IMPACT AND BLAST PERFORMANCE OF SANDWICH PANELS WITH CELLULAR HONEYCOMB AND LATTICE CORES

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Summary The aim of this presentation is to give a systematic, weight-related assessment of the extent to which cellular and lattice core architectures affect the load-carrying and failure performance of sandwich (as well as some three-dimensional and hybrid lattice) structures when subjected to high intensity blast and impact conditions. A number of both standard and novel (e.g. auxetic) cellular configurations are considered, and the influence of key geometric and material parameters on the dominant structural properties is discussed.

There is a growing consensus that cellular and lattice structures may exhibit considerably more favorable load-carrying, thermal, buckling, failure, and energy-absorption characteristics than monolithic structures of the same shape, areal density and mass. In particular, hybrid, multi-material lattice structures offer a remarkable design flexibility and have a considerable potential for optimization because their mechanical and thermal characteristics may be fine-tuned to conform to a broad range of operating requirements. Moreover, standard, cost-efficient engineering materials and manufacturing technologies may be used to produce cellular lattices with global thermo-mechanical (as well as other physical) properties which are unattainable by equivalent monolithic structures of uniform density. Examples are e.g. auxetic grids with negative global values of Poisson's ratio and hybrid lattices with negative thermal expansion behavior.

Although there has been steady progress in this area of research and development in recent years, comprehensive, systematic and highly realistic investigations allowing direct weight-specific comparisons are still rare. The aim of this presentation is, therefore, to give a detailed qualitative and quantitative description of the extent to which cellular and lattice core architectures may affect the load-carrying, buckling, crushing, failure, and rupture behavior of all-metal sandwich structures subjected to high intensity blast and ballistic impact loads. In addition, certain three-dimensional and hybrid configurations will be considered. It gives a systematic overview of the inelastic deformation behavior of various low-density cellular honeycomb configurations as well as more general – single- and multi-layered – lattice types and their influence on the respective structures' stiffness, reaction forces, failure modes, and energy-absorption efficiency. To facilitate comparisons on a weight basis, the conclusions are derived from extensive numerical analyses of families of laterally impacted flat panels having precisely the same outer dimensions and mass.

To be able to capture all relevant deformation mechanisms, uniformly fine finite element meshes and a material model have been used which is suitable for the time-dependent description of large displacements as well as localization and perforation/fracture phenomena of aluminum alloys. As a result, details of the local and global deformation, buckling, damage, failure, and fracture evolution of the cell/lattice elements and face sheets can be traced throughout the entire loading and response history not only in the immediate vicinity of the center of impact but throughout the entire structure. Difficulties normally associated with homogenization procedures or the generalization of results derived from simplified analyses of isolated subregions of the complex overall topologies can thus be avoided. Specifically, a family of cellular honeycombs (of e.g. the hexagonal, square, Kagome, isogrid, auxetic, and prismatic type) as well as novel single- and multi-layered lattice configurations are considered, and the influence of the various configuration parameters (cellular/lattice pattern, mass distribution, areal density, porosity, cell size, strut and cell wall thickness, etc.) on the dominant safety-related mechanical properties are assessed.

For both traditional as well as auxetic honeycombs and lattices the results clearly demonstrate that lightweight structural components with suitable cellular/lattice geometries may considerably outperform standard monolithic configurations of equal shape, dimensions and mass. In particular, the respective peak and average load-levels are substantially reduced, and the mass distribution as well as the kinematic characteristics of the core architecture is found to be of primary importance. In certain cases, the latter can act as a constraint which may considerably delay – or even prevent – rupture of the face sheets. This increases the shock resistance and safety margin of such structures substantially and makes them highly attractive candidates for novel classes of lightweight, multifunctional impact and blast mitigation devices with customizable energy-absorbing and load-limiting properties.

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