

Editorial

Cellular Metals: Fabrication, Properties and Applications

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1. Introduction and Scope

Cellular solids and porous metals have become some of the most promising lightweight multifunctional materials due to their superior combination of advanced properties mainly derived from their base material and cellular structure. They are used in a wide range of commercial, biomedical, industrial, and military applications. In contrast to other cellular materials, cellular metals are non-flammable, recyclable, extremely tough, and chemically stable and are excellent energy absorbers. The manuscripts of this Special Issue provide a representative insight into the recent developments in this field, covering topics related to manufacturing, characterization, properties, specific challenges in transportation, and the description of structural features. For example, a presented strategy for the strengthening of Al-alloy foams is the addition of alloying elements (e.g., magnesium) into the metal bulk matrix to promote the formation of intermetallics (e.g., precipitation hardening). The incorporation of micro-sized and nano-sized reinforcement elements (e.g., carbon nanotubes and graphene oxide) into the metal bulk matrix to enhance the performance of the ductile metal is presented. New bioinspired cellular materials, such as nanocomposite foams, lattice materials, and hybrid foams and structures are also discussed (e.g., filled hollow structures, metal-polymer hybrid cellular structures).

2. Contributions

Sixteen original scientific contributions (fifteen original articles and one review paper) on different topics of cellular metals have been published in this Special Issue. Seven contributions focus on the advances in production and manufacturing technologies for aluminum alloy foams and the understanding of the foaming behavior and the fundamental relationships between their structure and their properties, with some even exploring nano-sized reinforcement elements. García-Moreno et al. [1] investigate the influence of the alloy composition and the role of the liquid phase and its influence on the gas nucleation and foaming of Al–Si–Mg alloys prepared by the powder metallurgy method using in-situ X-ray radioscopy, X-ray tomography, and X-ray tomoscopy. Lehmus et al. [2] analyze the effects of the solidification rates and addition of Sr, B, and TiB₂/TiAl₃ on the foaming behavior and microstructural, morphological, and mechanical properties of aluminum foams fabricated by the powder metallurgy method. Duarte et al. [3] present an automated production line composed of a continuous furnace, a cooling sector, and a robotic system to fabricate metal foam parts and/or components using a powder metallurgical method. Several case studies are also provided. Three original contributions from Kuwahara et al. [4–6] related to direct foaming methods, as an alternative to the powder metallurgy

method, are also presented. In the first contribution, Kuwahara et al. [4] investigate the pore formation of Al-Cu-Mg foams fabricated by the melt route using magnesium as a thickening agent or by the semi-solid route using primary crystals at a semi-solid temperature with a solid fraction of 20%. They analyze the nano-sized and micro-sized precipitates of the cell wall and the effect of the cell wall structure and pore morphology on the compressive properties. Kuwahara et al. [5] characterize the compressive properties of Al-Cu-Mg foam fabricated by the melt route and the semi-solid route. They also provide a morphological, microstructural, and metallurgical analysis. Kuwahara et al. [6] analyze and numerically evaluate the stabilization mechanism of the cell walls of the aluminum alloy foams prepared by a semi-solid route in which the melt is thickened by primary crystals. Trejo-Rivera et al. [7] present a methodology based on a direct foaming method to fabricate aluminum alloy foams made of A-242 alloy from the recycling of secondary aluminum obtained from beverage cans, using calcium and titanium hydride as a thickening and blowing agent, respectively. They provide microstructural and metallurgical analyses and the mechanical properties. Three contributions discuss the reinforcing role of carbon nanostructures (e.g., multiwalled carbon nanotubes and graphene oxide) in developing new cellular structures with enhanced properties. Damanik and Lange [8] investigate the effect of multiwalled carbon nanotubes coated with nickel on the foaming behavior and morphology of reinforced AlMg₄Si₈ foam prepared by a powder metallurgy process. Pinto et al. [9,10] present novel aluminum foam–polymer nanocomposite hybrid structures, providing the structural, mechanical, thermal, and acoustic properties. These hybrid structures are prepared by infiltrating an open-cell aluminum foam with a polymer (epoxy [9] and polyurethane foams [10] with or without graphene oxide) to enhance the performance of the resulting hybrid structures. The three following contributions are focused on new cellular structures to be applied for structural applications. Vesenjok et al. [11] present a novel approach to fabricate aluminum unidirectional cellular structures with longitudinal pores by rolling a thin aluminum foil with acrylic spacers and finally compacting by explosion welding. They provide the metallographic, quasi-static, and dynamic compressive properties. The fabrication process and influencing parameters have been further studied using computational simulations. Yang et al. [12] present a comparative numerical study of the uniaxial behavior of three lattice materials—face center cube, edge center cube, and vertex cube—generated using topology optimization and crystal inspiration. They provide a characterization of their deformation modes, mechanical properties, and energy absorption capabilities. Xu et al. [13] analytically and numerically describe the elasto-plastic behavior of transversely isotropic cellular materials with inner gas pressure, focusing on a gas-filled ellipsoidal-cell face center cube foam with a relative density of 0.5. Yang et al. [14] report the findings of an experimental and numerical work developed to study the sound absorption performance of 10-layer gradient compressed porous metal to be applied for noise reduction. Hangai et al. [15] introduce a new manufacturing method to fabricate steel tubes filled with aluminum foam from aluminum burrs of die-castings by friction stir back extrusion. They further determine the compressive behavior and potential applications for impact energy absorption. Finally, Duarte et al. [16] present a brief review of the main experimental and numerical techniques and standards to investigate and quantify the structural, mechanical, thermal, and acoustic properties of cellular metals.

3. Conclusions and Outlook

The contributions of this Special Issue present recent advances in cellular metal research. Cellular metals enable an immediate weight reduction and material saving of components. Simultaneously, they can perform multiple functions due to their three-dimensional cellular structures. Despite these advantages, the commercial use of cellular metals is still limited due to the high production costs required to create regular cellular structures (topology and morphology). Another inhibitor to their application is the random variation in their mechanical, acoustic, and thermal behavior. However, new technical solutions ensure that these materials can be produced in a commercially profitable way

with the required quality and reproducibility, such that their integration into engineering structures can fully utilize their unique properties.

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