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Current State of Research at the EMAD Research Centre from „Ştefan cel Mare" University in Connection with Actuators and Solar Motors with Solid Heating Medium

Within the EMAD Research Center of the USV have been developed since 1996 a number of solutions in heliothermic actuators and motors area made on the basis of solid heating medium. The solutions relates to rotary actuators and motors as well as linear actuators with limited movement. Are presented the primary constructive solutions with the peculiarities and finally, the general conclusion regarding the experimentation and practical implementation.

Keywords: *thermo bimetal, shape memory material, heliothermic actuators and motors*

1. General considerations

By solid heating medium is meant a thermobimetal or a shape memory material after the action of temperature.

In technical applications the thermobimetals are widely used because at temperature variation can produce:

- movement due to deformation;
- force due to internal stresses that occur if external forces oppose producing strain.

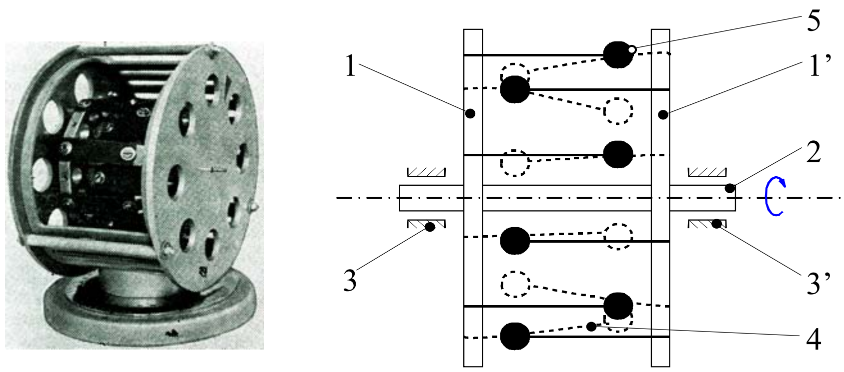
Both of these effects can be achieved with thermo bimetals of different forms, such as: hogging thin bands, **U** shaped work where the angular aperture vary, twisting contrivance or helical spiral, discs whose bend vary.

Overall technical applications using the combined effect of force and motion production by a heated thermo bimetal. The two effects are applied in sequence or simultaneously. For example, a bimetallic band embedded at one termination can operate as a pawl. By heating the band hogs at the free point and its moving, proportional to the temperature, to pawl until comes in contact with it and then the movement ceases in practice. By raising the temperature further, appear the internal stresses that increase in proportion to temperature until achieve the value necessary to operate the pawl. Then the bimetallic piece can close or disclose a contact [3], [4]. In that manner numerous constructions, used in electrotechnics, operate to actuate when limit temperature is reached, as: overload protecion relay and temperature controller (thermostat for warming pad or chamber, flatting mill with regulator, warmers, baking machine, etc.) [1], [5].

Another is the operation of a helical band in the form of an arc, from thermobimetal, that must overcome the elastic force of an spring.

The thermo bimetal member through heating, deforms and acts with a force over the spring, compressing it. Increasing the resistance force of the spring, as it is compressed, proportionally with the extent of deformation prevents the thermobimetal movement. The thermobimetal will continuously shift on increasingly smaller distance, as the spring elastic force increase, not in proportion with temperature variation [1], [2], [6].

One of the first applications of the bimetal in heliothermal is represented by *thermal heliotrope* designed for sun orientation solar panel [7], [8], [10], [11]. In Romania one of the first bimetal applications in heliotechnic is represented by the gravitational solar motor presented in figure 1 [10], [11].



a) b)

Figure 1. Solar motor with thermo bimetal [10], [11]:
a) general view; b) outline drawing:
1, 1′- parallel discs; 2- horizontal shaft; 3, 3′- sliding bearing

If half of the described assembly is exposed to solar radiation, while the other half is shaded through a screen, the thermo bimetalics lamellas, located on the exposed area will inwardly strain, due to heating. Consequently, it will create a difference between the moments taken about weights shaft, from the shaded area among the area exposed to solar radiation, leading to assembly rotation in the direction of the arrow [6], [10], [11].

