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TOPOLOGY OPTIMISATION OF ROBUST FLEXOELECTRIC ENERGY HARVESTERS AT FINITE STRAINS

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Flexoelectricity is a two-way coupling mechanism between electric polarisation and inhomogeneous deformations (i.e., bending, torsion), only relevant at the micro and nanoscale [1,2]. Topology optimisation (TO) is a powerful tool that can help designing efficient energy harvesters taking advantage of the flexoelectric effect at small scales. Few works exist on the effective application of TO techniques for the design of energy harvesters based on the principle of flexoelectricity [3]. The latter works are restricted to piezoelectric crystals and ceramics, hence, exhibiting extremely small deformations. Dielectric elastomers, devoid from the piezoelectric effect, can also exhibit flexoelectricity in the microscale. However, unlike their crystal and ceramic counterparts, dielectric elastomers are capable of undergoing moderate to large deformations, due to their elastomeric composition, and therefore, have been identified as ideal candidates for their use as flexoelectricity-based energy harvesters.

As shown in [3], embedding TO algorithms with the aim of maximising an efficiency-based objective function, typically measuring the ratio between the global (integral) mechanical energy and the global electric energy generated through flexoelectricity, leads to designs characterised by a poor structural performance, with hinges where high stress concentration occurs. This mechanical deficiency is indeed promoted by the inherent flexoelectric nature of the material, which promotes the development of hinges with highly localised large strain gradients. The latter leads to an extremely rapid growth of the electric energy generated when compared with the associated mechanical energy decay, yielding extremely efficient designs according to the metric chosen, but inappropriate from a structural/mechanical standpoint.

In order to remedy the above shortcoming, we propose a new TO framework for the robust (safe) design of flexoelectric actuators with the following key novelties: **(a)** consideration of dielectric elastomers, hence, of finite strain scenarios; **(b)** definition of objective functions considering a weighted combination of efficiency-based measures and p-norm/KS aggregation/regularisation functions of the Von Mises stress distribution within the material. With regards to the Finite Element formulation employed, a mixed-type C^0 formulation has been pursued [1], in contrast to alternative C^1 formulations [2]. A series of numerical studies are analysed, proving that the designs obtained exhibit a balance between the two metrics, exhibiting thus an admissible structural performance.

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