STUDY ON THE STATIC CHARACTERISTICS OF THE ELECTROMECHANICAL ACTUATORS WITH LIQUID

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Abstract: *In this article, some theoretical and experimental aspects concerning the achievement of electromechanical actuators with liquid are presented. For find the optimal conditions necessary to study, must follows a number of experimental steps which must have as finality a good estimation of the problems and a continuous perfection of the experimental conditions. In this way, the results can be the image of the real operating. Firstly, the static characteristics at on-load operation and the experimental test stand used for the data acquisition are investigated. Secondly, it is presented a new test stand used to obtain the experimental data necessary for the graphical representation of the static characteristics at no-load operation of the electromechanical actuator with liquid. The importance of the study of the electromechanical actuators with liquid is justified by the international tendencies to find and make new models for the actuation and control devices with small dimensions, economical costs, easy for manipulation and which reclaim the reconsideration of the operating principles.*
Keywords: *electromechanical actuators, bellow, volatile liquids, on-load operation, no-load operation.*

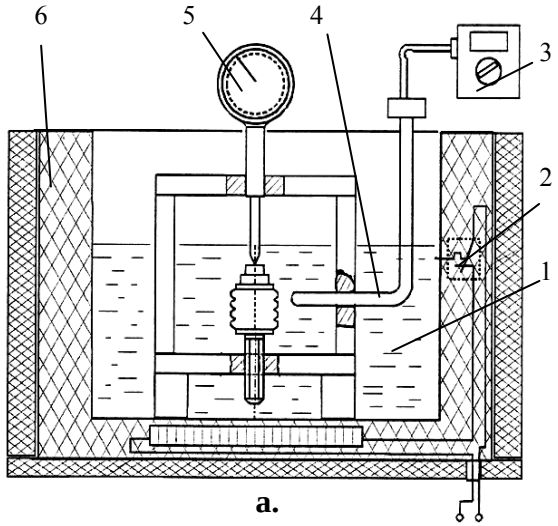
Introduction

The research and the development of new models of actuators have been one of the active fields of the engineering. The interest on achievement of new powerful actuators and advanced motion control systems it is possible by use of the volatile liquids.
To make and experiment the electromechanical actuators it is important to establish the efficiency for the experimental conditions. Therefore, it is impose to represent the graphical operating characteristics and to describe the operating functions, for on-load or no-load regime. The static characteristics of the electromechanical actuators with volatile liquid can be obtained using various experimental test stands with respect of the conditions for the electromechanical machines tests in various operating regimes [1].
For the experimental study of new models, with respect to these aspects, at "Stefan cel Mare" University of Suceava was studied some variants of actuators, especially the actuators with liquid used at solar motors and was a real interest regarding the theoretical and experimental study on the operating principles and characteristics of this class of actuators.
These studies date from 1996, when first experimental results were presented in diploma project [2] or scientifically papers [3], [4], [5]. The main subject of these papers is the presentation on the experimental test stand and the static characteristics for an actuator with liquid, especially with petroleum ether and ethyl ether [6].
The graphic characteristics are analyzed as transient process [7] characterised by an input value $\Delta\theta\ [^oC]$ and an output value $\Delta l\ [10^{-3}m]$.

Consideration on the static characteristics of the electromechanical actuator with liquid at on-load operation

The experimental test stand showed in figure 1 is used for test on the operation of the electromechanical actuators with liquid, to

obtain the experimental data for graphical representation of the static characteristics.



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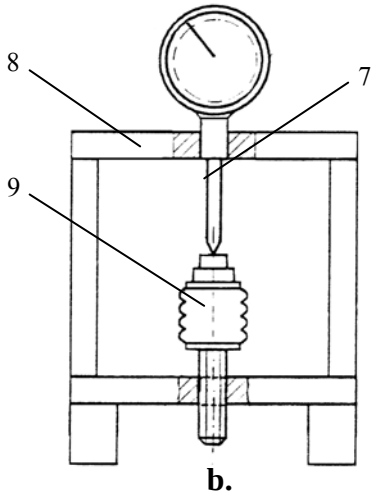
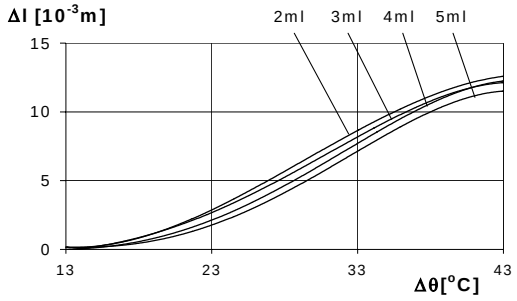


b.

