Engineering of a foam-filled auxetic absorber for localized impact

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The work describes the design of an impact energy absorber, based on a foam-filled auxetic frame and is focused on the identification of the geometrical parameters for the fulfilment of the requirements in a pre-defined application scenario.

The innovative absorber is based on a concept described in [1], i.e. an auxetic hexachiral structure filled with foam. The importance of material choice was investigated by conducting numerical simulations on both a 3D-printed polymeric hexachiral frame filled with polyurethane foam and a metallic frame filled with aluminium foam [2]. Specifically, the previous results obtained with polymeric foam-filled frames highlight the importance of the beneficial effects of the interaction between an auxetic frame and foam, which leads to substantial increments of absorbed energy per unit volume and mass. Using materials with high elongation at break, such as an elastomeric material, deserves investigation since it could guarantee the preservation of the auxetic property for the whole duration of the localized impact, as the early breakage of ligaments or nodes, which induce the loss of the auxetic property, could be avoided.

All these aspects have been considered in the design of an absorber concept in a specific crash scenario, represented by the impact between a Vulnerable Road User (VRU) and the bumper of a vehicle. Moreover, among different polymeric materials, a thermoplastic polyurethane (TPU) with micronized waste-tire-rubber (WTR) was used to build the auxetic frame. It exhibits a large strain at failure [3] and can be 3D-printed to obtain auxetic topologies, and involves the use of recycled material.

Dynamic drop tests were conducted on sample structures and compared with the numerical model. The numerical-experimental correlation allowed the numerical model to be enhanced by implementing new features, such as the usage of cohesive contacts to simulate the breakage during the impact of the foam bonded to the hexachiral frame. The validated FE model was used to build a metamodel and sensitivity analyses were performed on geometrical parameters.

Finally, an optimization procedure based on a genetic algorithm is presented. The aim is to find an optimal solution of foam-filled hexachiral structure, considering desired levels of force and impact energy as target and using as variables all the geometrical parameters of the auxetic frame. Results indicate that the optimized absorber is able to absorb the impact energy by mitigating the forces on the VRU below the desired level, with a limited stroke with a completely reversible process.