Stresses manipulation in shape memory alloys using magnetic particles

J. Kharlan,[1,2] O. Salyuk,[2] V. Chernenko,[3] G. Kakazei,[4] and V. Golub[2]

[1] *Faculty of Physics, Adam Mickiewicz University in Poznan, Poznan 61–614, Poland*
[2] *V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine, Kyiv 03142, Ukraine*
[3] *Basque Center for Materials, Applications and Nanostructure, BCMaterials, Leioa 48940, Spain*
[4] *Departamento de Física e Astronomia, Institute of Physics for Advanced Materials, Nanotechnology and Photonics, Universidade do Porto, 4169-007 Porto, Portugal*

Today, an urgent task is to obtain effective materials used in modern types of actuators, sensors, and mechanical energy harvesters. One of the possible solutions to this issue is the use of composites, such as ferromagnetic shape memory alloy particles incorporated into a polymer [1] or ferromagnetic particles embedded in shape memory alloys [2]. However, during the production of such materials, a problem arises related to the constraints of twin reorientation by adjacent grain boundaries, leading to low values of magnetic field-induced strain. To eliminate the influence of grain boundaries, it was suggested to disintegrate polycrystals of Ni–Mn–Ga into individual grains and use them to produce composite magnetostrain active materials. But due to the constraints from neighboring particles, some particles did not show a shape deformation, and the inhomogeneous distribution of stress concentration was discerned.

To avoid the inter-particle constraints, laminate composites were designed, where particles were mounted between two Cu foils and fixed by thin layers of silicone rubber. These composites showed magnetic field-induced strains values around 3.5% under a magnetic field 0.7–0.9 T applied in the film plane. The high value of the saturation field and the gradual behavior were attributed to the influence of the polymer. Recent experiments have shown that this problem can be overcome if Fe foils are used instead of Cu ones.

The magnetically induced stresses in "Fe/Ni-Mn-Ga single crystalline particles/Fe" laminate composites have been studied depending on the thickness of the framing Fe foils and distances between them. It was evaluated the magnetically induced repulsive force between the two Fe foils which results in additional tensile stress of NiMnGa particles experimentally observed.

We also discuss another possibility to control the transformation behavior using magnetic nanoparticles embedded in shape memory alloy matrix. The resent experiments on CuMnAl system will be presented.

References:

[1] D. K. Han, et al., Scripta Mater. 261 (2025) 116624
[2] D. K. Han, et al. Acta., Mater. 277 (2024) 120158