

# Lightweight structures with autarchic functional piezo ceramic modules for energy harvesting

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## Introduction

For the research and development of line production technologies for active structural elements high productive manufacturing processes have to be linked to each other and at the same time the integration of active functions has to be realized. On the basis of the quantity oriented processes, the textile technology, polymer-print technology and the injection moulding technology will be developed and researched to produce piezo-ceramic modules with integrated 3D-stitchensors and polymer electronics for usage in active metallic parts.

The innovative 3D-stitchsensor, which is made by the textile technology, is used for stress differentiated measurement and initiates encoded control signals when default values are obtained. At this the piezo ceramic constitutes the activation and the energy supply for the 3D-stitchsensor in the overall system. The embedded polymer electronic is responsible for the signal transmission and signal conditioning. Depending on the characteristics and functions, the several module components will be arranged stress specific. The overall system consisting of the piezo ceramic, the 3D-stitchsensor and the polymer electronic will be protected against environment and process relevant loads by embedding in a material and sensor compatible polymer matrix [1-5].

## Manufacturing and experimental

According to figure 1 samples in the form of a beam made from glass fiber reinforced (GRP) and carbon fiber reinforced (CRP) plastics where produced for the assay. Concerning to the transmission of the piezo ceramic charges the fiber composite layers conduce in each case as electrical isolator (GRP) or rather as conductor (CRP).

By the use of milled micro flutes the carbon fiber layers are unstitched and electrical isolated in order to integrate piezo ceramic fiber composite (PFC) elements. Therefore an electrical contacting of these piezo modules and

also their mechanical embedding will be coevally realized. The piezo modules (1x1x30) mm which are used are polarized in through-thickness direction and will be arranged according to their electrical orientation  $d_{33}$  along the beam. For the sensitivity analysis of the transformed energy and the mechanical prestressing of the piezo modules samples where produced with different wide micro flutes in a range from 960  $\mu\text{m}$  to 1000  $\mu\text{m}$ .

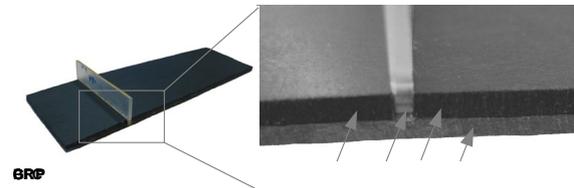


Fig. 1 Reference block with integrated piezo ceramic fiber composite

For that experimentation the reference blocks where one side fixed and each PFC element was fit in the micro flutes. The mechanical strain of the beam is effected by an electric motor fixed on the free side with defined unbalanced mass. The dynamic stimulated beam result in periodic expansions and compression of the outside of the neutral fiber of the arranged piezo-electric modules.

At the experimentation the test sample has been dynamical stimulated for a time of about 500 sec. Over a down streamed bridge rectifier the generated alternating voltage was transformed into direct current voltage and the charge was stored in a capacitor with 22  $\mu\text{F}$ , cf. figure 2.

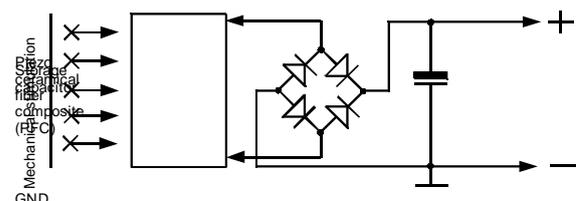


Fig. 2 Circuit diagram of the piezo ceramic generator with bridge rectifier and storage capacitor

## Results and analysis

The focus of the development of the piezo ceramic generator was aimed on electro mechanical characterization of the PFC modules. Therefore the transformed energy under constant generated voltage (off-load voltage) at  $U_{ss} = 30 \text{ V}$  per stimulated period as well as constant frequency of  $f = 34 \text{ Hz}$  was analyzed in plot against different widths of the integration flutes.

Preexaminations of the contacting of the piezo modules show, that because of the high internal resistance of the piezo ceramic from about  $1 \text{ M}\Omega$ , no relevant fall of voltage as a result of the power resistor of the CRP results. For that reason the application of the CRP as the electrical contacting and transmission of the generated charges finds favor in the piezo ceramics.

The results from the experimentation of the generation of electrical charges and its storage arise out of the charging characteristic from figure 3. The top chart illustrates the charging at constant off-load voltages whereas despite of different mechanical prestress no significant difference can be noticed in the course of the charging characteristics. The bottom chart illustrates the charging with constant mechanical excitation frequency. It shows that there is an intense increase of the level of the charging voltage of the capacitor with the extension of the width of the micro flute. This is because of the higher off-load voltage or rather of the generated voltage  $U_{ss}$ .

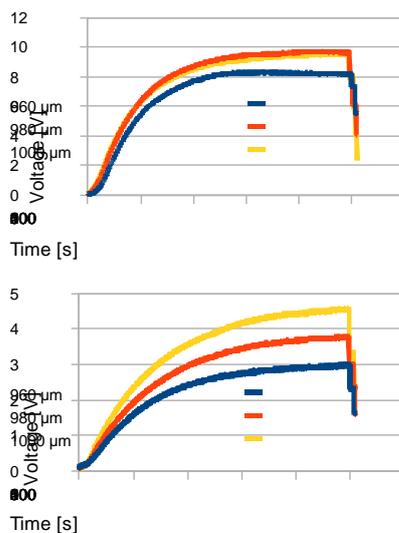


Fig. 3 Charging characteristics of the storage capacitor; top: constant off-load voltage; bottom: constant excitation frequency

The outcome of the both charts is that the loss of power did not come from a possible change of the internal resistance of the piezo ceramics. Simply the change of the mechanical prestress of the PFC modules or rather of the structural assembling of the test samples accompanying with the change of stiffness of the complete system brings different off-load voltages at the same excitation frequency.

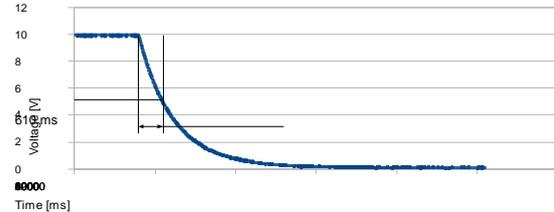


Fig. 4 Discharging characteristic of a  $100 \mu\text{F}$ -storage capacitor

Continuing findings for the stored energy in the capacitor are shown exemplarily in figure 4. Therefore the discharging of a capacitor from  $100 \mu\text{F}$  over a time of 10 sec with a connected load at  $8,2 \text{ k}\Omega$  is specified. The analysis resulted that there is a time frame with 610 msec available for the operation in this circuit by a minimal needed operation voltage of 5 V.

## References

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