EXPERIMENTAL APPARATUS FOR SMA ACTUATORS TESTING

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Abstract:
Paper deals with measuring apparatus for shape memory alloy (SMA) wire actuators. The apparatus has been developed as didactic tool for exercises in mechatronic study program. Apparatus enable contact-less measuring of static and dynamic characteristic of SMA actuators.

Keywords: *SMA actuator, measuring, mechatronics*

1. Introduction

The most famous SMA material is Nitinol, which is an alloy of nickel and titanium. It has been discovered in Naval Ordance Laboratory in sixty years of twentieth century. Phenomenon of SMA occurs in more then 20 alloy types. The SMA actuators are made as wire, spring or ribbons shape.

Nitinol wire actuator named as FLEXINOL 250LT with 0.25 mm in diameter has been tested in this paper. Recommended activation temperature is 70 °C. Recovery force is recommended at value of 9,3 N. Activation electric current is defined at the 1000 mA. Limit maximum stress (pull force) is 172 MPa [3].

In this paper, the contraction and pull recovery test stand has been developed for testing of SMA wire actuator [1, 2, 3, 4, 5, 6, 7].

2. Apparatus arrangement

Apparatus (Fig. 1, 2) consists of a frame with an arm and two pulleys for guiding of nylon wire connected with SMA wire actuator. One end of the Flexinol wire is attached to the frame and second free end is connected *via* nylon wire with bias weight. Nylon wire is guided with two pulleys to the place for hook with bias weight. There is a reference point (Fig. 3) from permanent magnet placed on the nylon wire. Deformation of the Flexinol wire is represented with the reference point (permanent magnet) and position of the magnet is measured *via* Hall position sensor SS495A. Consequently, output sensor voltage represents the deformation of the Flexinol wire.

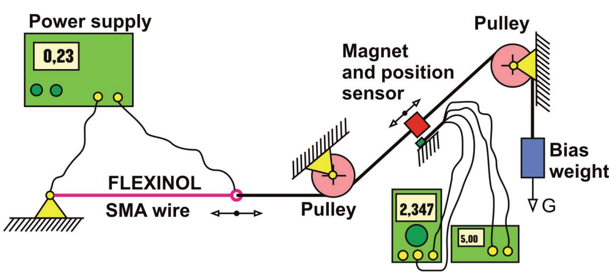

Fig. 1. Measuring apparatus arrangement

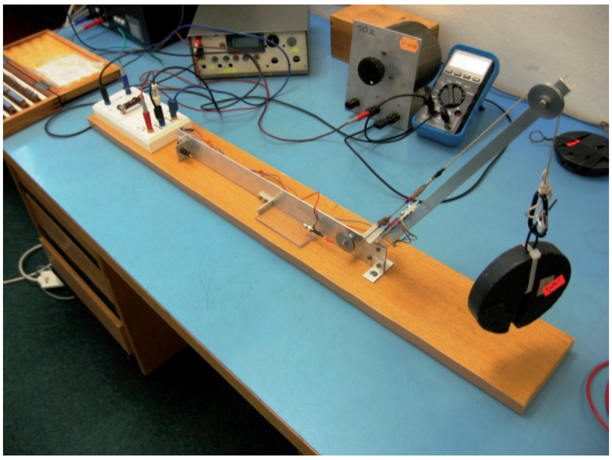

Fig. 2. Realization of SMA actuator measuring apparatus

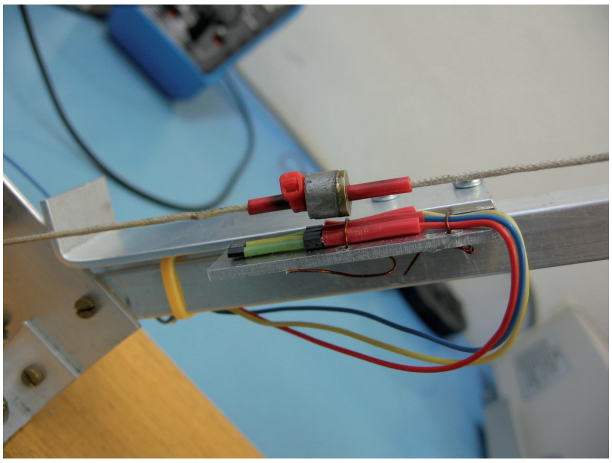

Fig. 3. Reference point (magnet) for contact-less measuring of SMA deformation

It is necessary to do calibration of the hall position sensor with length etalons (Fig. 4). The calibration process associates the sensor output voltage with Flexinol wire deformation.

Results from calibration process are shown in Figure 4. Output sensor voltage has nonlinear behavior which corresponds to Flexinol free end position. The measured points are as result of average from 10 measurements. Expected uncertainty of measurement for measurement of position is 0.2 mm. Uncertainties of length etalons have been neglected. Relation between the free end position and output sensor voltage has been fitted *via* polynomial model mentioned in Figure 5.

Thermal activation of the SMA can be easily driven by electrical current from power supply *via* Joule heating. Cooling of the SMA can be realized *via* heating radiation into surroundings at the room temperature.

