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Quasistatic and dynamic mechanical responses of load-bearing structural batteries for electric vehicles

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ABSTRACT

We are in the process of developing multifunctional load-bearing structural batteries for electric vehicles (EVs). The battery system not only stores electricity for vehicle propulsion, but also reduces impact forces for the EVs getting into crash loading conditions functioning as a shock absorber, thus decreasing the impact shock to the vehicle occupants for increased safety. Our research focuses on two EV battery systems: Granular Battery Assembly (GBA) and Topologically Interlocked Battery Assembly (TIBA). In GBA, the term "Granular" originated from the recent findings on the granular mechanics. Parab et al. [1] demonstrated the fundamental mechanism of impact energy dissipation with the pulverization of a sand particle in the granular load chain, where the pulverized sand particle interrupted the transmission of impact loads and forced the rearrangement of the remaining grains. Our GBA research extended the concept of granular load chains to the battery cell arrangement with the use of "sacrificing cells" that effectively limit the impact load propagation speed, thus isolating the mechanical impact shock. In TIBA, our research focuses on the use of topologically interlocked materials (TIMs). Mather et al. [2] showed the basic mechanism behind TIMs, where the nonbonded platonic solids were assembled and kept their structural integrity by the neighboring solids. Upon impact, these solids rub against each other, thus dissipating energy by friction. Our TIBA research transformed the application of topological interlocking as a design principle for EV battery pack in such a way that truncated tetrahedra, as either battery cells or battery carriers, created TIBA, a multifunctional structural battery system that has both the capability to dissipate impact energy and resistance to fracture propagation. Following the numerical analysis, quasistatic and dynamic impact mechanical responses were examined in the experiment. In each analysis, the experimental behaviors of the battery systems were compared against the numerical results to confirm the validity of the numerical models. Furthermore, we added a "Base" model, which has neither GBA nor TIBA to reduce the impact force, in order for us to compare against the GBA and TIBA results and to examine the improvement that the two EV battery systems delivered.

REFERENCES

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[2] Mather, A., Cipra, R., Siegmund, T. Structural integrity during remanufacture of a topologically interlocked material. *International Journal of Structural Integrity*. 2012, 3(1), 61–78.