

## Development of the Computer-Based Stand for Research of the Voltage Generation Effect of the Magnetic Shape Memory Material

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**Abstract:** The study discusses stand for research of changes in the magnetic state of the ferromagnetic shape memory alloy in variation of mechanical forces and the possibility of generating the output voltage by the coil applied to the sample. The test stand is based on PXI platform company National Instruments. The installation diagram, an example of testing and analysis of results is shown.

**Key words:** Magnetic shape memory, power generation, alternative energy sources, voltage, coil

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### INTRODUCTION

Magnetic Shape Memory Material (MSM) are materials that change their shape in a magnetic field (Vasil'ev *et al.*, 2003). Nickel-Manganese-Gallium ( $\text{Ni}_2\text{MnGa}$ ) is the most promising materials (Ullakko *et al.*, 1996; Sozinov *et al.*, 2002; Suorsa *et al.*, 2004). It can change its size up to 6% in the most popular materials (Murray *et al.*, 2000) and 10% in some of the experimental alloys (Gorbatenko *et al.*, 2011a). This alloy is investigated in this study. The magnetic properties of the material have a relative permeability of approximately, 2 in the longitudinal direction and 60 in the short direction. An additional application is their use as sensors or voltage generators. The objective of the study is to investigate the level and the possibility of using a voltage that occurs at times when the sample of MSM mechanically compressed within the installation.

Experimental studies were carried out on samples of size  $20 \times 2 \times 1$  mm of material  $\text{Ni}_2\text{MnGa}$ . The results show that the level of voltage is 6 V, in the case of mechanical effects of short pulses and applying the induction coil along the long side of the sample. The induced voltage depends on the geometry and type of material used as well as the pulse duration of mechanical action (Grechikhin *et al.*, 2014). The results of measurements obtained by a special apparatus in which impact occurs as a magnetic field to the sample to an elongation and a mechanical compression force.

### MATERIALS AND METHODS

Software was designed for this task carried out in the programming environment National Instruments LabVIEW 2013. Platform National Instruments PXI with real-time controller with NI PXI-8133 multifunction device and NI PXI-6341, a controlled current source NI PXI-4130 installed in the chassis NI PXIe-1078 laser triangulation sensor distance LS5 was used to implement the system.

Magnetic shape memory material is a smart-grade materials that change their shape when subjected to a magnetic field of  $500 \text{ kA m}^{-1}$  (Gorbatenko *et al.*, 2011b). MSM advantage compared to currently available smart-materials such as piezoceramics, materials with thermal shape memory, magnetostrictive alloys, the ability to generate power is already at frequencies below 100 Hz. Currently, MSM effect observed in alloys  $\text{Ni}_2\text{MnGa}$ , Fe-Pd and Co-Ni-Al.

A special stand was developed to investigate the possibility of generating of voltage. Block diagram of stand is shown in Fig. 1. Figure 1 shows: EM: Electromagnetic implementing Mechanical action on the sample; MD: Magnetizing Device (magnetizing system); IT: Inductive Transducer; MSM: Magnetic Shape Memory alloy and MS: Motion Sensor.

Block diagram of the magnetic system with position and voltage sensors is shown in Fig. 2. In Fig. 2, 1: direction of mechanical action on the sample; 2: magnetic pole magnetizing device; 3: magnetizing coils; 4: distance meter; 5: sample MSM; 6: substrate fixing the direction of

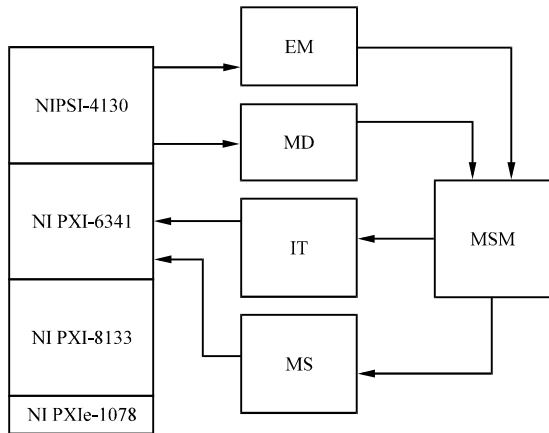


Fig. 1: Block diagram of the stand for the study of the generation effects MSM

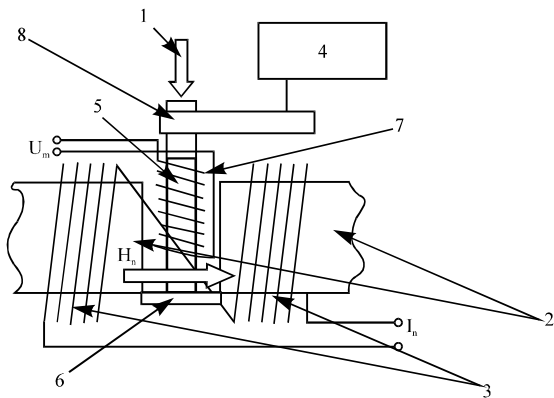


Fig. 2: Block diagram of the magnetic system with position and voltage sensors

change in the size of the sample along the length of its sides; 7: inductive transducer; 8: transfer nonmagnetic element mechanical impact with a fixed label to measure the length of the sample;  $H_m$ : the direction of the magnetic field lines in the MD;  $I_m$ : magnetizing current and  $U_m$ : induced voltage.

