PAPER REF: 3970

HIGH POWER INTERACTIVE ACTUATOR SYSTEM BASED ON MAGNETOSTRICTIVE COMPOSITE CORE

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ABSTRACT

This work compares the maximal values of magnetostriction obtained for interactive actuator system with magnetostrictive composite core. Two methods of excitation: quasi-static and at low frequencies of magnetic field strength changes have been used. Performed tests allowed to identify that there are no significant differences of the maximal values of magnetostriction obtained for prepared composites cores independently from the methods of the excitation.

Keywords: GMM, Terfenol-D, Smart Materials.

INTRODUCTION

The role of Smart Magnetic Materials (SMM) in many different fields such as: automotive and oil industry, civil engineering, medicine, mining industry, etc. is rising very fast. Giant Magnetostrictive Materials (GMM) are the ones of SMM types, mostly represented by Terfenol-D (Engdahl 2000, Schwartz 2002), especially if they should be applied in devices working at room temperature. The biggest difficulty with mechanical application of GMM is its brittleness. On the other hand, increase of frequency generates meaningfully eddy currents (Kendall 1996). These disadvantages are generating the need for finding new solutions. One of them are magnetostrictive composites (GMMc). The main objective of this work concerns the research on the application of specially prepared magnetostrictive composite materials as the cores in interactive actuator system.

In order to investigate the influence of magnetic field changes, on the performance of interactive actuator, quasi-static and cyclic tests were made. As a core of the actuator was used specially developed composite sample with 70% volume fraction of Terfenol-D. The testing were carried out on a testing setups purposely built for magnetostriction testing.

COMPOSITION OF MAGNETIC CORE INSIDE ACTUATOR

The material used for an actuator core was a magnetostrictive composite (also referred to as GMMc). It was made by combining an epoxy resin and the GMM material (Terfenol-D) powder. At first, the epoxy resin Epolam 2015 (from Axons Technologies company) was mixed with the curing agent. Next, the appropriate amount of Terfenol-D powder (Gansu Tianxing Rare Earth Functional Materials Co., Ltd.) was added, with particle size of about 5-300μm. The grain size distribution and the shape and size of the particles was shown in Fig. 1.

The manufacturing procedure, consisted in intensive mixing of all the ingredients until their complete homogenization. The mixture was then vacuum vented, poured into the dedicated cylindrical containers and subjected to initial polarization. After that, the material was once again vented in the vacuum chamber to eliminate the air introduced during the mixing stage.

The out-gassed samples were put in between the two strong neodymium magnets (which would lead to their final polarization) until the epoxy resin was completely cured. The manufacturing procedure was described in greater detail in (Kaleta 2011).

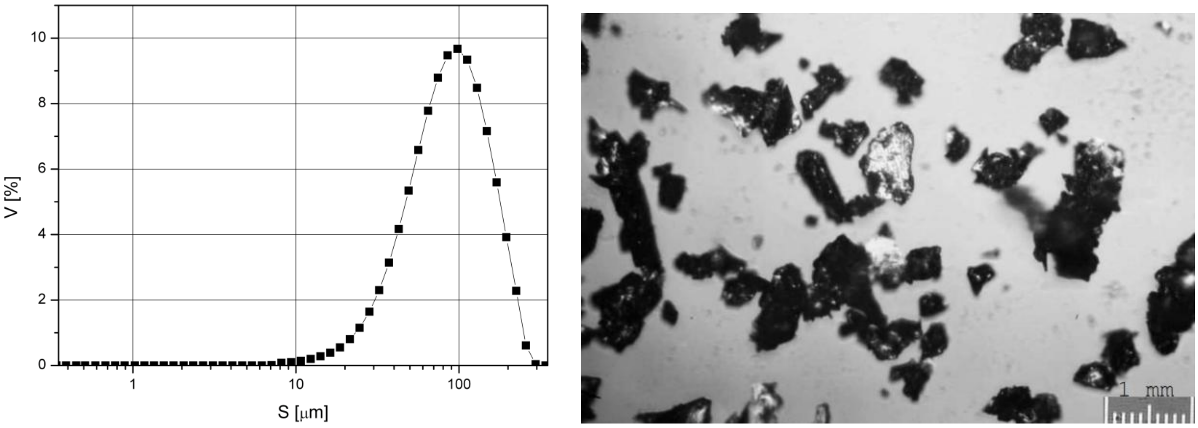


Fig.1 Grain-size analysis of the Terfenol-D powder, and the shape and size of the particles (Kaleta 2011).

