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CHARACTERIZATION OF THERMOPLASTIC-COMPATIBLE PIEZOCERAMIC MODULES FOR FUNCTION INTEGRATIVE COMPOSITE STRUCTURES

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ABSTRACT

This work deals with the performance and the opportunities of novel thermoplastic-compatible piezoceramic modules (TPM). The TPM are suitable for matrix-homogeneous, adhesive-free integration of the modules in fibre-reinforced thermoplastic structures by means of high-volume manufacturing technologies. In order to evaluate the performance of the TPM, high voltage actuation tests are accomplished.

Keywords: piezoceramic actuators, thermoplastic composites, functional integration, energy harvesting, health monitoring.

INTRODUCTION

For the application of active structural parts appropriate for mass production, novel piezoceramic modules are developed, which are specifically tailored to the fibre-reinforced thermoplastic composites. They permit a homogeneous embedding within a composite structure by hot-melt adhesion technology during an adapted hot-pressing process and thus without additional bonding efforts [Hufenbach et al., 2009].

TEST SETUP AND PERFORMANCE

Thermoplastic-compatible piezoceramic modules contain thermoplastic carrier films made of polyetheretherketone (PEEK) or polyamide 6 (PA6), respectively. As the active layer, a lead zirconate titanate (PZT) piezoceramic fibre, also embedded in the respective thermoplastic matrix system, is used. To supply electric voltage, the active layer with a thickness of about 100 µm is provided with interdigitated electrodes (IDE), so that the so called d_{33} active principle is used for actuation. The active layer has a size of 35 mm x 22 mm with a thickness of 180 µm oriented on the commercial available macro fiber composite (MFC).

The executed electromechanical tests point a way to characterize the performance of piezoceramic actors under free deformation due to the use of the digital image correlation method. Therefore, the actor is prepared with a stochastic black and white pattern on the surface. During the load application, a stereo-camera-system is observing the prepared surface and a strain field is computed by a special software. All tests were driven by sinus voltage (amplitude 1 kV, offset 0.5 kV) at 10 Hz to receive an electric field up to 2 kV/mm for all test configurations.

RESULTS AND CONCLUSION

Fig. 1 (right) shows the measured strain-voltage-hysteresis of selected TPM in comparison to a conventional MFC. The free strain in the main actuation direction is displayed as a function of the maximum electric field intensity that arises over the module cross section. In detail, the hysteresis is caused by inner material friction and microscopic inverting polarization effects.

To obtain fundamental information about the operating stability of prototypic TPM under dynamic loading different load cases up to 60,000 cycles were applied. The loading was performed for a time of 60 s under a constant frequency of 1, 10, and 1000 Hz, respectively. After each increasing step of frequency, the strain hysteresis measurement and recording was accomplished by means of the previously described method. Fig. 1(left) illustrates the exemplary strain voltage hysteresis results of a PA-TPM.

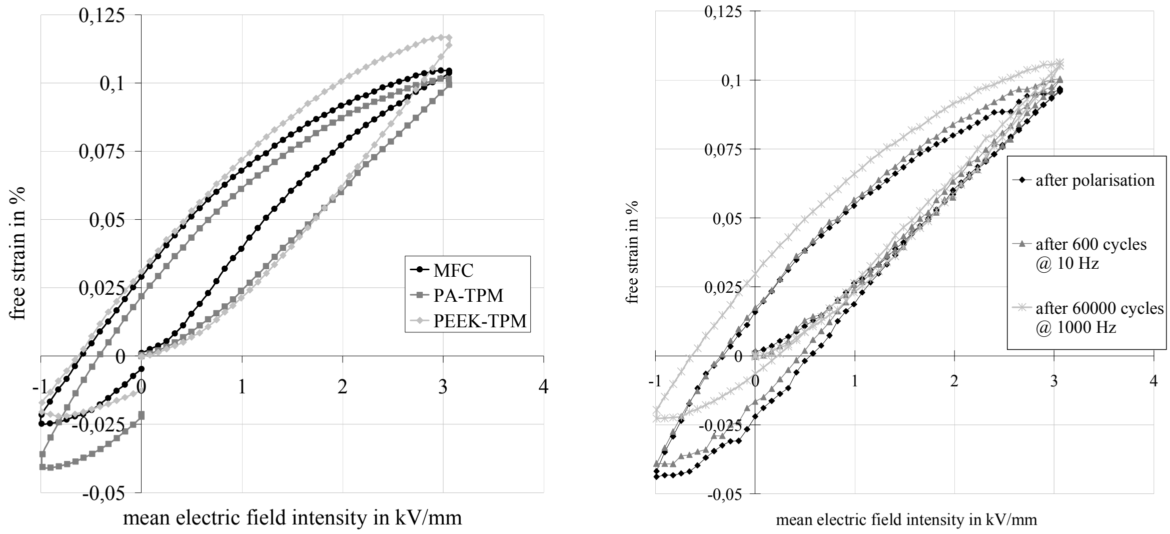

Fig. 1 - (left) strain-voltage-hysteresis of prototypic TPM with 0.1 Hz triangle signal
(right) strain-voltage-hysteresis after frequency dependent long-term loading

The accomplished studies prove the qualitative and quantitative functional ability under static and dynamic loading of developed thermoplastic-compatible piezoceramic modules manufactured by an adapted hot-pressing process. In particular the obtained free strains are within the range of the maximum accomplishable strains of conventional actuators. Based on these results a demonstrator is designed, which is aimed at the application of TPM as energy source for a closed health monitoring device (Adhikari et al., 2009).

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