surface of case has been increased slowly in the established time period T=180 s (continuous function).
Also, it was made a no-load test for TWUM and the speed was established at a maximum value, n=300 rpm. In this case, analyzing the obtained characteristic from figure 4, it is observed an accelerated heating process in the established time period previously.
.

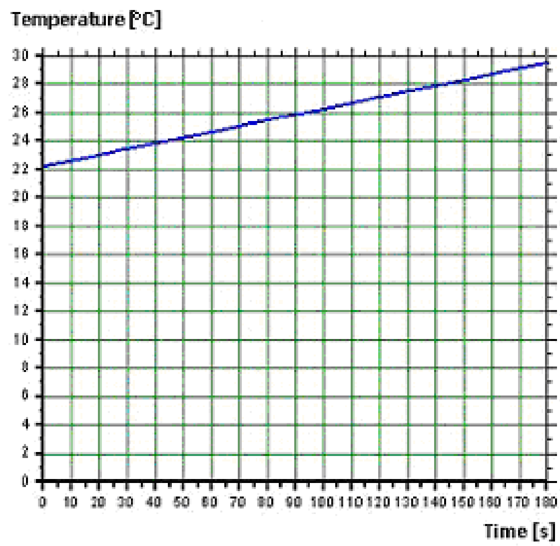

Figure 3: The characteristic *θ=f(t)*, at no-load conditions (n=60 rpm).

The study of motor's function in load conditions was made while maintaining the same time period as in no-load case. Thus, using a mechanical break system(not represented in figure 7) it was maintained the mechanical torque at nominal value. (M_n=0,05Nm). The speed established before coupling the brake had a value n=220 rpm.
Thus, at torque's nominal value the speed of micromotor has decreased at a minimum value n=60 rpm. Thus, the graphic from figure 5, presents the heating process of TWUM at nominal value of torque in the established time period.

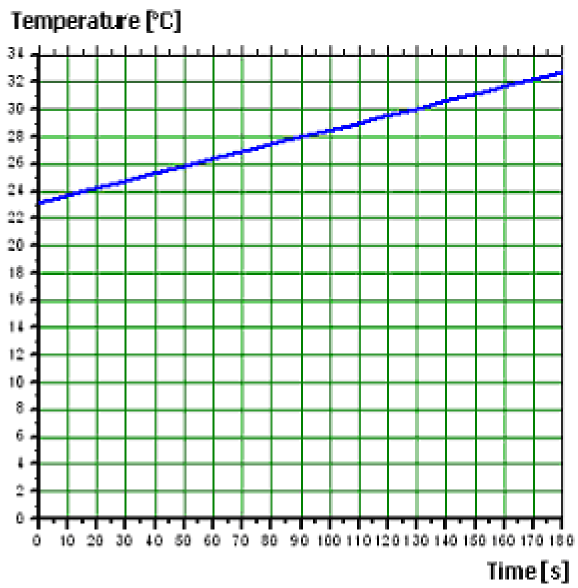

Figure 4: The characteristic $\theta=f(t)$, at no-load conditions (n=300 rpm).

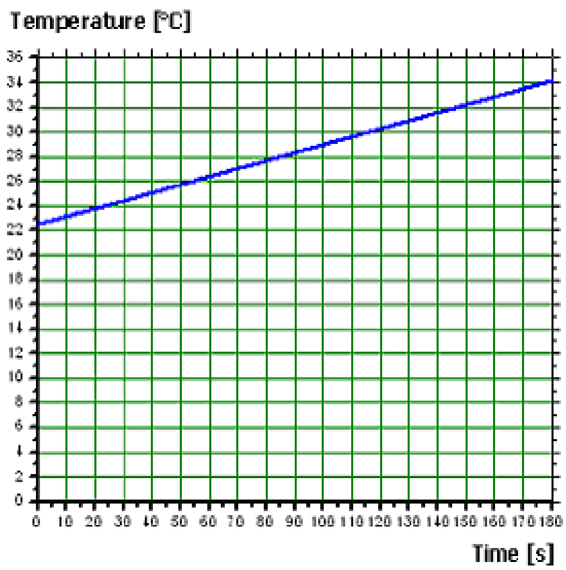

Figure 5: The characteristic θ=f(t), at no-load conditions (n=60 rpm).

Later on, the speed of micromotor was established at a maximum value of n=300 rpm and the machine has been loaded at nominal value of torque (Mn=0,05Nm).
The value of speed, has decreased (n=180 rpm), and later on, it was made the measure of the temperature's increasing value in time.
The graphic is presented in figure 6 and it must be mentioned the fact that it is observed an accelerated increase of temperature at the surface of motor's case.

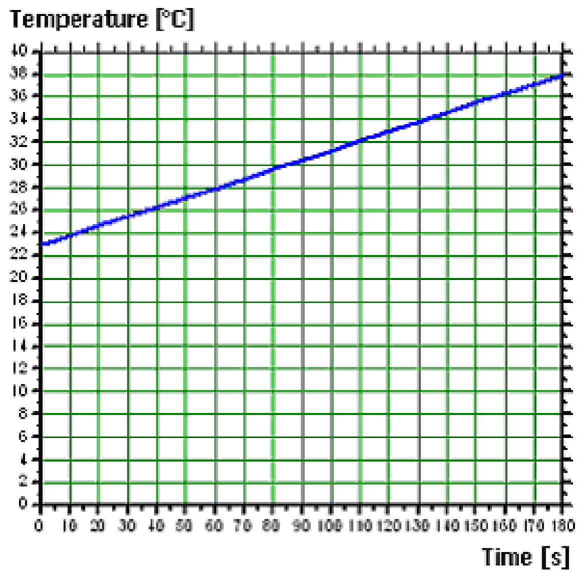

Figure 6: The characteristic θ=f(t), at load conditions (n=180 rpm).

