A STUDY ON MANUFACTURING LIGHTWEIGHT COMPOSITE METAL FOAM

FOR HIGHER ENERGY ABSORPTION APPLICATIONS

ABSTRACT

Metal foam is a synthetic cellular material being used for various commercial and military applications. For instance, Titanium and Magnesium foams serve as bone implants due to their biocompatibility. On the other side, Aluminum foam can be applicable for building wall construction, sound, shock or vibration damping, thermal insulation, heat exchangers, automotive body parts, collision/crush protection. Additionally, military products such as blast mitigation and ballistic protection applications. While steel foams were studied for ballistic protection applications, the common metal foams currently in use for blast mitigation and collision protection are aluminum foams due to their high strength-to-weight ratio and corrosion resistance. However, the limitation associated with the aluminum and steel foams produced using foaming agents like TiH_2 powder was their low strength-to-weight ratio, which was unable to meet the current requirement of higher energy absorption capability. For this, researchers tried to use space holders to create pores in the aluminum matrix. One of the recently conducted studies used stainless steel hollow spheres (SHS) and ceramic hollow spheres as reinforcement in the aluminum matrix to improve the compressive strength of the foam. Further, in another study, the ceramic hollow spheres were layered with a steel powder layer, sintered at the sintering temperature of the steel and used as reinforcement to improve the compressive strength and deformation strain of the aluminum matrix foam and hence had higher energy absorption capacity compared to the aluminum foam. However, these foams still have inferior mechanical properties. A new study was needed to enhance compressive strength, porosity and deformation strain since these parameters are directly related to the higher energy absorption property. Therefore, the matrix material should be changed from aluminum to aluminum-alloy, similarly the properties of the ceramic and steel hollow spheres need to be improved for higher performance of the closed-cell foam.

Generally, by controlling the properties of the input materials, the main properties of the metal foam, such as its lightweight, high compressive strength, low specific weight, improve stiffness and superior energy absorption. Therefore, in this work, a novel material is developed as a reinforcing agent in the aluminum matrix called the Cermet Hollow Sphere (CHS). The CHSs were developed from ceramic powder (SiC) and steel powder (316L) using the powder metallurgy

technique. The CHSs have a diameter range of 3 to 9 mm of shell thickness of 0.5 ± 0.1 mm to increase toughness of the cermet. On the other hand, the pure aluminum matrix is replaced with a strong aluminum matrix (LM24), which is commonly used in automotive industries for engine block, cylinder head and transmission case manufacturing due to its excellent die-cast characteristics and strength.

In this work, four categories of foam samples were manufactured for comparative study to identify the best performance, in terms of energy absorption. Then, the foam samples were produced using:

- TiH_2 as a foaming agent.
- LM24/CHS at different mixing ratios of the CHS.
- Hybrid foam from LM24/Al_2O_3/SHS at different ratios of the Al_2O_3 and SHS
- LM24 Foam reinforced with CHS at different weight ratios of the CHS

Furthermore, the detailed manufacturing process of the CHS, SHS, matrix and composite metal foam samples, as well as testing and characterization are discussed in the study. Among the developed foam samples, the LM24/CHS foam has shown superior mechanical properties such as high strength-to-weight ratio, compressive strength and higher energy absorption, which are the essential parameters of any metal foams for impact applications.