PRODUCTION AND PROPERTIES OF ULTRA-LIGHTWEIGHT ALUMINUM FOAMS FOR INDUSTRIAL APPLICATIONS

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Ultra-lightweight materials provide promising solutions for the increased demands on safety and reduced energy consumption in many new engineering applications. While polymer foams have been used extensively in the automotive industry for years, the potentials for metal foams with porosity values of up to 90% and increased temperature resistivity are just beginning to emerge. Materials of high energy-absorbing capacity and low specific weight are of special interest for energy absorbing structures.

The Metal Foaming Process

At the Fraunhofer Institute for Applied Materials Research in Bremen, Germany, a new powder metallurgical process to manufacture metallic foams in a near-net-shape-manufacturing process has been developed and patented [1,2] that has recently been introduced in the US by the Fraunhofer USA – Resource Center Delaware.

In this process, shown schematically in Figure 1, commercially available powders are mixed with small quantities of a powdered foaming agent through conventional techniques such as tumble mixing. In the case of aluminum powder, the foaming agent of choice is TiH_2. The powder mixture is compacted to a semi-finished product of low porosity by applying compaction techniques such as extrusion or axial compaction. Under the proper process conditions, the compaction step results in a foamable semi-finished product that can be worked into sheets, profiles, and other geometries by applying traditional metal forming techniques.

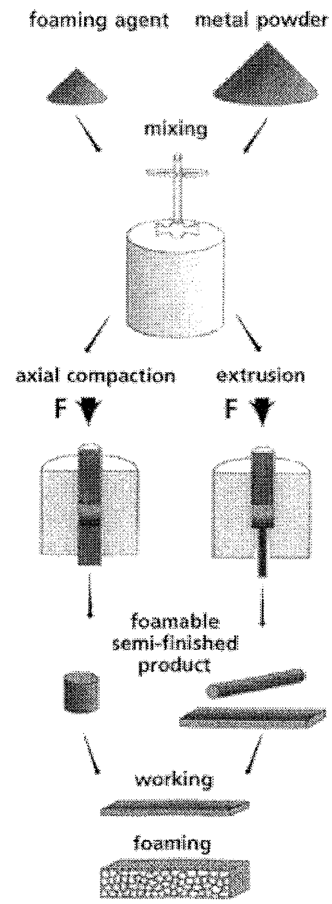

Figure 1: Schematics of processing steps for metal foaming by powder metallurgy.

During the foaming step at temperatures above the melting point of the metal powder, the foaming agent decomposes and generates the foaming gas. The expanding material develops a highly porous, closed cell structure. The foam fills the space available within the mold and creates the near-net-shaped, low-density, and highly porous metal component. The process is environmentally friendly - during the foaming step for aluminum foam, only hydrogen gas is released from the TiH_2 agent. In addition to aluminum and its alloys, other metals such as zinc, tin, and lead can be foamed in a similar fashion.

Sandwich structures with metal face sheets and a highly porous metallic core can be manufactured by cladding sheets of foamable precursor material with conventional sheets and then foaming the entire structure. In addition, through deep-drawing of the pre-foamed sandwich structure and then foaming up the core material, it is possible to produce complex three-dimensional sandwich structures with metallic foam cores.

Properties

The density of aluminum foams typically ranges between 0.5 and 1g/cm^3, and lower densities are achievable. Due to its closed porosity property, aluminum foam would actually float on water. Figure 2 shows a typical pore structure of aluminum foam.

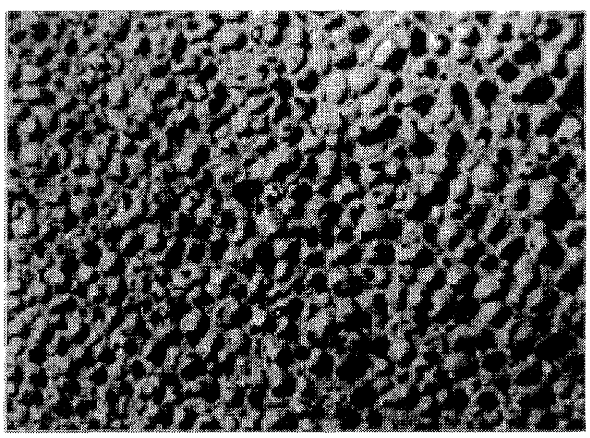

Figure 2: Typical structure of aluminum metal foam produced with powder metallurgy.

The modulus and other critical properties of foamed metals can be tailored by adjusting one or more of the following process parameters:

- Specific Weight (Porosity)
- Alloy Composition
- Heat Treatment Status
- Pore Morphology

Due to their highly porous structure, metal foams have a high specific stiffness. The electrical and thermal conductivity of metal foams are considerably reduced, but still within the range of other metallic materials. Aluminum foams show good mechanical damping and sound insulation properties. Metal foams provide excellent energy absorption features at substantially higher strength levels than polymer foams. The increased service temperatures and the nonflammable feature of the material can be important design advantages. Finally, the recyclability of foamed metals is an important factor for many applications. Metal foams can easily be joined by adhesive bonding, braising, and special welding technique and machined through sawing, drilling, milling, and other common metal working technologies. [3]

Applications

Opportunities for metal foam exist in energy absorption, thermal barrier insulation, light-weight construction, flame arresting walls, and vibration damping applications. Crush-energy conversion elements may be filled with foamed aluminum to optimize the deformation behavior of crush zones in automotive structures.

[1] Baumeister, "Method for Producing Porous Metal Bodies," German Patent DE 4018 360, 1990.

[2] Baumeister and Schrader, "Methods for Manufacturing Foamable Metal Bodies," US Patent DE 5151246, 1992.

[3] Banhart, Baumeister, and Weber, "Powder Metallurgical Technology for the Production of Metallic Foams," European Conference on Advanced PM Materials, 1995