CONTRIBUTIONS ABOUT THE MAKING OF EXPERIMENTAL STANDS FOR UNPROTECTED SUBMERSIBLE PIEZOELECTRIC MOTORS

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Abstract. *The focus of this paper is the presentation of some considerations about the functioning of unprotected submersible piezoelectric motors. The development of microrobotics and micromachines has led to some diversified research activities about their function and construction. The implementation of micromachines in nowadays domains like automatics, microsurgery, positioning systems, office applications due to advantages, has concomitantly imposed some technical requirements like small dimensions, fiability and also the function in different mediums as vacuum or other severe conditions. The authors present their contributions to conceiving and making didactic experimental stands to study the behavior of submersible motors made using reverse piezoelectric effect. The experimental results regarding the influence of liquid's depth on motor's function are presented in a graphic mode. Mention is also made about the fulfilment conditions for its construction as well as about the conclusions of this research. The study of piezoelectric motor's function in other severe conditions is the main subject of a future paper.*
Keywords: *piezoelectric motors, submersible motors.*

Introduction

The interest in the study of piezoelectric motors is highly justified, because, regarding conventional electromagnetic motors, we can certainly enounce the following advantages: high load torque in low speed range, low acoustic noise in operation, fast response, negligible effect from external magnetic or radioactive fields, hard brake and no backlash.
Unprotected submersible electric machines are used in applications like: cooling plant of electrical high power transformers where the motor is submerged in insulating oil [4, 5], case presented in figure 1, and also at a freezing plant used in compression-type refrigerator [14].
Also, the use of piezoelectric motors in many applications has required at the same time the study of their function in mediums like: vacuum and different liquids with different viscosities. They have also been used for the construction of robots used in N.A.S.A. projects.

The functioning of unprotected submersible electric machines is conditioned by the folowing aspects [3]:

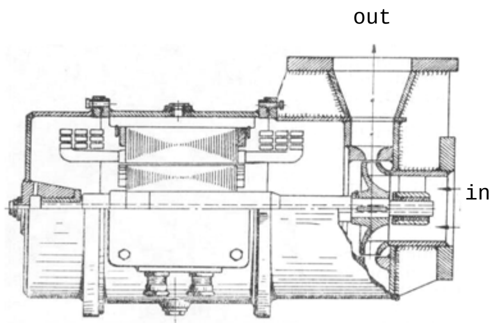

Figure 1. Oil pump, used at cooling plant on electrical high-power transformers
(reproduced from: [5]).

- compact size (simple structure; stator and rotor with no windings);
- the motor must operate independent from the insulation resistance of the constructive elements;
- the function of the motor must not depend on resistivity of the liquid in which the motor is submerged;

▪ the electrocution risk must be maximum reduced;
▪ the function of the motor must be posible at supply voltages like: 10-15V;
▪ the motor must have the capacity to function without disturbing another devices or equipments also placed in liquid;
▪ the constructive parts of motor must have resistance to corrosion.

As a result of different studies, it has been discovered that neither of the known solutions aplly totally these conditions.

Instead of this, there are some motors that approach by a constructive model which fulfils the conditions previously mentioned.

From this category we can mention: acyclic electric machines, vibromotors and piezoelectric motors.

Researches about the unprotected submersible electric machines at the „Ştefan Cel Mare" University of Suceava

The studies about unprotected submersible electric machines are concerning different research communities from Japan and U.S.A. but also from other states, and so, after many experiments, there were built ships (figure 2), their function being based on the electromagnetic or magnetohidrodynamic propulsion.

Figure 2. Yamato submarine-which uses the principle of electromagnetic propulsion

These types of submarines are used in military applications [6, 7].

In Romania, the unprotected submersible electric machine concept, was enounced in a scientific paper [3] presented at "Development and Application Systems" Conference, organized by the Faculty of Electrical Engineering, "Ştefan cel Mare" University of Suceava.

Later on, the development and the diversity of researches at the "Ştefan cel Mare" University of Suceava regarding the unprotected submersible electric machines has undergone, the following stages:

♦ Stage I: 1999-2000- finalised with a diploma project [12], which presents the test of a piezoelectric motor operating like an unprotected submersible electric machine, the use of acyclic motor for making a submersible motor, the test of electric motors with liquid rotor (figure 3);

Figure 3. Experimental stand for the study of an electric motor with liquid rotor

♦ Stage II: 2001-2002-finalised with a diploma project [10], which presents an analysis of an acyclic machine operating like a unprotected submersible electric machine;

♦ Stage III: 2002-2003-finalised with two diploma projects [8,9] which present experimental stands to demonstrate the principle of magnetohidrodynamic propulsion, the test of an acyclic generator (shown in figure 4) and a piezoelectric motor.

All these types of motors are conceived like unprotected submersible electric machines.

Figure 4. Experimental stand for the study of acyclic generator operating like an unprotected submersible electric machine (reproduced from: [9]).