Within EMAD Research Center contributions are presented and analysed in two directions [4], [5], [6], [10], [11], [12], [13]:

- rotative actuators and motors with solid heating medium;
- linear actuators and motors with solid heating medium;

2. Rotative actuators and motors with solid heating medium

One of the contributions in the domain is presented in figure 3, which shows a heliothermic motor with cam armature actuated by four thermobimetalic propeller, placed on a circular contour with a mutual offset of $\pi/2$. The sequence for a full rotation is presented in figure 3 [4], [5], [9], [10], 11].

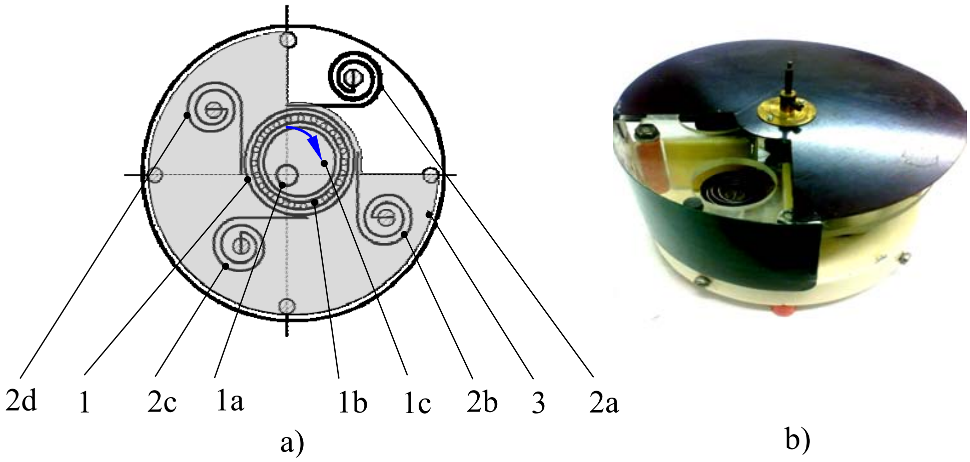


Figure 2. Solar motor with thermo bimetalic propeller– first variant
[4], [5], [9], [10], [11]
a- quadrature – axis division; b- experimental model
1- eccentric rotor; 1a-axle; 1b- ball bearing; 1c-eccentric member;2a, 2b, 2c, 2d- thermo bimetalic propeller; 3- slotted obturator disk

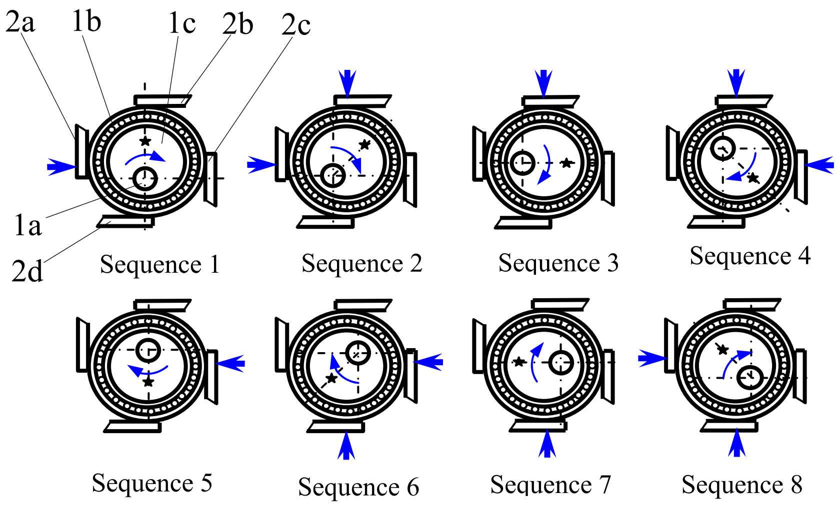


Figure 3. Subsequent sequence for a complete rotation of the solar motor axle [4], [5], [9], [10], [11];
1a – axle; 1b – ball bearing; 1c – eccentric member; 2b, 2c, 2d – thermo bimetalic propeller.