The specimens with 70% volume fraction of the Terfenol-D particles were obtained. The strong polarization field was used to rotate the particles in such a way that their internal domain structure was parallel to the field lines, a scheme of this process was shown in Fig. 2. As a result of such particle alignment, the magnetic field which, acting parallel to the sample axis, activates the composite, will cause the particles to rotate. In this way the resulting magnetostriction should be stronger than in the case of randomly dispersed particles.

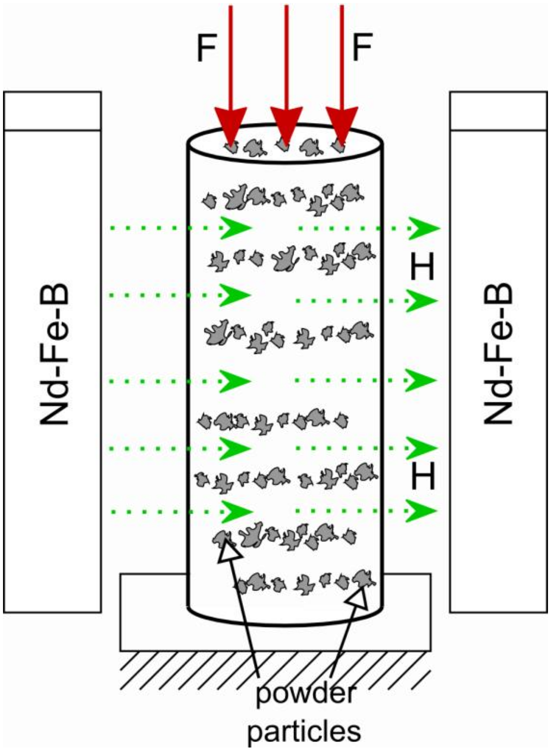


Fig.2 Scheme of the polarisation process of the magnetostrictive composite core during epoxy resin curing.

DESIGN OF HIGH CURRENT AND HIGH FORCE ACTUATOR

To investigate properties of high power actuator system based on magnetostrictive composite core, an original test rig was prepared. It should be noticed, that the maximum current value that could flow continuously through the actuator is 15A and the power that could be obtained at 60V of power supply is about 450Watts. Additional an important property of the actuator is its weight, which has about 12kg. The scheme of test setup was presented in Fig. 3.

