LMS Seminar

8 June 2023 at 2:00 pm - Room Jean Mandel

Highly strain rate sensitive and ductile composite materials combining soft with stiff polymer-based interpenetrating phases

Nikolaos Karathanasopoulos

New York University, Abu Dhabi campus & Tandon School of Engineering

ABSTRACT

Nature-inspired architected materials premise effective properties that are well beyond the limits of classical engineering materials. Advanced material architectures based on strut, periodic and stochastic topologies have been up to now proposed either in single-phase or double-phase configurations. The current lecture addresses the static [1] and strain-rate performance of polymeric reinforcement phase and rubbery matrix interpenetrating phase composites (IPC), with the topological designs of the stiff phase to follow different triply periodic minimal surface and random function stochastic designs, in a comparative manner. The effective mechanical properties are thoroughly explored as a function of the metamaterial architecture and loading characteristics. Thereupon, fundamental insights in the role of the reinforcement phase design of the composite metamaterial on the static and strain-rate mechanical attributes are derived as well as on the resulting failure patterns through Digital Image Correlation (DIC) and finite element analysis. It is shown that the loading rate response of such advanced IPC architectures utterly differs from the corresponding static, low strain-rate performance and well separates from the attributes of the constituent phases. The performance of stochastic, random function based interpenetrating phase materials is classified with respect to the one of triply periodic minimal-surface based material designs under static and impact loadings. Moreover, the dependence of primal mechanical parameters, namely of the elastic modulus, plateau stress, overall and specific energy absorption are assessed. Overall, substantial strain-rate sensitivities are recorded, with strong underlying topological dependencies. Five orders of magnitude increase in the applied loading rate have been associated with up to one order of magnitude increase in the elastic stiffness, plateau stress and energy absorption attributes; a performance scaling that goes well beyond the limits of most common and architected materials. Specific energy absorptions values up to 16 MJ m-3 were recorded upon exceptionally high crushing force efficiency values and moderate densities, classifying them among the most energy efficient advanced materials and structures up to now reported. Moreover, machine learning techniques are employed for the modeling of the dynamic interpenetrating phase composite material performance. High accuracy and low numerical cost surrogate models are developed, upon which the importance of the underlying topology and loading influential parameters is classified.

BIOGRAPHY

Nikolaos Karathanasopoulos is a global network Assistant Professor of the New York University, affiliated both with the Mechanical engineering Department of the NYU Abu Dhabi Campus and with the Tandon School of Engineering in Brooklyn, New York. He finished his undergraduate studies in the University of Patras in Greece, obtained a Master's Degree in Structural Engineering, Mechanics, and Materials from the University of California (UC) Berkeley and a PhD from ETH Zurich in Switzerland in computational mechanics. He has working experience in the private sector as a software engineer in Switzerland and has followed, post-PhD advanced studies in Computer Science. His research interests include the development of computational methods for the analysis and modeling of advanced materials, structures and processes. He has worked or is actively working on different engineering research projects, which include the modeling and analysis of helical structures, the engineering of advanced materials known as «metamaterials», as well as the structural analysis and design of advanced composites with extra-ordinary mechanical and functional attributes, through both experimental and numerical techniques, integrated in newly developed artificial intelligence frameworks. His research has received support from private and public European organizations, including the Novartis Research Institute and the Marie Sklodowska-Curie actions, as well as the excellence graduate research programs of New York University.

REFERENCES

[1] Agyapal Singh, Oraib Al-Ketan, Nikolaos Karathanasopoulos, Mechanical performance of solid and sheet network-based stochastic interpenetrating phase composite materials, Composites Part B: Engineering, Volume 251, 2023, 110478