Based on the analogy with electromagnetic motor with pawl was designed the heliothermic bimetallic motor presented in figure 4 [10], [11].

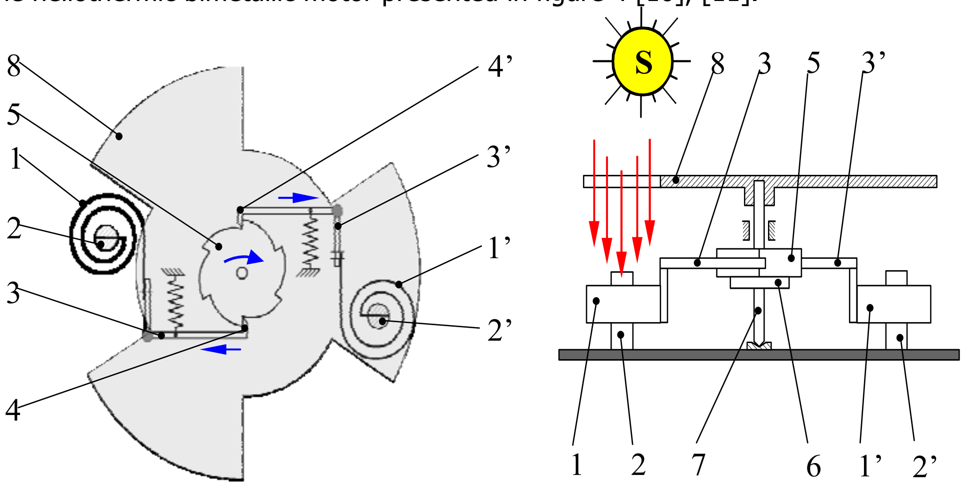
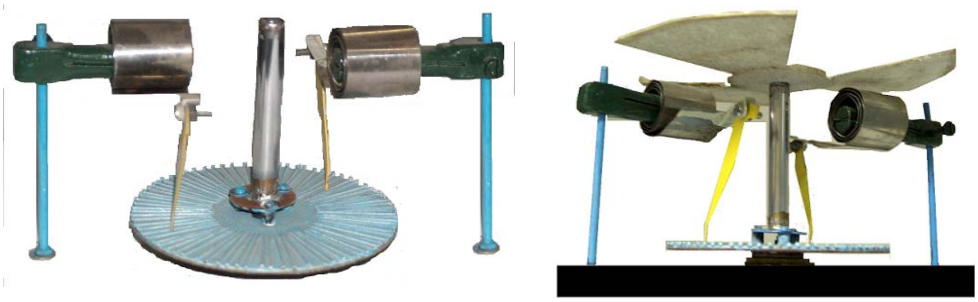


Figure 4. Solar motor with thermo bimetallic propeller–second variant [10], [11]
1, 1'-thermo bimetallic propeller; 2, 2'- support; 3, 3'-hinged arm; 4, 4'- pawl; 5- ratchet wheel; 6- one-way apparatus; 7- axle; 8- slotted obturator disk.

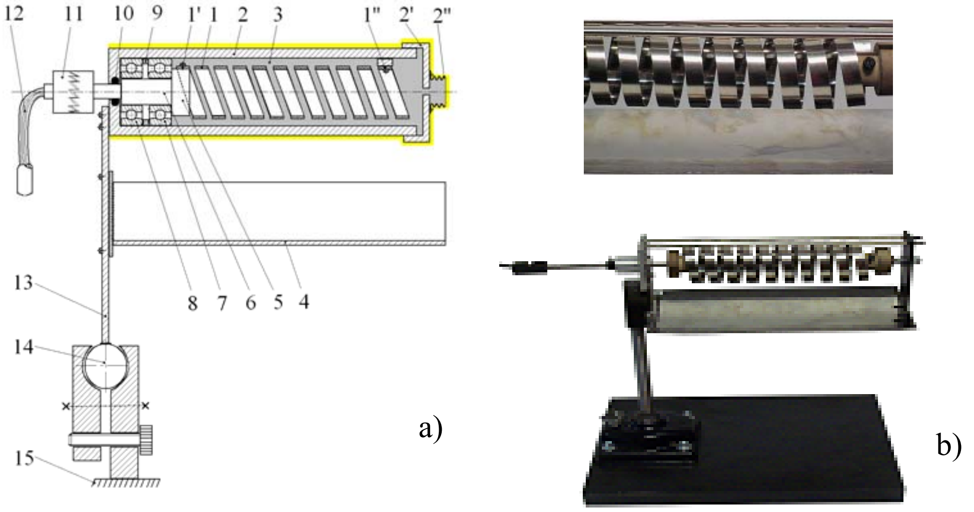
Alternatively, the helio thermic motor with bimetallic propeller and pawl is presented in figure 5 [9], [10], [11].