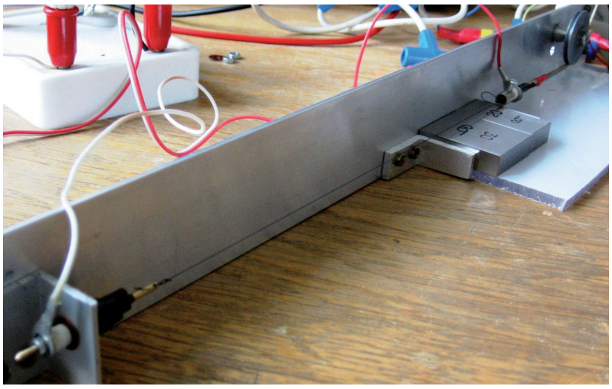

Fig. 4. Calibration process of contact-less measuring of SMA deformation

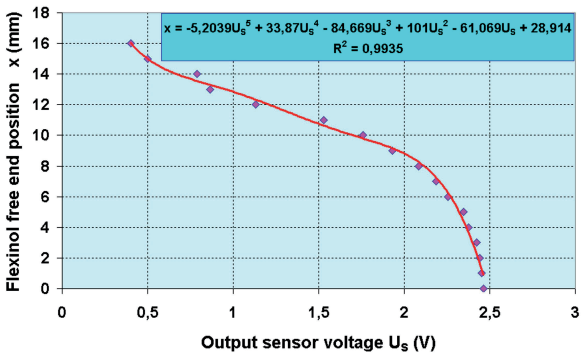

Fig. 5. Calibration process characteristic

Heating and cooling of the Flexinol causes change of the Flexinol free end position. Fig. 6 shows this dependence of free end Flexinol position on value of electric current, which shows highly nonlinearity and hysteresis behavior. The characteristic shown in Fig. 6 has been measured with bias weight 1 kg, which corresponds to maximum recommended pull stress.

Dynamic characteristic has been tested through the step response testing. Excitation electric current is shown in Fig. 7 and it has been controlled *via* microcontroller. Step response has been measured *via* measuring adapter MF624 with personal computer in Matlab/Simulink environment.

The designed test bench also enables to cyclic test lifetime of actuator.

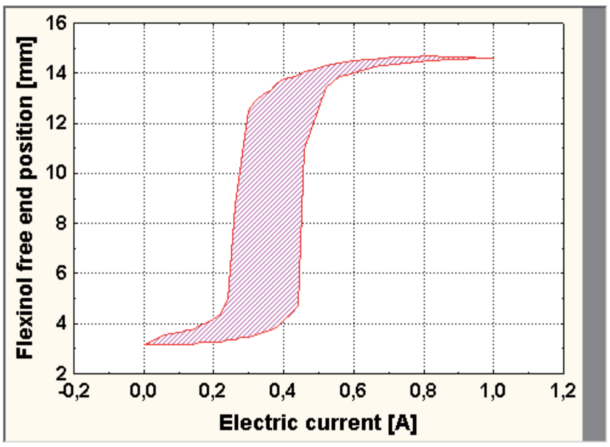

Fig. 6. Static characteristic of SMA wire actuator

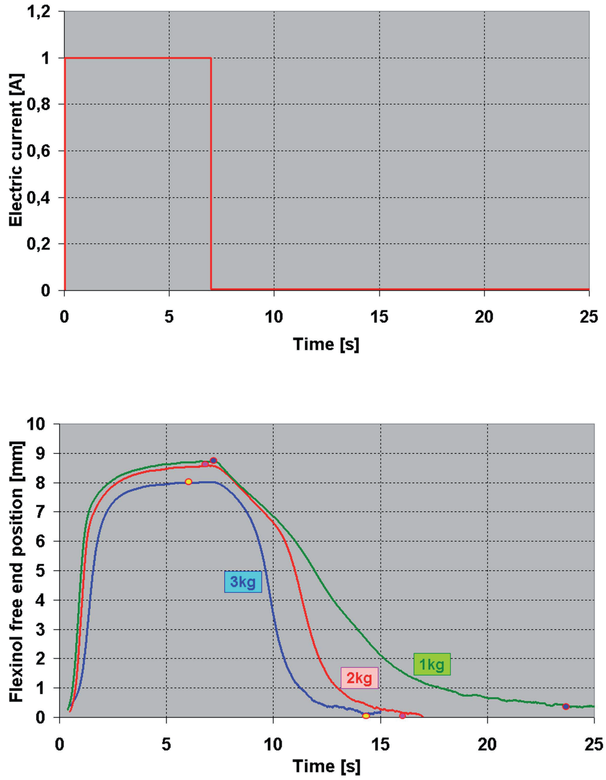

Fig. 7. Actuator step response testing

It is possible to determine activation and deactivation time for Flexinol which are correspond with heating and cooling time. Figure 7 shows that cooling is slower then heating. Step response is tested for overloaded mode and it is possible to say that overloading causes a decreasing of the heating and cooling time. Students also can identify mathematical model of actuator, which can be inserted into complex model of the mechatronic system.

3. Conclusion

The measuring apparatus is used as didactic tool for practical exercises in mechatronic subjects. Students can practically try to use SMA wire actuator. They can test various condition of actuator using.

Shape memory alloy has a lot of advantages as clean, silent and spark free operation, high biocompatibility and excellent corrosion resistance. They are also free of parts such as reduction gears and do not produce dust particles. Actuators based on this principle are very often used in robotic and mechatronic application [8, 9, 10, 11, 12].

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