Processing and Properties of Steel Foam Sandwiches

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Abstract

Metallic foams have a combination of attractive properties such as high specific mechanical properties and good energy absorption characteristics. This paper presents the properties of steel foam sandwiches produced using powder metallurgy approach. Metallic powder, solid polymeric binder and a foaming agent are dry-mixed and molded into the desired shape. The molded powder mix is then heat-treated to foam, debind and sinter the material. The resulting material has an open cell structure with high porosity. The structure and properties of sandwiches specimens produced with the process are presented and discussed.

Keywords : foams, steel, iron, sandwich, mechanical properties

1. Introduction

Metallic foams offer a combination of interesting properties for different types of applications. While steel is a relatively inexpensive material, has good mechanical properties and offers the possibilities to tailor the properties of the material by modifying its composition, relatively little work has been done on steel foams and these materials are still not available industrially in large volumes. A process has been recently developed to produce metallic foams by foaming a mixture of metallic particles, a polymeric binder and a foaming agent. The material is foamed at low temperature to melt the organic binder, to decompose the foaming agent and foam the powder suspension. After foaming, the material is treated at moderate temperature to decompose the polymeric binder and is sintered at high temperature to consolidate the material.

2. Experimental and Results

Steel foam sandwiches were produced using the process presented in Figure 1 and described in more detail in [1,2]. The powder formulation used in this study contained screened (-45 µm) diffusion-bonded steel powder premixes containing 4%Ni, 1.5%Cu, 0.5%Mo and 0.15%Mn (Figure 2b) from QMP. The iron-based powder was admixed with the binder and foaming agent and then placed between perforated steel sheets before foaming (Figure 2b). After sintering, some sandwiches were submitted to a cementation treatment in order to raise the carbon content of the steel foam. Some of the sandwiches were coated with polymer composites (pression molded) and aluminum (thermal sprayed).

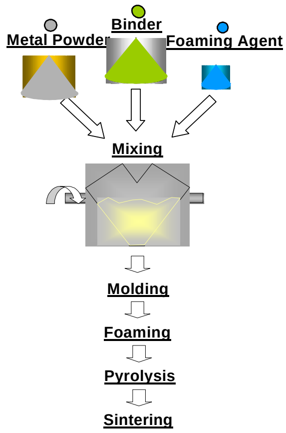

Fig. 1. Process used to produce the steel foam.

Examples of sandwiches produced are presented in Figure 2. The porosity of the foams is 93% while the density of the sandwiches is 1.98 g/cm^3. The major contribution to the weigth comes from the face sheets (71% of the total weigth of the as produced steel foams).

The structure of the foam (Fig. 3) is composed of cells and openings in the cell walls. The foam is integrated in the pins of the perforated plates as shown in Fig.2c. After sintering, the steel sheet is free from carbon due to the sintering treatment used (1200°C in Ar-20%H_2). To get the optimum properties of the foam and sheets, sintering conditions allowing maintaining acceptable level of carbon should be used. To evaluate the effect of carbon on the properties, cementation treatments were done on the sandwich.

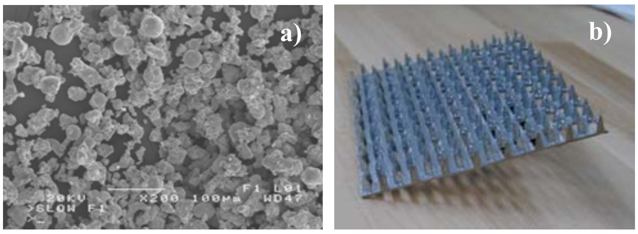

Fig. 2. a) SEM micrograph of the steel powder premix used to produce the foams and b) perforated steel sheets used to produce the sandwiches.

Fig. 2. Steel foam sandwiches a) as-produced, b) coated with polymer composite, c) coated with aluminum.

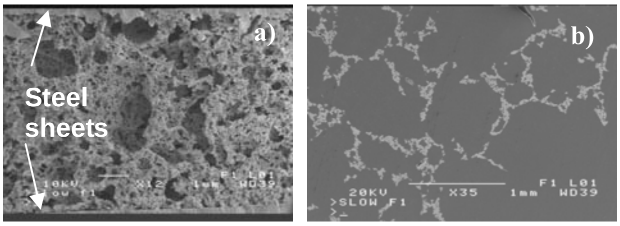

Fig. 3. SEM micrographs of the foam a) edge of the sandwich and b) polished cross section.

The compressive properties of a sandwich panel are presented in Figure 4. The vertical lines on the curve represent unloadings used to evaluate the elastic modulus (i.e. 6.4 GPa). The curve shows a smooth increase of the stress up to 25% deformation (i.e. 17 MPa). Between 25 and 60% deformation, the stress increases from 17 up to 40 MPa. After 64% deformation, the stress increases dramatically due to the densification of the material. The energy absorbed up to densification is significant (10.5 MJ/m^3). The compressive strength and the energy aborbed up to densification are significantly higher than those observed on the foams only [3]. Indeed, for the same foam density, compressive strength around 1.2 MPa and energy absorbed up to densification of 2 MJ/m^3 were observed on the foams. The compressive stress and high energy absorbed by the sandwich under compression comes from the combined effect of the foam and reinforcement provided by the pins.

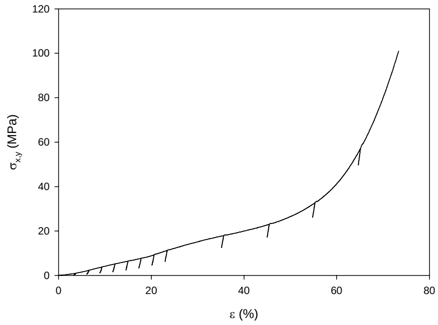

Fig. 4. Compression curve of a steel foam sandwich (before cementation).

Compressive properties of foam sandwiches highly depend on the density of the material, as described by Gibson and Ashby's scaling laws [4]. The properties also depend highly on the composition of the foams. Accordingly, the properties of the sandwich panels can be tailored by adjusting the density (or porosity) and composition of the core of the sandwich.

3. Summary

Steel foam sandwiches can be produced using a powder metallurgy approach. The density of the foam core is low (i.e. 14 times lower than dense steel). A major contribution to the weigth of the sandwich panels of the foams presented in this study comes from the face sheets. Thus, the density of the sandwiches can be further reduced by increasing the spacing between the plates or using thinner sheets. The sandwiches can be coated to improve their properties. The process could be used to produce sandwiches with different cores (titanium, ceramic) and coatings (stainless steel, titanium, ceramic) to obtain sanswiches with improved properties or to produce functional components (absorption of energy combined with thermal insulation, for example).

4. Reference

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