a) b)

Figure 5. Solar motor with bimetallic propeller achieved on Research Center EMAD Suceava [9, 10, 11]
a), b) – general view of solar micromotor with propeller

Figure 6 presents a variant of rotative helio thermic motor with bimetallic band associated with a cilindrical – parabolic concentrator [10], [11].

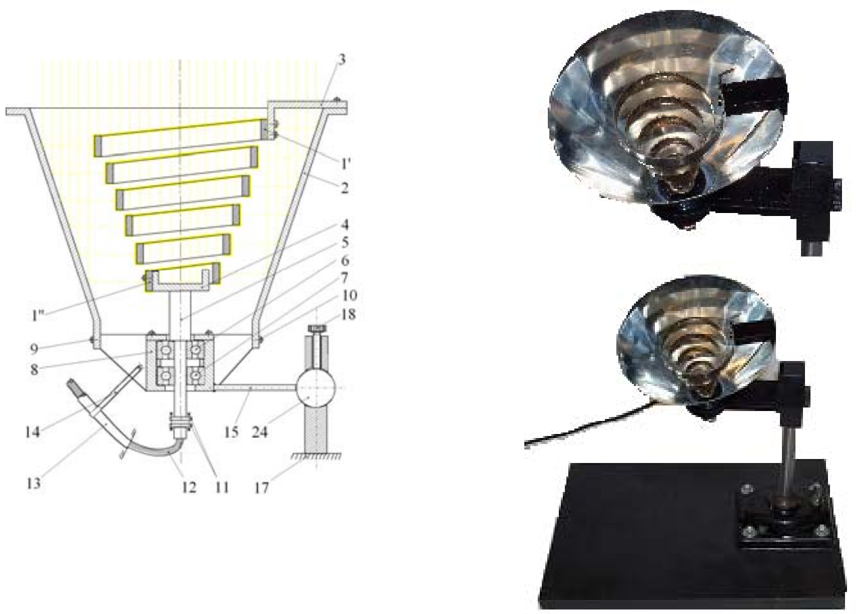


a) b)

Figure 6. Heliothermic actuator with bimetallic band associated a cilindrical – parabolic concentrator [10], [11];
a- quadrature – axis division; b- experimental model
1 – thermo bimetal band; 2 –tubular container; 2' – cap; 2" – sylphon; 3 –thermo-conductor fluid; 4 – cilindrical – parabolic concentrator; 5 – pap; 6 – angular arbor; 7, 8 – roller bearings; 9 – distance piece; 10 – semering; 11 – one-way apparatus; 12 – flexible axle; 13 – holder; 14 – toggle joint; 15 – supporting surface.

To increase efficiency in another variant the bimetallic coil is dipped in a liquid conductive heating medium as shown in the previous version.

