Performance optimization of soft dielectric elastomer generators

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Abstract:

This work concerns the performance enhancement of Dielectric Elastomer Generators (DEGs), compliant transducers able to produce electrical energy by converting mechanical work. These devices, basically conceived as highly stretchable parallel-plate variable capacitors, typically undergo a four-stroke load-driven cycle, where applied load and charge are alternately held constant. The amount of energy that can be extracted during each cycle is limited by various mechanism of failure, namely, electric breakdown, material rupture, buckling-like instabilities due to loss of the tensile stress state and electromechanical instability.

Assuming isotropic hyperelasticity and ideal dielectric behavior, the optimal cycle complying with these limits is identified by solving a constrained optimization problem. The optimization process results in a universal curve, in the plane dielectric strength – ultimate stretch, defining an upper bound on the amount of energy that can be harvested as a function of the ultimate stretch ratio. Besides the simple parallel-plate configuration, an annular layout has been considered. This configuration is interesting for the fact that, as deformation can take place on both sides of the membrane, the annular DEG can perform a double cycle along a complete oscillation of the mechanical load and its performance can be definitely improved by prestretching the membrane.

Nonetheless, dielectric elastomers, as all polymers, are affected by time-dependent effects. Hence, the conservative hypothesis appears to be not completely realistic. Indeed, a predicting model for soft DEGs must include an accurate model of the electro-mechanical behavior of the elastomer filling, the variable capacitor and of the electrical circuit connecting all the device components. A phenomenological electro-viscoelastic model at large strain is proposed and calibrated on the basis of experimental data available in literature for a polyacrylate elastomer (VHB-4910). The effects on the generator performance of viscoelasticity and of possible changes of the permittivity with the strains are investigated.

Dr. E. Bortot is Postdoctoral Fellow at the Faculty of Mechanical Engineering - Technion. In 2015, she received her Ph.D. degree in Engineering of Civil and Mechanical Structural Systems from the University of Trento (Italy), where she worked under the supervision of Prof. M. Gei. Her research interests focus on dielectric elastomers and include performance optimization of DEGs and control of wave propagation in DE composites.