Figure 1. Experimental stand used for obtain the static characteristics for an electromechanical actuator, where: a – cross sectional view; b – detail on actuator placement; 1 – thermal agent; 2 – thermal relay; 3 – thermometer; 4 – well whit thermocouples; 5 – dial extensometer; 6 – recipient made from thermoinsulating materials; 7 – pointed pin; 8 – support; 9 – actuator. (Reproduced from: [2])

This type of actuator was used as propulsion element in the solar motor's operation [2].

The experimental stand is constitute by a bellow which have an volatile liquid sealed inside, where the bellow is disposed on a mobile support and is immersed into a recipient with thermal agent. The thermal agent (which can be the water) is heated using an electrothermal source. The actuator comprises an elastic bellow makes by beryllium bronze which contain an volume of volatile liquid, used as active agent, necessary for experimental determination.



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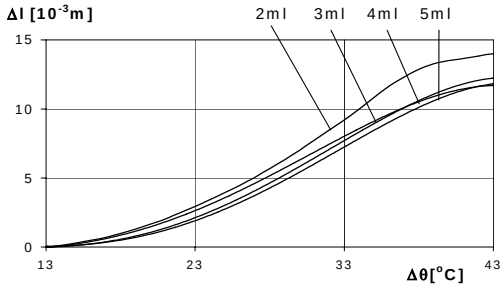

b.

Figure 2. Static characteristics at on-load regime of an electromechanical actuator with different liquid's volumes, where: a – ethyl ether; b – petroleum ether (Reproduced from: [2])

The bellow have two sealed heads, one of them having a threaded extremity, the other one having a cavity in which pleased the pointed pin of an dial extensometer. The dial extensometer is used to measure the value of displacement obtained like response at the upper pressure of the liquid sealed inside of the bellow. This upper pressure is obtained by thermally phase change of the volatile liquid within the elastic bellow is immersed in a thermal agent [8], [9].

In the same time, the dial extensometer represents a load for the operation of the actuator.

Then, the variation $\Delta l=f(\Delta\theta)$ is the static characteristic at on-load regime.

In accord with the art review [2], the ethyl ether and petroleum ether volume, between *2ml÷5ml*, are used for experimental determination.

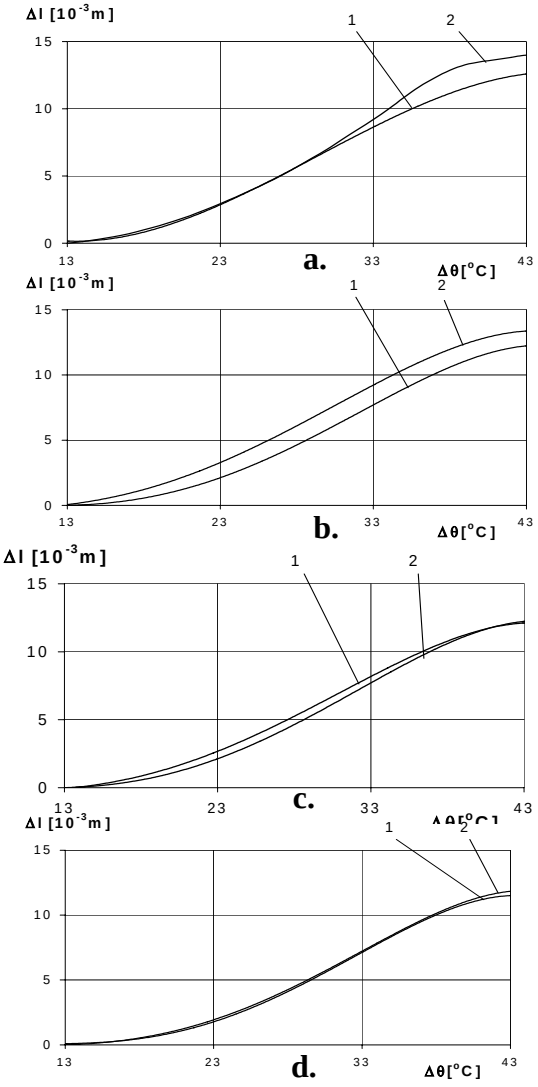

Figure 3. Static characteristics for an electromechanical actuator at on-load operation, using: 1 – ethyl ether and 2 – petroleum ether, where: a – *2ml*; b – *3ml*; c – *4ml*; d – *5ml*. (Reproduced from: [2])

