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Perspective

Mechanical Properties of Metallic Cellular Solids

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DESCRIPTION

Metallic cellular solids are known for their high strength-to-weight ratio. It is suitable for applications in the transportation industry to reduce fuel consumption and emissions. Although great progress has been made in the fabrication and prediction of static mechanical properties of these materials, their dynamic behavior (eg, harmonic response and damping ratio) remains difficult to characterize in a direct manner. This is due to the usual complex geometry and low damping of metal cell bodies, and the incorporation of external damping from instruments in vibration tests. In this work, we present an indirect method based on a numerical inverse engineering approach to determine the true apparent elastic modulus and damping ratio of metallic cell solids. For validation purposes, the proposed method was applied to Al-based non-stochastic cellular solids prepared by investment casting of various architectures, where the apparent dynamic elastic moduli (1.4-217.2 MPa) were compared with the static structural results. It turned out to be very different. The damping ratios of these samples were also successfully determined (0.002 to 0.011), showing that these values are within the expected range for these aluminum-based cellular solids. Cellular solids are a class of high specific strength, low specific gravity materials characterized by interconnections of ribs/struts to a rigid framework. Due to their lower CO_2 emissions and reduced fossil fuel consumption, these materials are believed to have a wide range of applications in the transportation industry, aerospace and more. The solid phase of these scaffolds can be made of a variety of materials, but metal-based grids seem to be the most suitable when high load-bearing capacity is required.

Metal stochastically cellular solids can be prepared by a wide range of techniques, often using molten blowing/blowing agents, powder metallurgy, and casting with leachable/permanent placeholders. Recently, there has been increasing interest in fabricating non-stochastic cellular solids to control/tune mechanical properties associated with additive manufacturing and casting. In the fabrication of non-stochastic cellular solids, significant progress has been made to refine the fabrication process, including controlled geometries with thicknesses down to 0.80-0.24 mm. Over the years, there has been great progress in predicting the static mechanical properties of cellular solids, with various models being developed to account for rib/strut bending, hinge/strain, thickness and even negative Poisson's ratios. Since the 1980s, there have been various approaches to determine the dynamic mechanical properties of cellular solids, but anomalies arise from measurement errors in the transfer function and the inherent errors of the direct vibration response method due to the Poisson effect in prismatic samples.

We established a method to measure the dynamic elastic modulus based on the dynamic mass of cylindrical polymer foam samples in vacuum and determined the dynamic elastic properties at low frequencies using a laser vibrometer on prestressed polymer foams. Using accelerometers, a method was developed to monitor the vibrational response of this type of cellular solid and simultaneously identify both elastic and inelastic properties of the porous framework of anisotropic open-celled polymeric cellular solids and rice field. These methods have been used to characterize cellular solids, including polymeric viscoelastic solid phases. Nonlinear oscillations in systems with a single degree of freedom can suffer from harmonic instabilities in High Root-Mean-Square (RMS) harmonic responses. This affects the damping coefficient measurements, comparing the damping of conventional Poisson's ratio and negative Poisson's ratio polymer foams.

CONCLUSION

It was concluded that they exhibit complex behavior that does not fully comply with classical theories of elasticity or viscoelasticity. These inwardly twisted cells of the auxetic polymer cell body enhanced cushioning. The advantage of auxetic behavior in macromolecular cellular solids to reduce vibration transmissibility was confirmed. The above method has been successfully used to characterize polymer-based cellular solids. Second, the dynamic characterization of metallic cell solids is inherently difficult due to the parasitic damping of experimental setups. Even if the overall mechanical behavior of a substrate (e.g. aluminum) can be simplified as linear elasticity, the overall relationship between stiffness and damping means that they are very difficult to characterize.

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