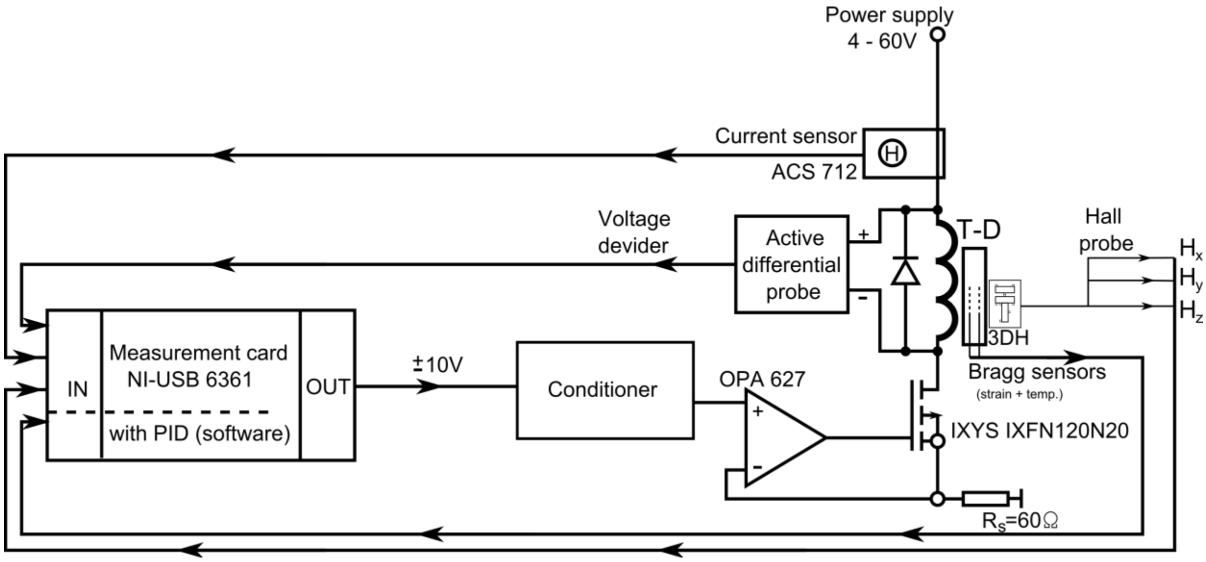
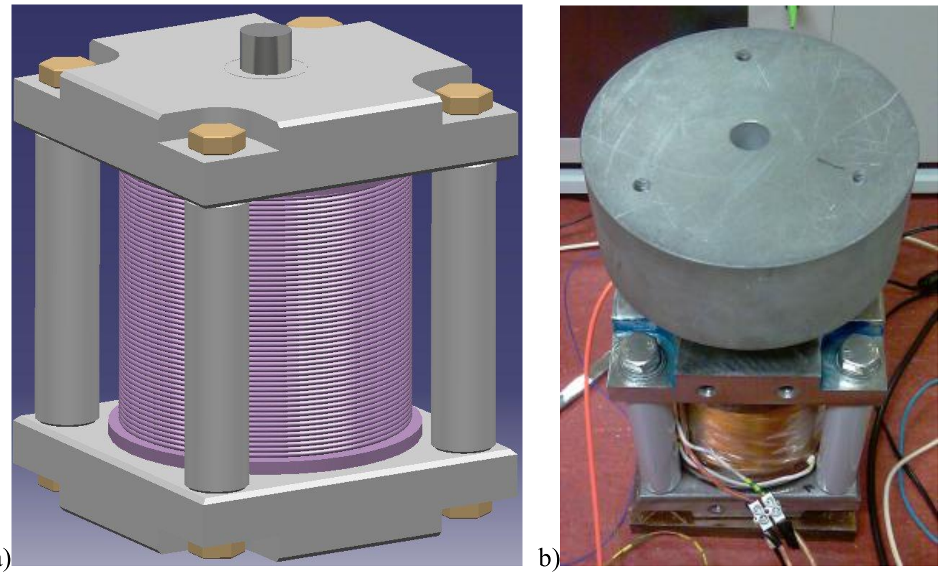


Fig.3 Scheme of high power actuator system, used for cyclic tests with specified frequency of magnetic field changes.

The tests were conducted at the room temperature, for the specific and constant value of the initial pre-stress which was applied by the hydraulic testing machine (MTS). The machine had the task of keeping the constant load acting on the actuator core, which was placed inside a coil closed in a steel housing Fig. 4 a) and b). Next, the strain was measured. Such strain appeared as a result of the magnetic field with a time-varying strength which was acting along the main axis of the examined samples. The magnetic field strength which was acting on the magnetostrictive composite was dependent on the strength of the current in the coil.

The measurement was conducted with use of the 3D Hall probe, which was placed inside the coil along the core sample and allowed to measure magnetic field in three directions. The sample strain $\Delta\lambda$ was measured using the innovative method of fibre Bragg grating (FBG) sensors, which were implemented into the structure by a special connector, which was closing actuator housing. In this way the influence of the electromagnetic field on the results was eliminated. The FBG method is described in more detail in (Blazejewski 2011). The strain sensors were placed directly on the specimens. One of the sensors was placed along the main axis of the specimen, while the second sensor was placed freely next to the sample and was responsible for the temperature compensation during the work of actuator, even though according to a previous study (Kaleta 2009), temperature does not influence the results significantly.

