Metal Foams: A New Automotive Material ?

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Most people are familiar with three of the four states of matter as solids, liquids, and gases. However, both nature and engineers have created matters that are mixtures of these three states. For example, mists and liquid foams are made of mixture of gases and liquids, and suspensions, soft matter, semisolids, and liquid crystals are mixtures of solids and liquids. What interests material engineers is the exceptional material properties that emerge as a result of mixing of these phases. Historically speaking, the current interest in mixed phases was proclaimed in the 1950s by the MIT metallurgist Cyril Stanley Smith in his book titles, *A Search for Structure*.

Solid foams seen in everyday life includes polyurethane and polystyrene products for cushioning, packaging, and insulation. Other materials such as glass can also be foamed. A completely new class of foams is *metal foams* which attracted a lot of attentions due to its special and desirable properties. A metal foam consists primarily of a network of frozen borders meeting at junctions that usually have the prescribed tetrahedrally symmetric form. Basically, it is a metal with a large number of gas-filled holes distributed inside the material.

Metal foams have high stiffness-to-weight and strength-to-weight ratios, and thus offer a great advantage in situations where lowered weight is a key objective. They also show the ability to absorb a large value of energy during the compressive deformation, a highly desirable feature for an automotive crash material. The following summarizes the key characteristics of metal foams:

- Ultra lightweight with high degree of homogeneous closed-cell porosity
- Foam microstructures that can be tailored over a range of 40 to 80v/o porosity
- High stiffness-to-weight and strength-to-weight ratios
- Ability to absorb energy from impact, crash, and explosive blasts
- Vibration damping and sound absorption
- Fire resistance and thermal insulating properties
- Metal foams are easily recycles

There are several method for manufacturing metal foams. In 1990, however, an old compacted-powder foaming process developed in the late 1950s by Benjamin Allen at the United Aircraft Corp in Delaware was rediscovered by German physicist Joachim Baumeister. This method was considerably expanded later at Fraunhofer institute in Germany. The Fraunhofer Powder Metallurgy (P/M) process is based on blending metal powders with a foaming agent, compacting the powder mixture to high density, and then heating the compact to near the melting temperature of the metal. During the heating the foaming agent decomposes, forming a gas that is trapped inside the compacted powder body. The complete process consists of fives stages:

- Making the precursor
- Initial pore formation
- Pore inflation
- Foam degradation

- Solidification

As a result of this process, a lightweight structure with high degree of closed cell porosity material is formed. Amongst metals, aluminum was found to be particularly amenable to foam production.

The automotive industry has been most active in metal foam research and development activities in recent years. Aluminum foam sandwich (AFS) is a flat sandwich panel with a foamed aluminum core between two aluminum face sheet. Other shapes can also be made. They are damage tolerant and easy to vehicle's aluminum structural frame. The R&D works on AFS technology has started around 1994, and considering the rule of thumb of 12 to 15 years laboratory-to-commercialization timescale, the next few years might witness a boom in metal foam applications in automotive industry.