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MECHANICAL PROPERTIES OF FIBRE-REINFORCED LATTICE MATERIALS

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Summary: The work presented investigates the compressive behaviour of a square oriented lattice material reinforced by prestressed fibres. The potential of lattice materials in terms of their multifunctional use as sandwich core material has been widely discussed in the field of material science. Those cellular structures offer a high compressive-strength-to-density ratio along with an open interior. Since their application for lightweight purposes demands increasingly lower densities, the trusses of their constitutive unit cells become slender and are hence prone to stability problems. Thus, elastic buckling failure of such trusses often limits the compressive strength of low-density materials. The problem of elastic buckling in lattice materials has been observed in literature experimentally for different structures and dimensions (Finnegan et al., 2007; Gao et al., 2013). However, the theoretical investigation of this phenomenon including a thorough analysis of the post-buckling response has not been addressed in literature in detail.
The current study seeks to understand and overcome failure due to stability problems by reinforcing the buckling resistance of the unit cells using prestressed fibres. The concept of prestressing structures in order to improve their compressive strength is therefore applied from structural engineering and scaled down to lattice materials. A fibre-reinforced lattice material based on a square oriented lattice is designed. Furthermore, a representative element is defined. Its in-plane and out-of-plane compressive behaviour is modelled using a discrete, two-degree-of-freedom rigid-link model. Basing on geometrical considerations, the model parameters are assigned to the characteristics of the designed material. The deformational behaviour is evaluated by stating the total potential energy of the model. Critical buckling loads as well as load-displacement correlations in the post-buckling regime are determined analytically in accordance to the energy method by Thompson and Hunt (Thompson and Hunt, 1973). Owing to the periodic structure of the prestressed lattice material, effective material parameters can be derived from scaling the findings for the representative element. The results obtained underline the beneficial compressive properties of prestressed lattice materials and give an insight into an analytical approach of quantifying them.