The empirical data was processed using the programs for linearization and for graphical representation [10]. The static characteristics *Δl=f(Δθ)* which was resulted are showed in figure 2, for the petroleum ether and ethyl ether.
By analysis on the displacement's values obtained in rapport with the temperature's value, is evidently that the correspondent values for the stabilized condition, if the ethyl ether is used, are greatly than the values obtained for the stabilized regime for petroleum ether utilization.

In accord with the art review [2], the ethyl ether and petroleum ether volume, between *2ml÷5ml*, are used for experimental determination.
The displacement's variation is $\Delta l = (11{,}3 \div 12{,}7) \cdot 10^{-3}\, m$ for ethyl ether, with a domain of $1{,}4 \cdot 10^{-3}\, m$.
In the same time, for the petroleum ether, the displacement's values of stabilized condition are $\Delta l = (11{,}9 \div 14) \cdot 10^{-3}\, m$, with a maximum range of variation of $3{,}1 \cdot 10^{-3}\, m$. The time period to obtain the stabilized regime is t_t=*90s*.
In figure 3 it is showed a comparation between the static characteristics obtained for an actuator with ethyl ether and the static characteristics obtained for petroleum ether.
If the two sets of experimental data are analyzed, for each volume of used liquid, is ascertain that the characteristics *Δl=f(Δθ)* have the tendency to approach between them in rapport with the increasing of the used liquid's volume.
These processes represent the influence of the different values of boiling point between the volatile liquids, which are $34{,}5^{o}\ C$ for ethyl ether and $28^{o}C \div 60^{o}C$ for petroleum ether.
Another reason for the same variation can be the temperature range of the thermal agent [6].

Study on the static characteristics of the electromechanical actuators with volatile liquid at no-load conditions

Considering the experimental study presented in the previous paragraph, [2], was made a simplified solution of the experimental test stand, which it used to obtain the experimental data at no-load operation of an electromechanical actuator with volatile liquid.
This stand is showed in figure 4 and it is equipped with a length measuring system.
The measuring system is constituted by a dividing rule with indicator pointer actuated by the actuator's axe.

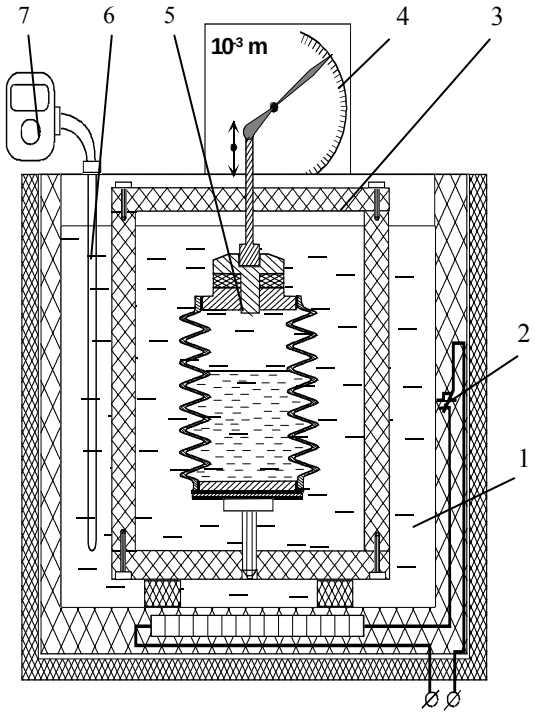

Figure 4. Experimental stand used for obtain the static characteristics for an electromechanical actuator,
where: a – cross sectional view; b – detail on actuator placement; 1 – thermal agent; 2 – thermal relay; 3 – support; 4 – scale; 5 – actuator; 6 – well whit thermocouples; 7 – thermometer.

The presence of the dial extensometer is eliminated by utilization of this measuring system. In this manner it is eliminated the load introduced by the dial extensometer and it is created the possibility to make an experimental study of the electromechanical actuator with liquid at no-load operation.

The experimental data was acquired, processed and graphical represented. In figure 5 are illustrated the static characteristics of an electromechanical actuator with petroleum ether and ethyl ether, when the actuator operate at no-load regime.

