EXPERIMENTAL CONTRIBUTIONS CONCERNING ACHIEVEMENT OF A ELECTROCHEMICAL MICRO PUMP

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REZUMAT. Lucrarea prezintă un studiu în legătură cu conversia electrochimică a energiei. Sunt prezentate rezultatele obținute în legătură cu realizarea şi încercarea unei micropompe electrochimice cu silfon.

Cuvinte cheie: conversia electrochimică a energiei, pompă electrochimică, silfon.

ABSTRACT. This paper present contributions regarding the achievement and experimentation of an electrochemical micro pump. Experimental results for an prototyp of electrochemical micro pump with bellows are presented.

Keywords: electrochemichal conversion of energy, electrochemical micro pump, bellows.

1. INTRODUCTION

Electrochemical actuation is an area that can be considered avant-garde, even being among the types of unconventional actuations (piezoelectric, magnetoelectric etc.), first electrochemical actuators being reported in the years 1988 to 1990. We can identify several operating principles. The first principle is based on electrolysis of liquid electrolytes (aqueous) achieving mechanical work, force and displacement, mostly by deflection of a elastic membrane (Figure 1).

National researches in electrochemical actuators and micro pumps were supported by the ICPE-Advanced Research, Unconventional Engineering Laboratory Bucharest [7] and EMAD Research Center from Stefan cel Mare University of Suceava [2, 3, 4, 5, 9, 10, 11, 12, 13]. Advanced study in electrochemical micro pumps are also found at international level [1, 6, 8].

Conversion efficiency and optimal parameters for this type of actuators depends on many factors, which may influence or affect the electrochemical processes (electrolysis): electrode material, geometry, surface and volume, gas diffusion and ion concentration of electrolyte, external effects (temperature, pressure, applied voltage).

Essential to achieving forces and displacements are also the membrane characteristics that transforms pressure in motion. Generally, to achieve micro pumps are specific flat or corrugated membranes.

Electrochemical micro pumps applications are numerous [7]. Are used in microsystems pumping, cutting and handling of liquid, specific to pharmaceutical or medical field (a micro valve whose structure is based on electrochemical actuators).

Also, in medicinal chemical industry is necessary, in most cases, the use of substances dosing devices that involves the development of simple devices in terms of construction.

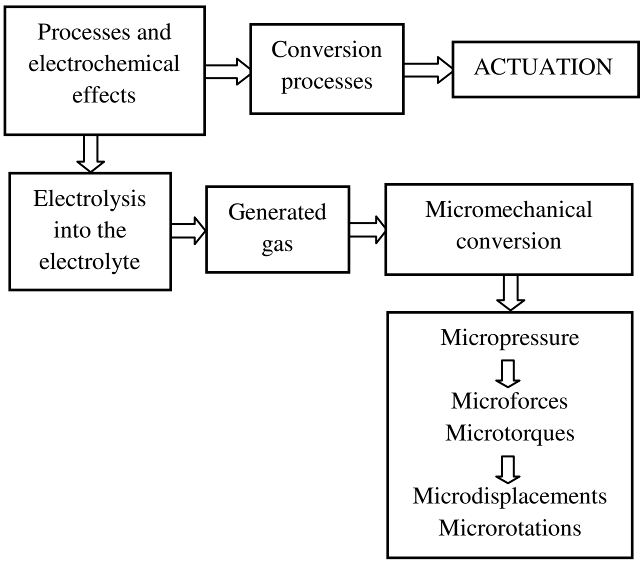

Fig.1 The schematic diagram of achieving mechanical actuation from electrolysis processes (reproduced from [7])

As regard the experimental study of the electromechanical micropumps, known from research in the field, is necessary to resolve problems on reliability which must be as possible higher. In order to transmit small amounts of liquids, in the state of the art are some common solutions known as electrochemical micro pumps.

A simple solution (theoretically) would be that in a single cavity (sealed container) to be placed two immiscible liquids with different specific weights, representing a active fluid and a circulating fluid, the latter being subjected to the action of electrolysis. Influenced by Joule-Lenz, by microwaves or by electric arc, the liquid will decompose in the gases, vapors, creating an excess pressure that causing the circulated fluid evacuation to outside pump.