Based on the spiral plane arc through coil bending in pivotal alignement was obtained the heliothermic actuator with bimetallic cone coil associated with a cone concentrator and at that the trap surface was noticeably increased.



a) b)

Figure 7 Heliothermic actuator with thermo bimetallic converter created after a volute spiral layout associated a cone concentrator [10, 11];
1 – bimetal band; 2 – cone concentrator; 3 – metallic stay; 4 – pap; 5 – axle; 6, 7 – roller bearings; 8 – fastening piece; 9, 10 – bolts capture; 11 – connection piece; 12 – flexible axle; 13 – holder; 14 – anchor; 15 – arm; 16 – toggle joint; 17 – supporting surface; 18 – clamp

In an improved variant the surface exposed to solar radiation is doubled by using two cone concentrator one inner and one outer as shown in figure 8.

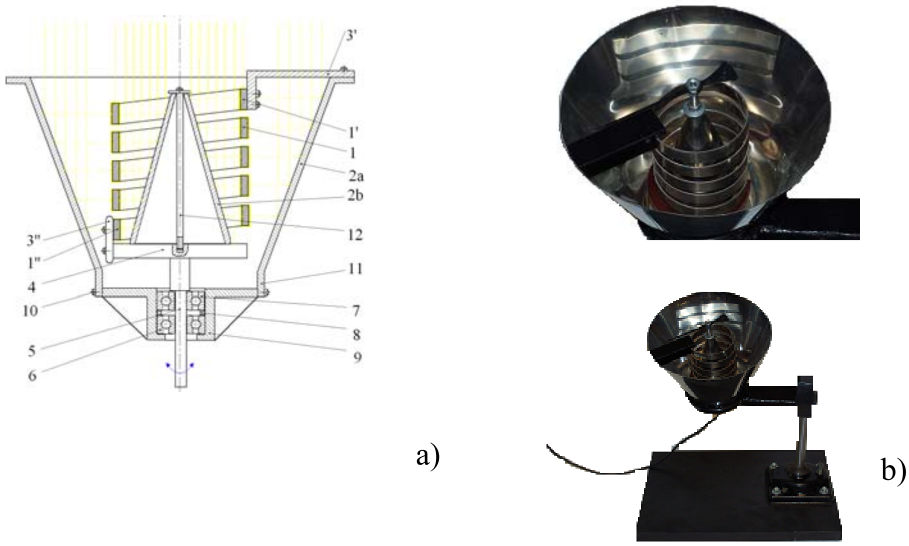


Figure 8. Heliothermic actuator with thermo bimetallic converter created after a volute spiral layout associated a cone concentrator [10, 11];
1 – bimetal band; 2a, 2b – cone concentrators; 3’, 3” – metallic stay; 4 – pap; 5 – axle; 6, 7 – roller bearings; 8 – backing piece; 9– fastening piece; 10, 11 – bolts; 12 –clamping bolt.

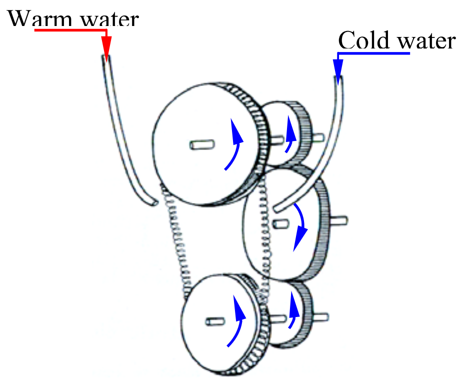
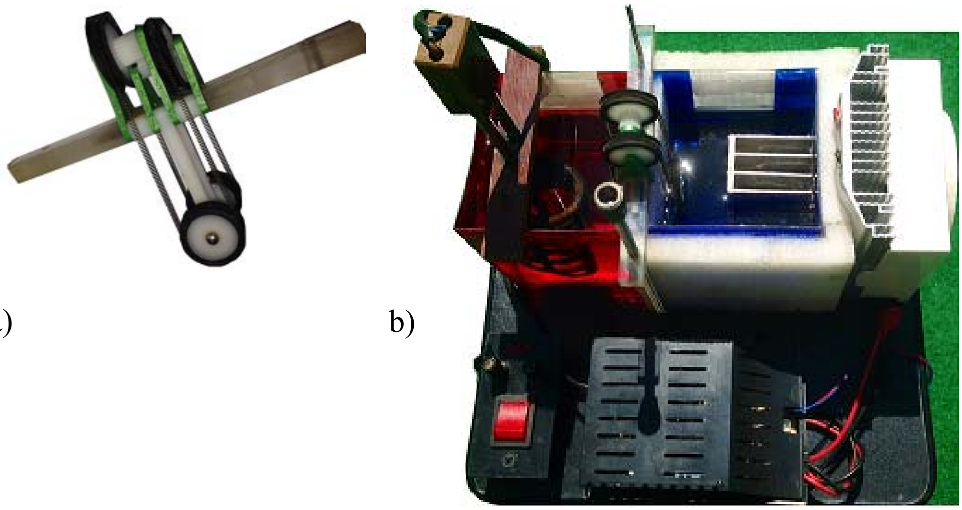


