СЕКЦІЯ 5
ТЕХНОЛОГІЇ ТА МАТЕРІАЛИ

Rusu Ioan,
Rusu Oana

Technical University «Gheorghe Asachi» from Iasi, Romania

POROUS METALLIC COMPOSITE MATERIALS BASED ON AlMg-SiC$_p$ FOR AUTOMOTIVE APPLICATIONS

INTRODUCTION

The modern society needs a continuous development of the improvement of the materials quality and, of course, the discovery of others with superior properties. Merging this two directions we can say that a outstanding category of materials was developed: ultralight metallic composite materials with particles (UMCMP). These materials are placed between composites and metal cellular/foam materials and that is why they borrow properties from both categories: low weight, high rigidity, high energy absorption capacity, high damping capacity, thermal and electrical conductivity, stability in harsh (aggressive) environments, etc. This fact allows their use for a wide range of applications: automotive industry, bioengineering, aerospace industry, etc.

It must be emphasized that, although mechanical properties of metallic foam are proportional with foamed solid metal, it varies depending on several criteria as production method, production parameters, density, cell wall thickness and pore distribution.

Some of this metallic materials are potentially very cheap, particularly when cost is measured in units of euro/unit volume. Here they rival wood (without the problems of decay) and other cheap structural materials such as plastics.

ULTRALIGHT METALLIC COMPOSITE MATERIALS WITH PARTICLES IN AUTOMOTIVE INDUSTRY

UMCMP already have a number of established and profitable market niches: heat exchangers, both of the regenerative and the purely dissipative types (DUOCEL); lightweight support structures for aerospace applications (DUOCEL), rechargeable batteries (INCO), baffles to absorb traffic noise on underpasses and cladding on buildings, structural panels (ALPORAS, CYMAT), body panels (KARMANN) and so on.

In the field of automotive industry we can remember such applications like automobile firewalls, parts with mechanical stiffness and energy-absorbing ability at low weight, components for rail-transport systems, etc.

For example, KARMANN GmbH is a system supplier for the automotive industry worldwide. They developed an UMCMP based on aluminum, allowing revolutionary technology in body panels. It claims that this materials offer cost-effective performance as structural automotive parts that are up to ten times stiffer and 50% lighter than equivalent parts made of steel. Such lightweight, stiff foam sandwich panels simplify body structure systems, enabling OEMs to produce different variations of low-volume niche vehicles based on a common body structure.

An ideal energy absorbing material has a stress–strain curve with a long, flat plateau region. Any spikes in the stress because unwanted spikes in deceleration. A plateau in the stress-strain curve tells us that the force is constant with increasing deformation in the material. The energy per unit volume of material that is absorbed is the area under the stress-strain curve (figure 1).

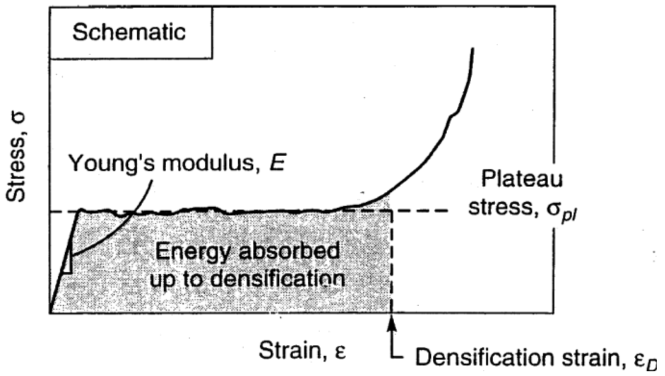


Figure 1 – Schematic of the stress-strain curve of UMCMP in compression

Energy absorption is important in all automotive applications. UMCMP is an ideal energy absorber. The potential for use of these materials in crashworthiness applications spans all transport. So, in automotive it can be used in bumper systems, side impact protection, pedestrian protection (hoods, cowlings, etc.) and interior occupant protection.

Crashbox. It is placed between the impact beam and the front rail of the car and it is design to absorb medium speed collision energy and reduce repair costs. The benefits of UMCMP-filled crashboxes are: eliminate damage to the front rail by absorbing the energy from collisions, thereby localizing damage and reducing repair costs; absorb energy in off-axis collisions more efficiently than hollow-section designs; absorb more energy than an empty section of similar mass; offer greater design freedom in the front-end by absorbing impact energy in a much shorter distance.

Rails. Much of the body of a car, including the front and rear rails, is composed of hollow sections. These sections offer very good bending stiffness for weight but often fail prematurely because of localized damage. Traditionally, steel stampings are used for additional support at weak points in a rail such as curves but these additional parts add complexity and cost to the system. The advantages of using UMCMP filled rails are: strength, energy absorption and length of elastic range of a UMCMP -filled rail are improved by preventing premature failure at a flaw or curvature; consolidating or eliminating small reinforcement stampings can reduce cost of the part; weight of the rail can be reduced compared to a traditional stamped reinforced rail with the same energy absorption and strength; energy absorption and strength of the foam-filled rail can be improved with the same weight as a traditional rail; passenger safety is improved by reducing intrusion into the passenger compartment in the case of high-speed crashes.

