ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XIV, NR. 1, 2007, ISSN 1453 - 7397

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Analysis and Design of Thermal Actuators

Current literature describes the use of multiple SMA elements placed in parallel to increase the lifting capabilities of an SMA actuator, which however, is limited to springs of like-diameter. A constrained optimization problem was formulated, with constraints on the maximum number of springs, voltage applied, and SMA spring length and cross sectional area for the development of an optimal SMA actuator that will be able to apply maximum force.

1. Introduction

The principal elements of execution system structure for an intelligent machine are actuators, having the role to convert a certain form of energy in mechanical energy (movement) to evolve the machine actions. The actuators specific to robotics are realized in a large functional – constructive variety, but all have as characteristic the following structure (**Figure 1**).

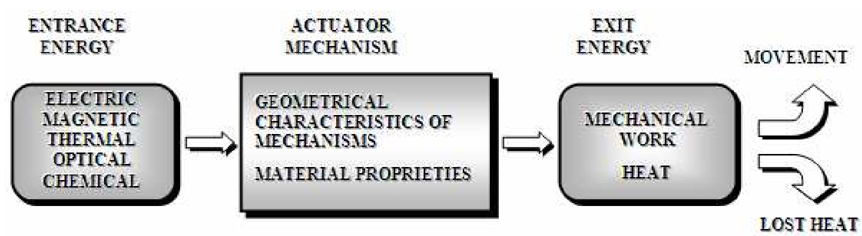

Figure 1. Structure of specific actuators for robotic applications

2. Analysis.

Actuation can be obtained in three discrete modalities: by electric and magnetic fields interaction, by mechanical interaction or by pinched, controlled deformation of some active elements, having different geometrical shape, obtaining linear as well as angular deformations.

These deformations can be transformed in rotation or translation continuous movement by mediation of mechanisms and appropriate disposal of active elements conditions. Transmission and amplifying these strains can be performed by all kinds of gears (toothed wheels, crank, screw-nut, pinion-rack, micro-gripper or friction).

In function of the entrance signal used for the controlled deformation of the active elements, the actuators from this category can be divided at their turn in: electrically commanded actuators (piezoelectric and electrorelogic actuators), magnetically commanded actuators (magnetostrictive and ferro-fluids based actuators) optically commanded actuators (thermo - / electro - fotostrictive and piro - piezoelectric) and chemically commanded actuators (artificial muscles).

A distinctive category, having numerous applications, represents the thermally commanded actuators (by heat flow mediation).

3. Function principle of thermal actuators.

Thermal actuators have in their structure active elements which convert thermal energy in some helpful action (movement). The activation necessary heat can be generated by several methods, the most utilized being the resistive one.

Regarding the microactuators, another used method represents optical heating. The thermal energy conversion grounds on distention phenomena of solid, liquid or gas active elements, or transformation from one phase to the other. The function principle of thermal actuators is presented in **Figure 2**.

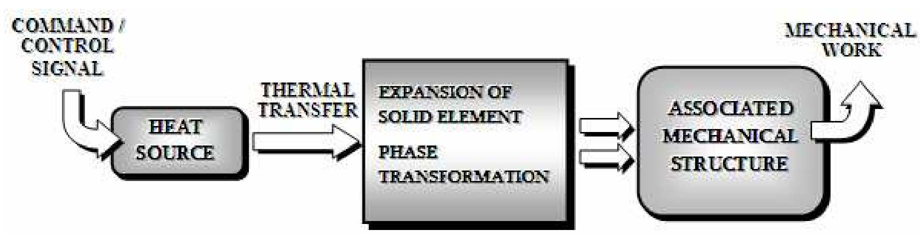

Figure 2. Function principle of thermal actuators

The control and command signal applied to the source determine the thermal transfer to the active elements of the actuator, which either take place a distention or undergo a phase transformation followed by limited deformations.

Helped by the associated mechanical structures, the strains and the developed forces or couples are amplified and transformed into mechanical work.

Thermal actuators present some advantages such as: develop relative high forces in conditions of large scale dimensions strokes and a precise dependence of this stroke with the temperature, simple and compact construction, precise control, high levels of miniaturization and low costs. They can be adapted to the application demands, being also able to be equipped with the necessary sensors.

As main disadvantages can be point out the high energy consumption, a pretty low energetic efficiency, heat dissipation in the environment, diminished cooling response time and non-linear effects such as hysteresis phenomena.

Despite these limitations, shape memory alloys actuators have one of the highest payload to weight ratios among "smart material" based actuators.

As main applications for this thermals actuators can be remark switches, valves, control devices or blocking mechanisms automatic drive, robotics and others.

In the category of phase transformation based actuators are also the shape memory alloys actuators. These have as constituents elements being able to recover memorized shapes / dimensions, due to the martensite – austenite reversible phase transformation, the leading mechanism of the actions.

It can be initiated either by a change in temperature and/or by a change in stress. Most functional properties of shape memory alloys are directly related to the following mechanism on the level of the shape memory alloys springs. Prestrained martensitic shape memory alloys springs operate during heating against the elastic stiffness of the host matrix, biasing the strain recovery of the shape memory alloys springs.

In figure **3** is presented an example of SMA thermal actuator. The SMA springs (4) are rezistive heated. Their distention insures remoteness of the mobile end plug (6) from the fixed end plug (1). By cooling and, implicit the contraction of the SMA springs (4) is realized the initial shape recovery. For this model of actuators were used 4 SMA springs in order to augment the actuation force. One spring dimensions are 6mm coil, 750 μm wire, activates at 45-55°C and can develop 4,4 N.

When cool, can be extended to 14cm. Heated, contracts to 29mm overall. With 350 gram hanging mass shrinks from 60mm long coil (cool) to 30mm long (heated) with 2 Amps.

With (2) was marked down the fixing hole and with (3) the water plug for the cooling system.

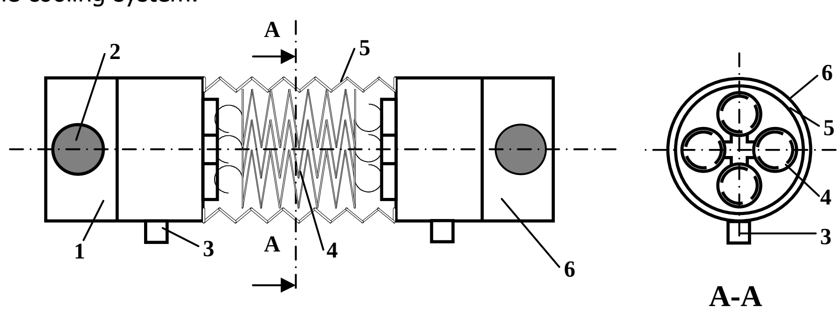

Figure 3. SMA thermal actuator diagram

Controlling well the dependence of temperature gradient permits the calculation of an optimal control for the actuator, in order to obtain an accurate positioning, which leads to the desired minimal prehension force necessary to grasp the workpiece, allowing in this way only elastic deformation.

4. Conclusion

SMA Thermal actuators are more simple and easier to be realized that other types, but present the disadvantage of a pretty reduced operating speed. This disadvantage is partially eliminated in miniaturization conditions, hereby being more frequently used in the microsystems structure.

The specific actuator designing steps are: dimensioning active elements in function of the imposed source and force; dimensional and structural synthesis of the associated mechanical structure; designing the activation (heating) and the command and control system.

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