Figure 9. Explanatory at synchronized solar motor with Nitinol [10], [11]

The synchronized version of the rotary motor with nitinol is shown in figure 9. The motor in this example comprises two axle, forced to rotate at the same angular gear, due to the presence of some sync gear. On these axle are mounted riggers of different diameters and around the two wheels is crossed a Nitinol spring, on spiral shape (the most effective was proved the spring made of Nitinol wire, with 0.5 mm diameter). If riggers are coiling in the direction suggested in figure 9, the Nitinol spring will be stretched on the right section, due to unequal wheel diameters. Keeping cool this portion, the spring of Nitinol will keep the compass state during its passage over the upper wheel with larger diameter [10], [11].

If now it is heated the Nitinol spring left section, it will tend to shrink, putting more couple over the biggest rigger, causing its circumrotating.

The rotation is transmitted through smaller rigger gears, which leads a new portion of the Nitinol spring, unto the cold area, where occurs again the extent. In this way, it provides a continuous motion, the machine can perform effective work.



a) b)

Figure 10. The Nitinol motor and experimental equipment used within the EMAD Research Center [4, 5, 10, 11]

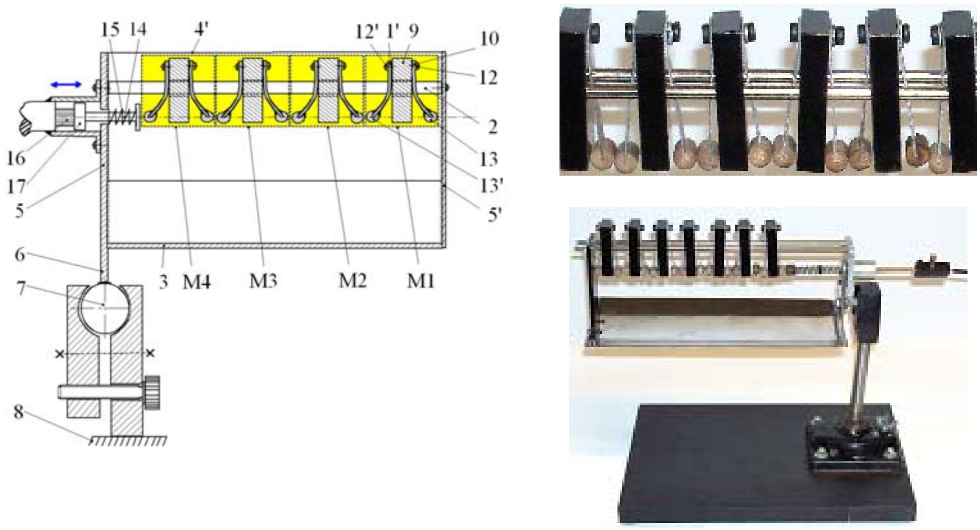
a) Nitinol motor detail; b) general view

The rotative synchronized Nitinol motor variant studied within the Research Center EMAD is presented in figure 10a, and the experimental equipment used to study performance characteristics is presented in figure 10b [4], [5], [10], [11].

3. Linear actuators and motors with solid heating medium

One of the first variant of linear motors with solid heating medium is presented in figure 11.