2. ELEMENTS OF CALCULIONS ON THE PRESSURIZED VESSELS DESIGN

To calculate and size vessels that will be under pressure in case of micro pumps and micro actuators will take into account the following loads: design pressure of the the container element; bending moments that occur in the sheaths of vessels whose longitudinal axis is not right; the vessel weight and its content, in working conditions, respectively, hydraulic test; additional loads results from other devices, thermal insulations, flooring, interior design etc.; reactions due to the vessel supports, dynamic loads, loads due to the prevented thermal expansion.

Hydrostatic pressure at a certain point, p_h, is the pressure created by the liquid column above the considered point and is calculated with:

$$p_h = \frac{y \cdot h}{10} \text{ [MPa or bar]},$$

where,
y is the specific weight of the liquid phase (daN/dm^3);
h is the height of liquid column above the considered point (*m*).

Hydraulic test pressure of a vessel (section), in MPa (bar), is equal to the calculated value by the following relationship:

$$p_{ph} = 1{,}25\ p_m \cdot \frac{f_{ap}}{f_a} \text{ [MPa or bar]},$$

where:
p_m - maximum allowable working pressure of the vessel (MPa or bar);
f_{ap} - allowable tension of the element for p_m, to the temperature at which have place the attempt, in N/mm^2;
f_a - allowable voltage of the determining element for p_m to the temperature calculation, in N/mm^2.

On vessels design shall consider also the following loads: design pressure of the the vessel and loads due to alternating dynamic loads acting on the vessel.

When calculating the strength of elements are used the following parameters:
p_c- design pressure, in MPa;
f_a- allowable tension, in N/mm^2;
E^t- elasticity module on calculation temperature, in N/mm^2;
s_p- design thickness of a vessel, in cm;
c_1- addition to operating conditions, in cm;
z- coefficient of resistance of welded joint;
c_{r1}- addition to rounding up, in cm;
c_{st1}- safety factor to loss of stability within the elastic range;
c_{st2} - safety factor to loss of stability outside the elastic limits;
D- inner diameter of the element, in cm;
H- height of the convex of the bottom, in cm;
L- length element calculation, in cm.

Calculation of simple cylindrical elements subjected to internal pressure is made with one of the relations below:

- design thickness of a vessel:

$$s_p = \frac{p_c \cdot D}{2 \cdot f_a \cdot z - p_c} + c_1 + c_{r1};$$

- design pressure at element checking:

$$p_c = \frac{2(s_p - c_1) f_a \cdot y}{D + (s_p - c_1)}.$$

3. ELECTROCHEMICAL MICRO PUMP WITH BELLOWS. EXPERIMENTAL RESULS

Electrochemical micro pump with bellows made and analyzed in this work, consists of a plate 10 of heat conductive material, which are placed the radiator 2 to prevent possible overheating, the micro pump body consists of a bellows (corrugated elastic tube) filled with volatile liquids or, in this case, with oil and the resistive element 3 which is the source of heat for micro pump actuation.

Bellows is provided at the top with a exhaust nozzle 6 of the pressure from within. The nozzle is connected, to an flexible element 5 (temperature resistant silicone tube) that connects the bellows and exhaust valve. Discharge valve is mounted on a support which is provided with a cover 8 which is supported by a spring 7. The cover is designed to release the valve at total stroke of bellows (fig. 2).

Resistive heating element 3 is fixed onto thermally conductive support and is designed as energy source for electrochemical pump. The heating element will give the energy as heat to the conductive support which, in turn, will give the heat to the bellows filled with fluid. The fluid will vaporize creating a pressure inside it that will elongate the corrugated tube that will push the cover 8 releasing the valve 6.

Discharge valve will release into a very short time accumulated pressure that will cause the resumption of a new cycle of operation of electrochemical micro pump. The experimental electrochemical micro pump analyzed in the paper can be seen in Fig. 3.

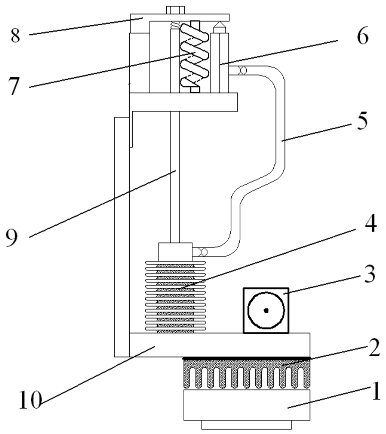

Fig. 2 Electrochemical micro pump with bellows
1-cooler; 2-heatsink; 3-resistive element; 4-bellows;
5-flexible connection; 6-discharge valve; 7-helical spring;
8-spring leaf; 9-actuating rod; 10- thermally conductive support.