Testing piezoelectric motors conceived like submersible electric machines

The main target of the research was to make some experimental stands to reproduce almost entirely the underwater conditions in order to determine the influence of liquid's depth on the speed of the unprotected submersible piezoelectric motor.

For tests, it has been used a piezoelectric motor with rotor disk conceived like an unprotected submersible electric machine.

In this study, there are also studied the following aspects:

- if the function of the motor in liquid has some influence on the speed of the motor;
- if the function of the motor in liquid has negative influences on the adhesive layer used to fix the support plate with piezoceramic element;
- the influence of liquid's viscosity on the speed of the motor.

First experimental stand, proposed by the authors, presented in figure 5, is composed from a glass recipient (1), containing a liquid (2), and the liquid's depth is adjusted while moving a mobile support (3) on which is placed the piezoelectric motor for tests.

The mobile support can be actioned from the exterior of the recipient with a magnet, (5) fixed on a piece (4), controlled by using a shaft (6) also placed in the exterior of the recipient.

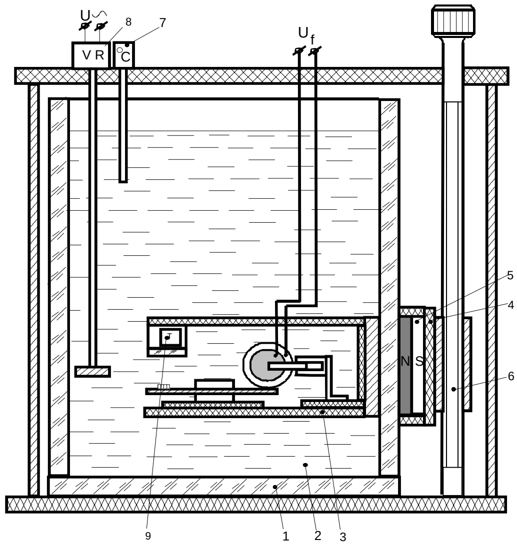

Figure 5. Experimental stand for testing the unprotected submersible piezoelectric motor: 1-recipient; 2-liquid; 3-mobile support; 4-piece; 5-magnet; 6-shaft; 7-thermometer; 8-rotational viscosimeter; 9-tachometer.

The advantages of this solution are: simply made, continuonsly and efficient adjustment of the liquid's depth.

The second experimental stand was made by using the "Pascal's barrel" principle for testing the unprotected submersible piezoelectric motor and it is shown in figure 6. The experimental stand is composed from a glass recipient (1) containing a liquid (2) while at the bottom of this recipient is placed, on a support (3), the object used for testing.

At the bottom of the vessel there is an orifice (a) in which is fixed a flexible pipe (4) also with liquid, lifted up, using a driving system (5), in order to modify the liquid's depth from a larger domain of values.

The advantages of this experimental stand are: high reliability and the possibility to enlarge the range domain for liquid's depth.

Also, for the determination of speed of unprotected submersible piezoelectric motor, each of the experimental stands contains a tachometer and is supplied from a high-frequency power supply.

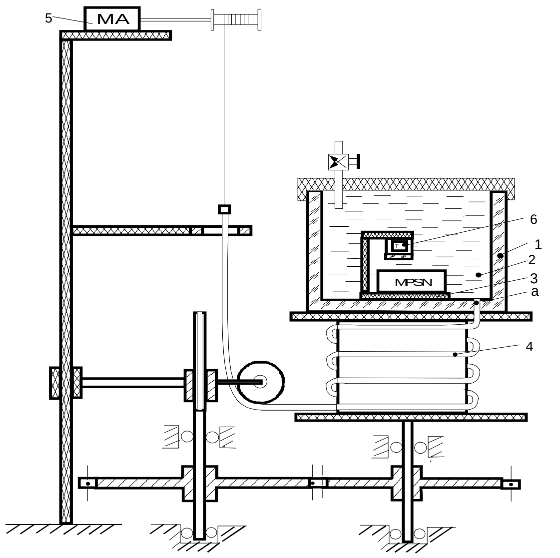

Figure 6. Experimental stand, using the ‚Pascal's barrel' principle: 1-reicipient; 2-liquid; 3-support; 4-flexible pipe; 5-driving system; 6-tachometer; a-orifice.

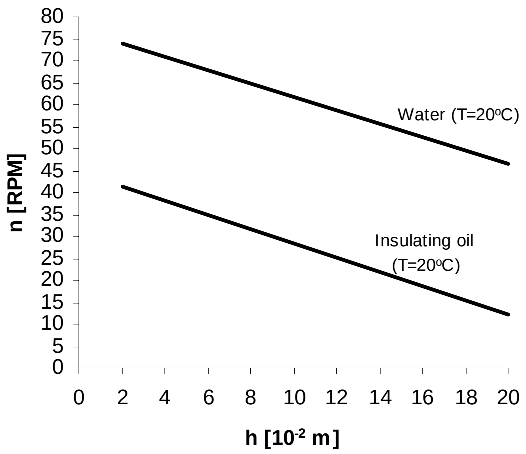

Figure 7. The relation between the speed of the unprotected submersible piezoelectric motor and the liquid's depth.