The version exposed previously was completed as linear motor with limited circulation, using as solid heating medium, bimetallic lamellar springs. The analyzed motor is constituted from several thermobimetallic module, each one being constituted from a aluminum parallelepiped bloc, found under the solar radiation operation. On its faces are placed two bimetallic lamellar springs that under the action of solar heating deforms outwards. The thermo bimetallic module deformations are added giving a resultant displacement that is transmitted to the actuated element, through a flexible cable [10], [11].

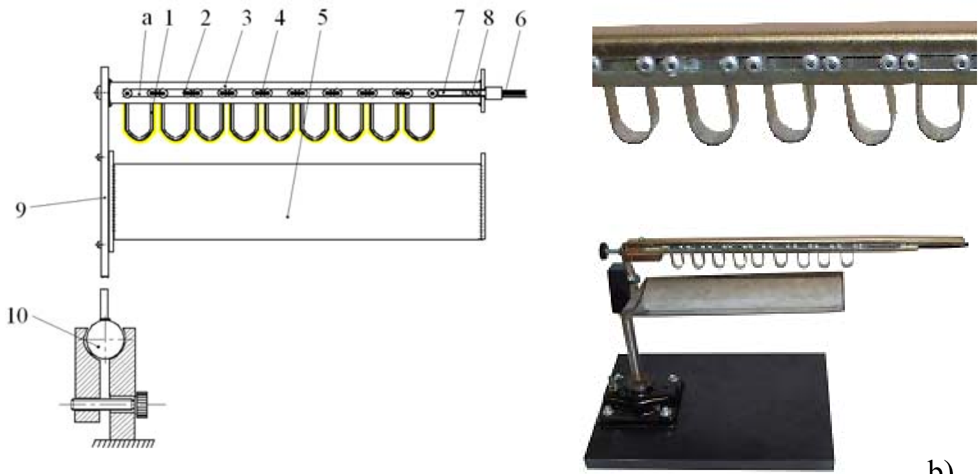


a) b)

Figure 11. Heliothermic motor with thermomechanical module with bimetallic lamellar springs [10], [11]
a- quadrature – axis division; b- experimental model
M1, M2, M3, M4 – thermomechanical module; 1, 2 – guards; 3 – cilindrical – parabolic mirror; 4, 4′ – plane mirrors; 5, 5′ – support plate; 6 – aid foot; 7 – toggle joint; 8 – horizontal surface;9 – bulky parallelepiped bloc; 10, 11 – bimetallic lamellas; 12, 12′ – bolts; 13, 13′ – metal parts;14 – floating draw bar; 15 – opposing spring; 16 – flexible wire; 17 – connector.

In another variant the thermobimetallic modules are represented through a bimetallic bent arc – preformed in the shape of "**U**", whereon the extremes are deformed outwards sliding on the guide channel.

The deformations of thermobimetallic modules are added and give a Resulting displacement produced by the deformations of thermobimetallic modules it is transmitted through the flexible wire to the driven element.



a) b)

Figure 12 Linear heliothermic motor with thermomechanical module with bimetallic bent arc – preformed in the shape of "**U**" [10], [11]
a- quadrature – axis division; b- experimental model
1 – thermobimetallic lamella; 2 – support member; a, a' – guide channel; 3 – steel support; 4 – anchor;
5 – a cilindrical – parabolic concentrator ; 6 – flexible aror; 7 – floating draw bar; 8 – opposing spring; 9 – aid foot; 10 – toggle joint.

4. Conclusions

1. The solar actuator with thermobimetallic converter motion is connected, mainly, of thermobimetallic material geometry and functional parameters, thermobimetallic element.

2. From the dynamic point of view, the thermobimetallic actuators represents dynamic systems that, under systems general theory, can be studied using mathematical model, through indicial function and the frequency characteristic. In the following, the authors investigations are oriented related to the indicial functions that reach the parameters that characterize the dynamic properties of the analyzed system: the delay, transitory regime speed (time constant T), time response, transmission gain etc.

3. The experimental tests points out that mathematical model (element equation) associated with the thermobimetal actuators is, generally, differential equation of first order, for which it is associated with the term *element of first order* (system of first order, PT_1 element).