Test setup allowed to perform two methods of excitation: quasi-static changes of magnetic field strength and low frequencies of magnetic field strength changes. From both test types, changes of magnetostriction under influence of magnetic field strength were obtained.



a) b)

Fig.4 Picture of the interactive actuator system: a) model of the actuator, b) photo of the real actuator.

RESULTS

The results from the excitation tests are shown in Fig. 5, respectively a) is for quasi-static test and b) for low frequencies of magnetic field strength changes. Results for the cyclic excitation were shown only for negative values of magnetic field strength, keeping in mind that the magnetostriction of the material is the same, regardless of the sign of the magnetic field, which we apply to the material. This assumption was made based on results received for quasi-static test of interactive actuator system.

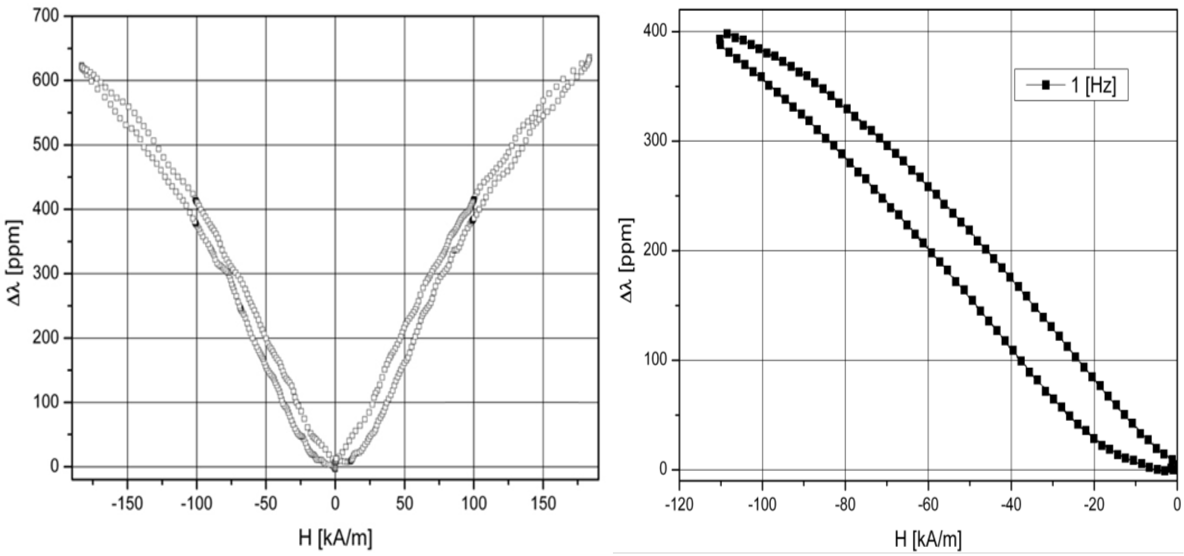


Fig.5 Results from the excitation tests, a) magnetostriction results for a quasi-static tests of actuator system, b) magnetostriction results for cyclic tests with specified frequency of magnetic field changes f=1 [Hz].

Comparing the two charts you can clearly see that the nature of change is very similar for both tests, quasi-static and cyclic. This allows to conclude that the actuator system should behave in the same way regardless of the excitation type, however, further studies are needed to determine whether the higher operating frequencies will not affect the characteristics of the system.

CONCLUSIONS

This study shows that for low frequencies of action (f=1 [Hz]) of interactive actuator system with composite core, there are no substantial differences on obtained maximal values of magnetostriction, for comparable values of magnetic field excitation, both in quasi-static state and for cyclic changes of magnetic field strength. Further tests should be performed in order to analyze higher frequencies of work of the system and to compare results with monolithic Terfenol-D core.

ACKNOWLEDGMENTS

The research was supported by Wrocław Research Centre EIT+ within the project "The Application of Nanotechnology in Advanced Materials" – NanoMat (POIG.01.01.02-02-002/08) financed by the European Regional Development Fund (Innovative Economy Operational Programme, 1.1.2).

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