It has been observed in practice that the mechanical resonance frequency of the motor shift towards lower frequencies during the operation of the motor due to the temperature increase within the body of the stator.
Also, it is known that, the most important control problem with the motor is the influence of the temperature on the resonance frequency of the stator.
That is the reason for which the researchers are now concerning for elaboration of some equivalent circuit models which must include the temperature parameter in it.
The main conclusion to be drawn is that for speed control purposes the influence of temperature changes must be integrated must be integrated in model prediction for long term operations.
Further on, the author will study the functioning of the piezoelectric motor presented in this paper, considering mediums with different viscosities and different conditions regarding pressure change and vacuum.

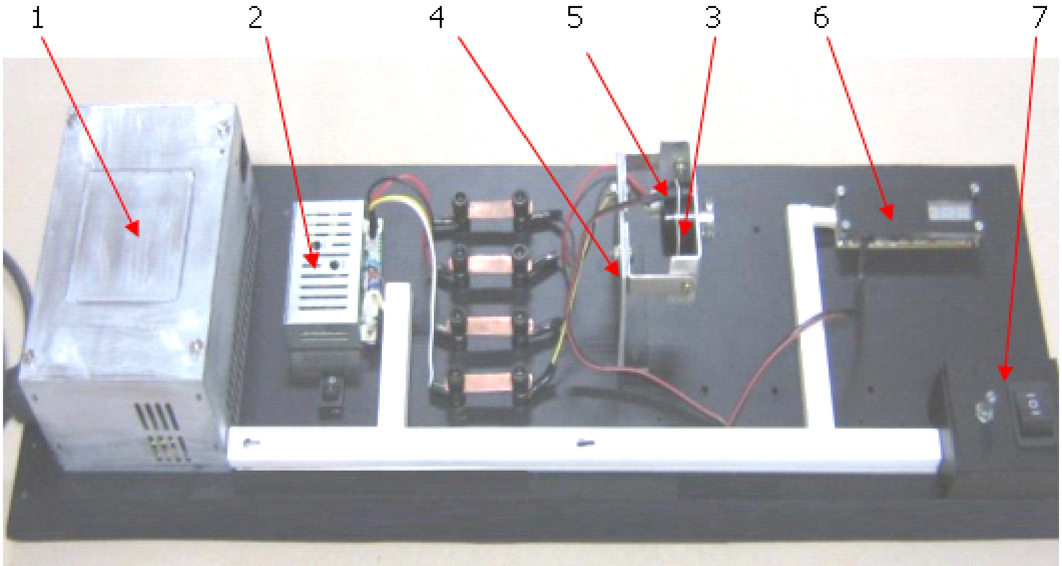

Figure 7: The monitorization of heating process at USR30-S3-type TWUM. 1. 12VCC voltage source; 2. D6030 driver; 3. TWUM; 4.support with radiator; 5. thermal sensor; 6. digital thermometer; 7. reverse of rotational sense.

3. CONCLUSIONS

At the final of TWUM testing, the author has found that although the micromotor has a compactness construction, the micromachine should have a case in order to allow yet a efficient cooling process.
A future optimization process for this type of micromotor should have included compulsory the reduction of friction losses, in order to obtain a decreased working temperature.
This fact is possible once there are used quality friction materials in the place of these used in present time.
Another aspect which was onserved, is that the speed of TWUM increases in time at no-load conditions having straight boundle with the increase of stator's piezoelectric material. (the piezoceramics have thermal hysteresis) and also due to friction between stator an rotor's motor.
At higher values for piezoceramic material's temperature, it may appear the depolarization phenomenon and the lose of piezoelectric properties.
We can also mention the following applications for piezoelectric motors: manufacturing process control, fiber optic positioning pick-and-place assembly camera auto-focus medical catheter placement, microsurgery, semiconductor test equipment computer disk drives robotic positioning pharmaceuticals handling.
There are well-known commercial applications of piezoelectric motors such as the mobile phones security equipment, automotive applications toys.

The monitoring of the temperature's variation for each element of the travelling-wave ultrasonic motor is one of future research directions.

References

[1]. H.Das, X. Bao, Y. Bar-Cohen, Y. Bonitz et al., *Robot manipulator technologies for planetary exploration*. Smart Structures and Materials, 1999, p. 1-8.

[2]. X. Bao, Y. Bar-Cohen, *Complete travelling of rotary ultrasonic motors actuated by travelling flexural waves,* Smart Structures and Materials, vol. 103, 2000, p.1-11.

[3]. A. Iino, K. Suzuki, M. Kasuga et al., *Development of a self-oscilating ultrasonic micromotor and its applications to a watch.*, Ultrasonics, vol. 38, 2000, p. 54-59.

[4]. Ma. Cojan, Al. Simion, L. Livadaru et al., *Încercările maşinilor electrice*. Iaşi: Editura Pamfilius, 2004, p. 57-74, 78-86.

[5]. I. Prisacariu, *Contribuţii teoretice şi experimentale preliminarii privind realizarea unor noi motoare electrice neconvenţionale* Referat III în stagiul de pregătire doctorală, Suceava, 2007, p. 5-16.

[6]. Shinsei Co. Ltd., (2007) http://www.tky.3web.ne.jp.