4. The element equation configuration, unit step response, transitory regime speed expressed through time constant T, is dependent on thermobimetal parameters.

5. Transient behavior of solar actuators is dependent on its position (vertical or horizontal). Influence of position is reflected in the transitory regime speed for the horizontal position. The speed difference between the two position depend on the properties of the material used as well as the surface exposed to thermal radiation.

References

[1]. Cernomazu D., Mandici L., *Contribution in achieving new types of solar motors,* Symposium ELECTROMOTION'97, Cluj-Napoca, România, 8-9 mai, 1997, p.216-221.

[2]. Cernomazu D., Bobric C., *Unconventional micromotors investigation direction,* Buletinul Institutului Politehnic din Iaşi, Tomul XLV (IL), Fasc. 5, Electrotehnică, Energetică, Electronică, 1999, p.28-31.

[3]. Cernomazu D., Bobric C., Raţă M., *Contribution in achieving and experimentation of new solar motors,* Proceedings of Simposium Electromotion '99, 6-7 iulie 1999, Patras, Greece, p.344-347.

[4]. Cernomazu D., Mandici L., *Contribution concernant à la perfectionnement des micromoteurs solaires utilisés comme des actionneurs des installations a „héliotrope autonome",* Simpozionul, Internaţional "Energii regenerabile – experienţa statelor Uniunii Europene şi aplicarea ei în Republica Moldova", 2 - 4 iunie, 1999, Chişinău, p.101 - 111.

[5]. Cernomazu D., *Contributions a la realisation d"instalations speciales utilisant des fonctions robotiques,* Suceava: Editura Universității din Suceava, 2004.

[6]. Cernomazu D., Mandici L., Graur A., Sorea N., Niţan I., Prodan C., Milici L.D., Milici M.R., Raţă M., Romaniuc I., *Motor solar,* Cerere de Brevet de Invenţie, nr A/01067 din 26.10.2011.

[7]. Cernomazu D., Mandici L., Graur A., Sorea N., Niţan I., Raţă M., Milici L.D., Milici M.R., Prodan C., Romaniuc I., Baciu I, *Motor solar.* Cerere de Brevet de Invenţie nr A/01163 din 16.11.2011 CMI nr.16605/31.10.2011.

[8]. Cernomazu D., Mandici L., Graur A., Sorea N., Niţan I., Raţă M., Milici L.D., Milici M.R., Prodan C., Romaniuc I., Baciu I., *Actuator solar*, Cerere de Brevet de Invenţie nr A/01164 din 16.11.2011 CMI nr.16599/31.10.2011.

[9]. Romanescu A.N., *Studiu privind realizarea unor sisteme de conversie a energiei solare în energie mecanică*. Suceava: Proiect de diplomă, Universitatea "Ştefan cel Mare" Suceava, Facultatea de Inginerie Electrică. Coordonator științific: Prof.dr.ing. Cernomazu Dorel, 1998.

[10]. Romanescu A.N., *Stadiul actual al soluțiilor în domeniul motoarelor solare bazate pe conversia termomecanică - Raport I în cadrul stagiului de pregătire*

pentru doctorat. Suceava: Universitatea Ștefan cel Mare, Facultatea de Inginerie Electrică și Știința Calculatoarelor, 2014
[11]. Ungureanu C., *Contribuţii teoretice şi experimentale privind realizarea şi experimentarea unor motoare electrice solare,* - Teză de doctorat. Suceava: Universitatea „Ştefan cel Mare", Facultatea de Inginerie Electrică, Suceava, 2011.
[12]. Ungureanu C., Cernomazu D., *Motor solar*, Int. Cl.: H02 N 6/00; F03G 7/06; H02 K 23/00. Brevet RO, 123263 B1. 2011-04-29. B.O.P.I. nr. 4, 2011.
[13]. Ungureanu C., Cernomazu D., *Motor solar*. Int. Cl.: H02N 6/00; F03G 7/06; H02K 23/00. Brevet RO, 123264 B1. 2011-04-29. B.O.P.I. nr. 4, 2011.

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