The values of displacement in stabilized regime are $\Delta l = (12{,}8 \div 14{,}2) \cdot 10^{-3}\, m$ for ethyl ether (with a domain of $1{,}4 \cdot 10^{-3}\, m$) and between $\Delta l = (11{,}95 \div 15{,}5) \cdot 10^{-3}\, m$ for petroleum ether (with a domain of $3{,}55 \cdot 10^{-3}\, m$).

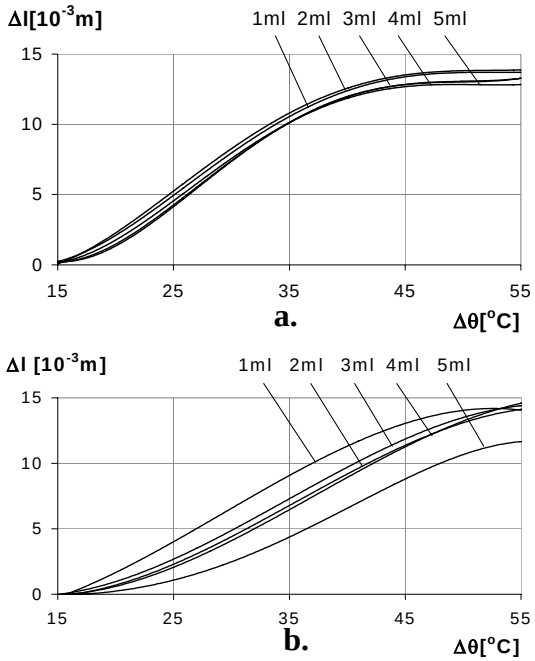

Figure 5. Static characteristics at no-load regime for an electromechanical actuator at different liquid's volumes,
where: a – ethyl ether; b – petroleum ether

The temperature range of the thermal agent was increased in the range of $\Delta\theta = 15 \div 55^{o} C$ and the used volume of volatile liquid was of *1ml*, 2ml, *3ml*, *4ml* and *5ml*.

The stabilized regime is obtained after a time period approximate at t_t=*60s* for ethyl ether and at t_t=*80s* for petroleum ether.

The static characteristics represented at on-load and no-load operation of electromechanical actuators with petroleum ether and ethyl ether corresponds to a vertical emplacement for bellow.

Another aspect for the static characteristics study is illustrates in the figure 7. This situation concerns the possibility to change the position of emplacement of the bellow. In this case, it is represented the horizontal emplacement of the bellow.