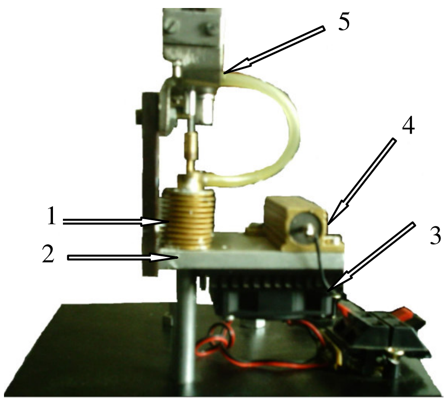

Fig. 3 Electrochemical micro pump with bellows
– experimental model –
1-bellows; 2-aluminum support; 3-radiator with fan;
4- resistive element; 5-valve.

In the case of excessive heating in the lower wall of aluminum support, is an radiator that will take the excess heat which will dissipate into the surroundings with a fan that cools the radiator. The radiator is designed to speed the return of electrochemical micro pomp to initial position.

Figure 4 show the evolution of temperature from the heating element to the actuator (bellows) of the electrochemical micro pump. To study the operation of the electrochemical micro pump two active substances were used: highly refined mineral naftelic oil and petroleum ether. Below are some experimental results on electrochemical micro pump operation.

To control operation of the electrochemical micro pump should know the phenomena that take place inside the considered bellows regardless of the substance type considered inside it.

Thus, the bellows represents the headquarters such phenomena as the atmospheric gas vaporization, evaporation, boiling and condensation. Main aspects and laws that governing the development of these phenomena are known in the literature.

But its expression in electrochemical micro pump operation is dependent on the nature of the volatile liquid used, ambient temperature, the geometrical configuration of the elastic chamber, the nature of the material used to achieve flexible chamber and the working position of the micro pump.

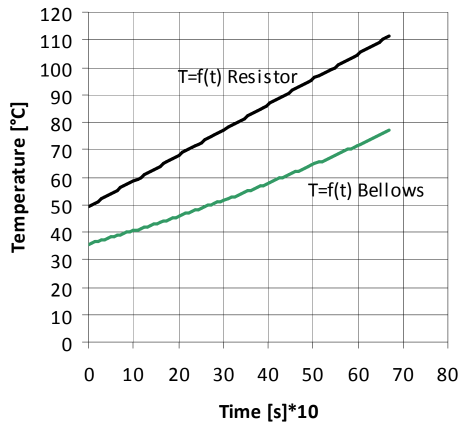

Fig. 4 The evolution of the temperatures developed by resistor and transmited to the bellows in the electrochemical micro pump

Carrying out the above phenomena depends on the influence of these factors and manifests itself in the speed of transient regime.

In this respect, the characteristics shown in Figure 5, highlight the evolution of pressure from inside the bellows (under constant ambient temperature) thermally excited through heating element (resistor) placed on the same aluminum support.

Changing the operating time (rapidity) can be achieved, obviously, throught a proper choice of the active substance, choice dictated by the application which uses electrochemical micro pump.

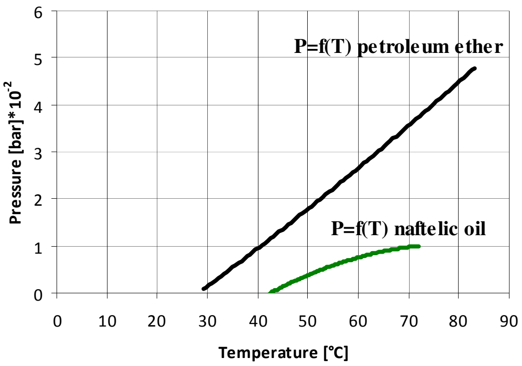

Fig. 5 The variation of the pressure inside the bellows depending on temperatures of the two active substances

4. CONCLUSIONS

Electrochemical micro pump performed and analyzed in this paper has the following advantages: simple construction and low energy consumption.

Electrochemical pump operating speed is dependent on the quantity and volatility of the active substance within the bellows, the ambient temperature and operating position, aspects supported by experimental results.

Choice of the active substance with low vaporization temperature leads to an optimum acting time and in the same time of an low energy consumption.

The characteristics P = f(T) leads to the statement that, the use in electrochemical micro pump of the naftelic oil is recommended in the applications where the acting time is large and petroleum ether in applications that require minimum response time.

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