Bumper. Safety requirements for occupants and pedestrians demand more functionality of bumpers. The consumer and the insurance industry desire systems that are easily repairable and that protect other, more expensive, components. Styling concerns limit the amount of space available to build in the required functionality. In addition to its use in crashboxes, the advantages of incorporating UMCMP into bumper beam design include: UMCMP does not rebound after it is compressed, which reduces whiplash concerns; UMCMP can increase the threshold collision speed before the impact beam is damaged; UMCMP may allow for a thinner bumper profile and greater design freedom.

Internal Occupant Protection. It is largely concerned with reducing the severity of head injury experienced by the occupant in an accident (for example, headliners, headrests, and pillar covers). When dealing with potential head injury, the forces must be kept low and that is why UMCMP is an ideal material for resolving internal occupant protection because: UMCMP exhibits no rebound after compaction; the properties of UMCMP do not change with temperature and speed of impact; it can absorb large amounts of energy in every direction.

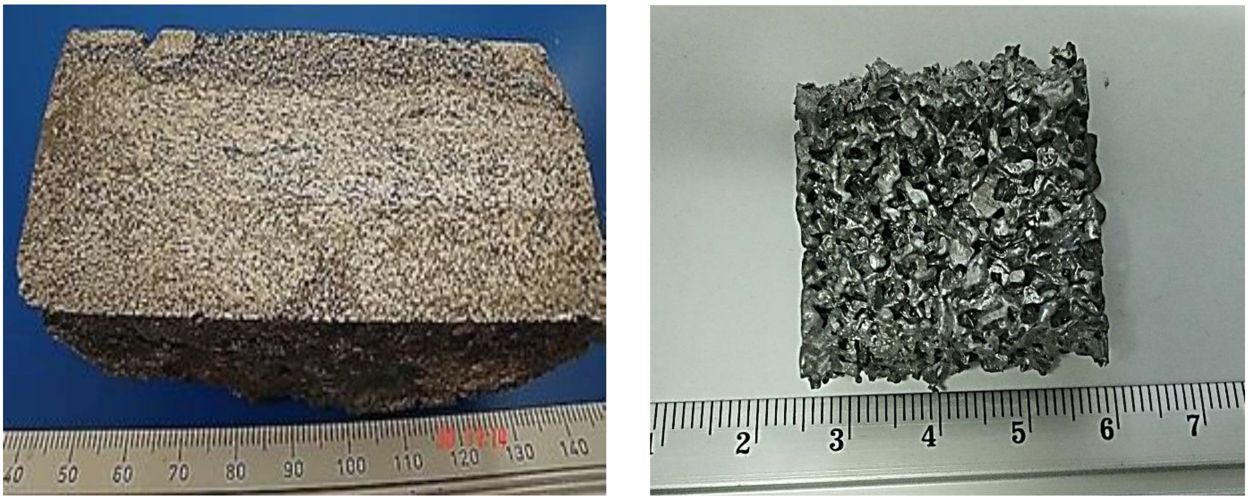
Pillars. The material can be inserted into pillars and held in place by adhesive, expanding polymer foams or by mechanical methods. Benefits are similar to those noted in rail-reinforced applications.

Hoods. Legislation in Europe require carmakers to make pedestrian safety an integral consideration in front-end design. UMCMP offers a unique combination of properties that make it ideal for a hood application: energy absorption, stable properties at elevated engine temperatures, good thermal insulation, and low noise transmission. Other advantages of an UMCMP hood are: excellent energy absorption in the delicate head injury regime; density can be varied as needed through the hood (or only placed in specific locations) to protect head injuries resulting from impacts with hard under-hood components; UMCMP provides a simple, passive solution (compared to very complex, active solutions that are being considered, such as airbags); UMCMP slows the head to a stop and does not accelerate in the opposite direction (whiplash considerations).

SOME DATA ON ULTRALIGHT COMPOSITE AlMg-SiCp

We chose AlMg10 alloy for the material base and SiC for inserted particles (with 120 micrometers medium size). The main criteria for the adoption of the obtaining method was the lowest cost applicability in industry, and that is why we focused on two methods:

- based on the reactive gas (butane) bubbling of a metal melt – lead us to ultralight cellular composite type AlMg10 with different amounts (5, 10 and 15%) SICp, with small and medium size open and semi-open cells. The method involves the addition of silicon carbide in the melted aluminum alloy, a vigorous agitation of the formed mixture simultaneously with it bubbling (figure 2a);
- based on the use of particles of various salts, in the form of powders, which are soluble in suitable solvents – lead us to ultralight porous composite AlMg10 - SICp (5, 10 and 15% SICp), with a structure close to metal foams, with generally semi-open cells. The method adopted by me used as soluble salt particles of sodium chloride and water as solvent and is based on the introduction in the molten metal alloy of a mixture of powders of sodium chloride and silicon carbide, followed, after cooling, by the dissolution of the sodium chloride in water (figure 2b).



