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SHAPE MEMORY Cu–Al–Ni SINGLE CRYSTALS FOR APPLICATION IN ROTARY ACTUATORS

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Abstract. Physical and technical potential of shape memory single crystals for applications in rotary actuators was experimentally studied. Single-crystalline Cu-Al-Ni cylindrical rods for tests and actuator applications were grown from melt by Stepanov method. The crystals were tested by tension under conditions simulating their work in the proposed design of a rotary actuator. Actuator performance parameters such as rotation angle, torque and useful work were estimated basing on experimental results. Actuators employing shape memory effect outperform conventional electric motors and actuators in terms of specific work output.

1. Introduction

Martensitic transformations in crystals with shape memory effect under the influence of an external force lead to large deformations of inelastic nature. In some materials, these reversible deformations are in the single-digit to low double-digit percentage range [1-2]. The recovery of accumulated inelastic deformation and, as a consequence, the return to the original form of the body can occur both in the unloading process at a constant temperature (superelasticity effect), and upon heating (shape memory effect). Both effects are interesting in view of their application in compact actuators.

In our previous study [3], we considered the design of cyclic linear motors based on the shape memory effect in Cu-Al-Ni single crystals. This paper is devoted to the development of cyclic rotary actuators employing shape memory effect.

Upon heating the shape memory effect generates stresses in the bulk of the material. If shape memory alloy faces any resistance to the recovery of the remembered shape it can generate the reactive force [4-6]. The importance of this effect in technical applications is that the reactive force significantly exceeds the force that caused the initial change in shape. This can be used to produce useful mechanical work [7].

2. Thermal cycling of Cu-Al-Ni single crystals under tensile load.

The studies were carried out on Cu-13.5 wt.% Al-5.0 wt.% Ni single crystals grown from the melt along the <100> direction by the Stepanov method [4] in the form of cylindrical rods with a diameter of 5 mm. Samples were heat treated, quenched from 900 °C into water followed by soft tempering at 373 K for 1 h. According to differential scanning calorimetry, they have the following characteristic transformation temperatures without load: Ms = 52 °C, Mf = 39 °C, As = 49 °C, Af = 60 °C.

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Next, we compare performance of SM actuators with that of convectional electric motors. Motor/gearhead assemblies RE35 + GP42 and RE50 + GP62 [9, 10] produced by MAXON MOTOR company were used for that purpose. These motors have close values of output torque of 15 Nm and 30 Nm, respectively. The values of specific work (i.e. work per unit volume) for these drives are 0,11 and 0,17 MJ/m^3, respectively. Thus the specific work for SM actuator is 2-3 times higher compared to that for a typical electric motor. Therefore SM actuators are particularly attractive for compact solutions where weight and size of the motor [11] are the most critical qualities.

4. Conclusions

Thermo-mechanical properties of shape memory Cu-Al-Ni single crystals under conditions simulating their operation in a rotary cyclic actuator were studied. The crystals exhibited completely reversible shape memory deformation over multiple thermal cycles in the stress range up to 180 MPa and temperatures up to 200°C. Performance characteristics of SM actuators based on Cu-Al-Ni crystals were estimated. The specific work for SM actuators is 2-3 times higher compared to that for electric motors. Therefore SM actuators are a good alternative to conventional electric drives in certain applications.

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