Stand operates as follows. In the first stage, a sample of MSM is in a “compressed” state. After feeding the coil current  $I_m$  3 magnetizing system MD formed magnetic field  $H_m$  affects on the MSM sample and it was deformed. Deformation of the sample 4 was recorded by the movement of the sensor marks for measuring the elongation of the sample 5 of the transfer member nonmagnetic mechanical impact 4.

It was measured that the sample was increased in length by 9%. On the next step was fed to the signal EM (Fig. 1). Anchor EM transmission through non-magnetic element mechanical effects produced 8 “compression” of the sample. It was processed and measured voltage  $U_m$  induced by the output coils 7 (Fig. 2).

### RESULTS AND DISCUSSION

The graph of the measured voltage on the coil with using the stand showed in Fig.1 and 2 is shown in Fig. 3.

The test of the  $Ni_2MnGa$  sample has shown that in the moments of mechanical impact material is capable of changing the magnetic field inside its volume. In this case, the generated voltage at the output of the induction coil applied to the sample was about positive 5.5 and 2.5 V negative when the number of turns of coil is 100.

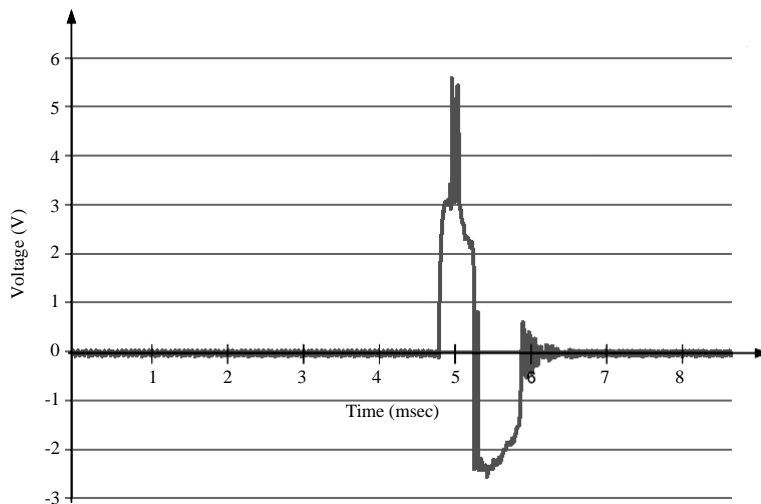


Fig. 3: Output voltage of the coil through the compression MSM sample in it

## CONCLUSION

Analysis of research results leads to the following conclusions:

- Phenomenon of the magnetizing state variation of magnetic shape memory alloys can be used for the voltage generation
- The level of the voltage generated using coil on the magnetic shape memory samples is about 5 V and it can be effectively used in sensors and alternative energy sources such as wearable electronics

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## REFERENCES

- Gorbatenko, N., V. Grechikhin, A. Kolomiets, A. Kucherova and N. Narakidze, 2011a. Characterisation of Ni<sub>2</sub>MnGa magnetic parameters based on indirect measurements and mathematical modeling of the experimental setup. Proceedings of the 6th International Forum on Strategic Technology, Volume 1, August 22-24, 2011, Harbin, Heilongjiang, China, pp: 12-14.
- Gorbatenko, N., M. Lankin, D. Shaykhutdinov, K. Gazarov and A. Kolomiets, 2011b. Electromagnetic induction system for testing ferromagnetic shape memory alloys. Proceedings of the 6th International Forum on Strategic Technology, Volume 1, August 22-24, 2011, Harbin, Heilongjiang, China, pp: 194-196.
- Grechikhin, V., O. Lozin, D. Shaykhutdinov and S. Yanvarev, 2014. A mathematical model of the active element of the actuator based on a shape memory material. Proceedings of the 5th International Conference on Functional Nanomaterials and High-Purity Substances, October 6-10, 2014, Suzdal, Russia, pp: 19-21.
- Murray, S.J., M. Marioni, S.M. Allen, R.C. O'Handley and T.A. Lograsso, 2000. 6% magnetic-field-induced strain by twin-boundary motion in ferromagnetic Ni<sub>2</sub>MnGa. *Applied Phys. Lett.*, 77: 886-888.
- Sozinov, A., A.A. Likhachev, N. Lanska and K. Ullakko, 2002. Giant magnetic-field-induced strain in Ni<sub>2</sub>MnGa seven-layered martensitic phase. *Applied Phys. Lett.*, 80: 1746-1748.
- Suorsa, I., J. Tellinen, K. Ullakko and E. Pagounis, 2004. Voltage generation induced by mechanical straining in magnetic shape memory materials. *J. Applied Phys.*, 95: 8054-8058.
- Ullakko, K., J.K. Huang, C. Kantner, R.C. O'Handley and V.V. Kokorin, 1996. Large magnetic-field-induced strains in Ni<sub>2</sub>MnGa single crystals. *Applied Phys. Lett.*, 69: 1966-1968.
- Vasil'ev, A.N., V.D. Buchel'nikov, T. Takagi, V.V. Khovailo and E.I. Estrin, 2003. [Shape memory ferromagnets]. *Physics-Uspokhi*, 173: 577-608, (In Russian).