a) b)

Figure 2 – Macrostructure of obtained AlMg10-SiCp ultralight composites;
a – cellular, b – porous

The measured densities and compressive strength allowed us to include our materials in an area suitable for using these materials in energy absorption applications. So, for the obtained samples we measured density, deformation mechanical work and the energy absorption. The results are:

- for the cellular samples: 2.26÷2.35 g/cm^3, 20.4÷26.8 Nm, 8.3÷16.7 J;
- for the porous samples: 1.45÷1.85 g/cm^3, 18.2÷24.9 Nm, 13.2÷22.8 J.

The obtained data permit us to place our materials in the compressive strength, plotted against density general overview, as showed in figure 3.

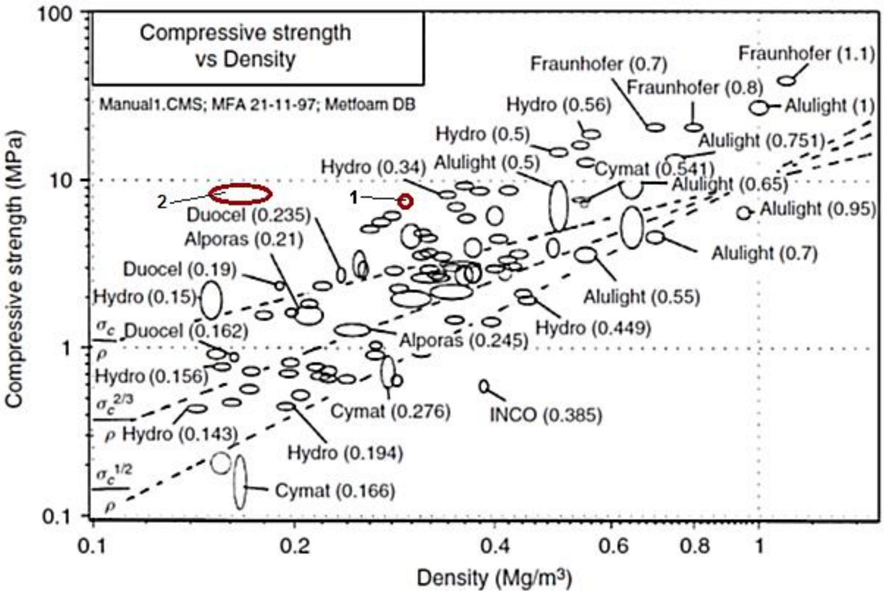


Figure 3 – The compressive strength plotted against density for some available metal foams and for obtained ultralight composites; 1 – cellular, 2 – porous

In figure 4 is presented the stress-strain curves of obtained UMCMP in compression.

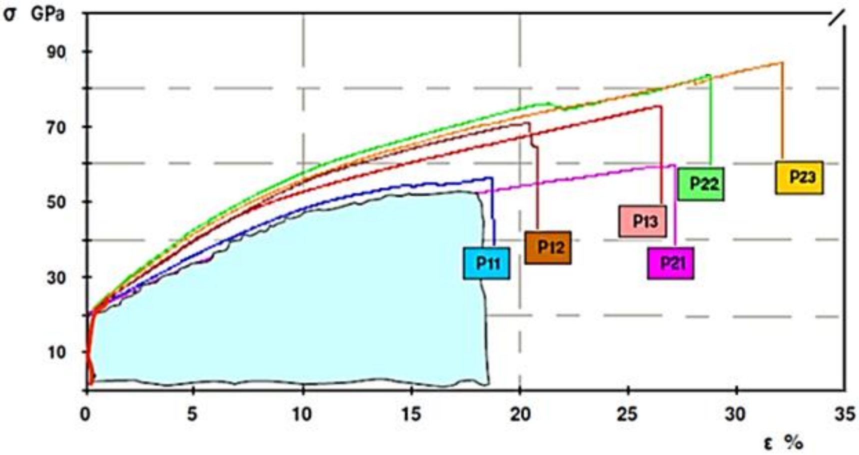


Figure 4 – Stress-strain curves of obtained UMCMP in compression; P1-i – composite test specimen obtained by bubbling method, P2-i – composite test specimen obtained by soluble salt method, i = 1, 2 or 3 according the percentage of SiC_p (5, 10 or 15%)

CONCLUSION

Ultralight metallic composite materials with particles based on AlMg-SiC_p can be used for energy absorbing material because their stress–strain curve had a long, flat plateau region and the absorbed energy per unit volume of material had relatively big values. From the obtaining UMCMP we recommend the porous ones because of their higher values for energy absorption and smaller for densities.

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