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A Numerical Hybrid Finite Element Model for Lattice Structures Using 3D/Beam Elements

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Abstract : Thanks to the additive manufacturing process, lattice structures are replacing the traditional structures in aeronautical and automobile industries. In order to evaluate the mechanical response of the lattice structures, one has to resort to numerical techniques. Ansys is a globally well-known and trusted commercial software that allows us to model the lattice structures and analyze their mechanical responses using either solid or beam elements. In this software, a script may be used to systematically generate the lattice structures for any size. On the one hand, solid elements allow us to correctly model the contact between the substrates (the supports of the lattice structure) and the lattice structure, the local plasticity, and the junctions of the microbeams. However, their computational cost increases rapidly with the size of the lattice structure. On the other hand, although beam elements reduce the computational cost drastically, it doesn't correctly model the contact between the lattice structures and the substrates nor the junctions of the microbeams. Also, the notion of local plasticity is not valid anymore. Moreover, the deformed shape of the lattice structure doesn't correspond to the deformed shape of the lattice structure using 3D solid elements. In this work, motivated by the pros and cons of the 3D and beam models, a numerically hybrid model is presented for the lattice structures to reduce the computational cost of the simulations while avoiding the aforementioned drawbacks of the beam elements. This approach consists of the utilization of solid elements for the junctions and beam elements for the microbeams connecting the corresponding junctions to each other. When the global response of the structure is linear, the results from the hybrid models are in good agreement with the ones from the 3D models for body-centered cubic with z-struts (BCCZ) and body-centered cubic without z-struts (BCC) lattice structures. However, the hybrid models have difficulty to converge when the effect of large deformation and local plasticity are considerable in the BCCZ structures. Furthermore, the effect of the junction's size of the hybrid models on the results is investigated. For BCCZ lattice structures, the results are not affected by the junction's size. This is also valid for BCC lattice structures as long as the ratio of the junction's size to the diameter of the microbeams is greater than 2. The hybrid model can take into account the geometric defects. As a demonstration, the point clouds of two lattice structures are parametrized in a platform called LATANA (LATtice ANAlysis) developed by IRT-SystemX. In this process, for each microbeam of the lattice structures, an ellipse is fitted to capture the effect of shape variation and roughness. Each ellipse is represented by three parameters; semi-major axis, semi-minor axis, and angle of rotation. Having the parameters of the ellipses, the lattice structures are constructed in Spaceclaim (ANSYS) using the geometrical hybrid approach. The results show a negligible discrepancy between the hybrid and 3D models, while the computational cost of the hybrid model is lower than the computational cost of the 3D model.

Keywords : additive manufacturing, Ansys, geometric defects, hybrid finite element model, lattice structure
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