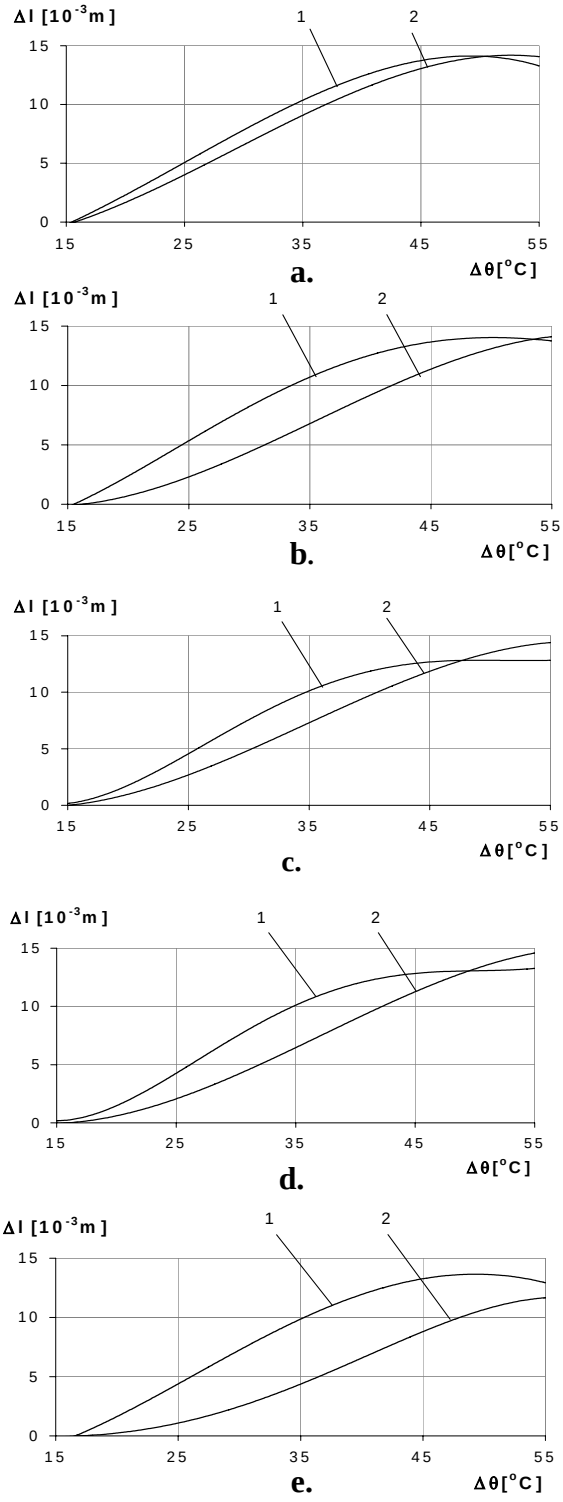

Figure 6. Static characteristics for an electromechanical actuator at no-load operation, using:

1 – ethyl ether and 2 – petroleum ether, where:
a – *1ml*; b – *2ml*; c – *3ml*; d – *4ml*; e – *5ml*.

In this manner, the free surface of volatile liquid, which is sealed inside of the bellow, increase with *~10%* in rapport with the free surface afferent to the vertical emplacement.

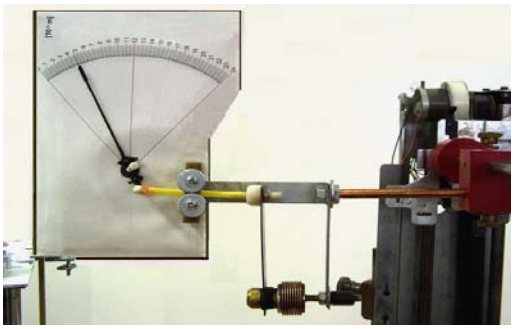

Figure 7. Detail on the horizontal emplacement of the bellows used at electromechanical actuators

Using the same experimental test stand, it is possible to make the study on the operation of the electromechanical actuator with more constructive types of bellows, as it is showed in figure 8.

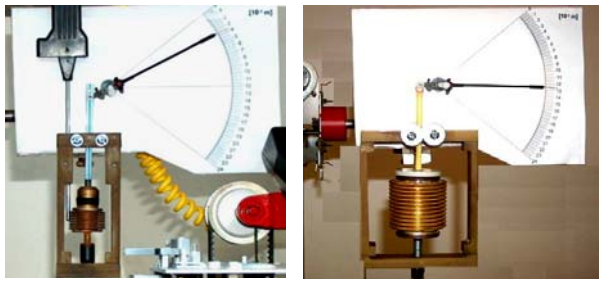

Figure 8. Some types of bellows used for the experimental study of the electromechanical actuators with liquid

Conclusions

The experimental test stand used for acquisition of the experimental data, which are necessary to plot the static characteristics $\Delta l=f(\Delta\theta)$ for an electromechanical actuator with volatile liquid, have the next advantages in rapport with the stand used in [2]:

- simply made and low cost;
- the elimination of the load which is introduced by utilization of the dial extensometer, creates the possibility to plot of the static characteristics at no-load operation.

The analysis of the static characteristics makes evidently the next conclusions:
- Both the no-load operation and the on-load operation has the variation *Δl=f(Δθ)* which corresponds of a transient process without dead time.
- The correspondent values obtained at no-load operation are superiors in rapport with values obtained at on-load operation, with $\Delta l = 4 \div 9\%$ for ethyl ether and $\Delta l = 6 \div 22\%$ for petroleum ether.
- The period of the transient process is smallest at no-load operation in rapport with the on-load operation, with *22÷33%*.
- The graphic curves of the static characteristic at on-load and no-load operation are influenced by the physical properties of the volatile liquids and by the there purity.

Future directions for research

- To establish the influence of the initially experimental conditions on the static characteristic's evolution.
- To establish the influence of the construction's type and of the physical properties of the material used for bellow's achievement.
- To establish the influence of the physic emplacement of the thermal sources on the static characteristic's evolution.
- The study on step response obtained for an actuator constituted on different types of bellows and using various volatile liquids.
- To establish the optimal solution for the bellow's constructive solution and for the type of volatile liquid used for operation of the electromechanical actuator.

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