Figure 7 shows in a graphic mode, a comparison between water and insulating oil (both have the same temperature T=20°C), regarding the influence of depth and viscosity of liquid on the speed of unprotected submersible piezoelectric motor.
Table 1 shows the results of the tests about the influence of the medium on the speed of unprotected submersible piezoelectric motor. It was considered two mediums characterized by different values of viscosity (air and water).

Table 1. The influence of medium on the speed of the unprotected submersible piezoelectric motor.

Medium	Resonance frecquency[kHz]	Speed of the motor [rpm]
Air	66,2	113
Water	66,2	74

For the study of functioning of unprotected submersible piezoelectric motor in a liquid characterized by a higher viscosity, it has been used the insulating oil.
Also, were run conducted tests of the unprotected submersible piezoelectric motor, at different values of temperature of the insulating oil, bearing in mind that his viscosity is also modifying.
The temperature of insulating oil has been modified, gradually at 20°C, 30°C, 40°C, 50°C, to obtain different values for his viscosity. In figure 8, the values for the viscosity of insulating oil are expressed in Engler degrees.
Figure 9 shows the piezoelectric motor conceived like an unprotected submersible electric machine.

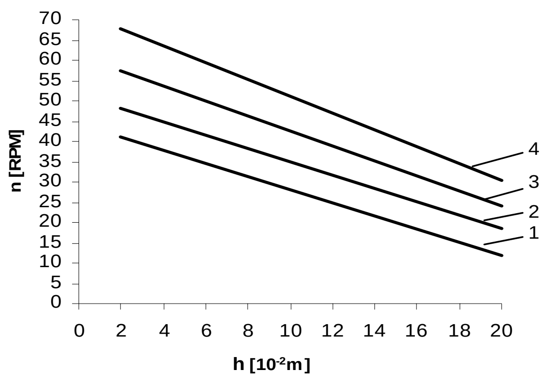

Figure 8. Viscosity vs. liquid's depth considering the unprotected submersible piezoelectric motor:
1-E=7,73°E (T=20°C); 2-E=5,4°E (T=30°C); 3-E=3,8°E (T=40°E); 4-E=1,53°E (T=50°C).

After the experimental tests, there were advanced two patent applications [1, 2].

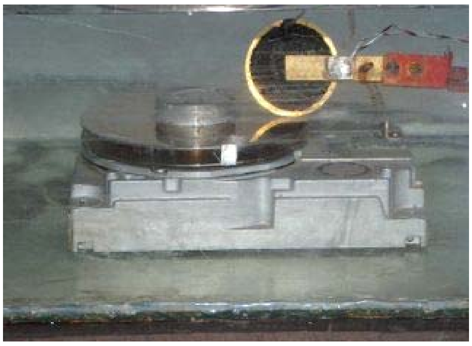

Figure 9. Piezoelectric motor conceived like an unprotected submersible electric machine.

Figure 10 shows the unprotected submersible piezoelectric motor immersed in insulating oil. When the temperature of the insulating oil has been increased, it has been produced the cast of the layer pitch.
In this case, it is important to find a material which doesn't cast at higher temperatures of the liquid in order to protect the piezoelectric material or to test the piezoelectric motor in liquids with different viscosities without modifying their temperature.

Figure 10. Unprotected submersible piezoelectric motor immersed in insulating oil.

The studies and the tests of piezoelectric motors are important because there are many applications which require the function of these motors in different mediums.
As an example, we can mention the articulation mechanisms that drive space and planetary instruments.

Conclusions

At the final of this research of piezoelectric motor with rotor disk conceived like an unprotected submersible electric machine there was enounced following conclusions:

- the piezoelectric material is the most vulnerable part of the motor, which is placed in liquid;
- a possible solution for the protection of the piezoelectric material consists in the consolidation with a thick layer of pitch;
- the speed of the unprotected submersible piezoelectric motor slows down in liquid medium (ex: water) during the modification of the depth, but also in mediums with higher viscosity (ex: insulating oil);
- influence of liquid's depth on the speed of unprotected submersible piezoelectric motor is obvious, because of the action of fluid's pressure;
- it was observed the depositing of a slime on the surface of the constructive parts of the motor derived from the settle of the different elements dissolved in water;
- while increasing the temperature of the insulating oil it has been produced the cast of layer pitch (used to protect the piezoelectric material).

Future directions of research.

Further on, we will study the functioning of the piezoelectric motor presented in this paper, considering mediums with different viscosities and different conditions regarding pressure change, cryogenic temperatures and vacuum.
Also, other types of piezoelectric motors will be tested operating in mediums previously mentioned.

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