Composite Structures 118 (2014) 170–177

Contents lists available at ScienceDirect

Composite Structures

journal homepage: www.elsevier.com/locate/compstruct

Numerical and experimental investigations on the acoustic power radiated by Aluminium Foam Sandwich panels

Giuseppe Petrone *, Vincenzo D'Alessandro, Francesco Franco, Sergio De Rosa

PASTA-Lab: Laboratory for Promoting experiences in Aeronautical Structures and Acoustics, Department of Industrial Engineering – Aerospace Division, Universitá degli Studi di Napoli "Federico II", Via Claudio 21, 80125 Napoli, Italy

ARTICLE INFO

Article history:
Available online 28 July 2014

Keywords:
Aluminium foam
Sandwich panels
Radiated acoustic power
Sound intensity technique

ABSTRACT

Aluminium Foam Sandwich (AFS) panels are a new class of flat structures, constituted by two aluminium layers with a core made by foamed aluminium. Their excellent combination of properties, arising from the metallic nature of the matrix and from the porosity behaviour of the foam core, guarantees high specific stiffness, thermal and acoustical isolation, as well as vibration damping. For these reasons, they are becoming more and more attractive in transportation engineering applications.

In this work, numerical and experimental investigations on the acoustic power, radiated by Aluminium Foam Sandwich panels, are carried out. Two different Alulight® specimens, made of the same material but with different thickness and percentage of foam density, are investigated. A Finite Element model is used to estimate the distribution of velocity over the panel surface and, then, the radiated acoustic power is calculated through the discrete formulation of the Rayleigh integral for flat radiators. The numerical model is validated by means of experimental tests, performed by using a sound intensity technique.

1. Introduction

The demand for bigger, faster and lighter vehicles, such as cars, trains and aircraft has increased the importance of efficient structural arrangements. Among the several new and enhanced configurations, the sandwich structures offer a wide range of attractive solutions. Sandwich configurations are used in several engineering applications where a high bending stiffness to weight ratio is required.

A sandwich structure is a layered media, obtained generally by bonding (or welding) two thin but strong and stiff face sheets to a relatively thick and low-density core [1,2]. Furthermore, this pattern can lead to improved fire resistance, noise control, heating and cooling performance. However, the same high stiffness-to-mass ratio allows not only the mechanical efficiency, but also determines an efficient transmission and radiation of acoustic noise, posing a serious problem for some applications where comfort is required.

The face sheets of a sandwich panel are chosen in order to withstand the in-plane tensile, compressive and shear stresses. Both conventional (aluminium, steel) and composite materials can be used for these layers. On the other hand, the core has several different functions: first of all, it must be stiff enough in compression along the out-of-plane direction to keep constant the distance between the face sheets; furthermore, it must be stiff enough in shear to ensure that, when the panel is bent, the face sheets do not slide, merely working as two independent plates. In the last case, the adhesive plays a fundamental role too.

The core of a sandwich structure can be made with different materials and architectures, such as honeycombs, foams, cellular metals, etc. [2]. The type of core has to be carefully selected depending on the specific application requirements. In fact, among the load bearing capabilities, the selection of the core should take into account the enhancement of the performance in terms of fire retardant, thermal conduction and sound transmission/absorption. Porous foams can be used as cores for sandwich structures when all these functional requirements must be satisfied. The nature frequently uses cellular materials for load-bearing and functional purposes, such as wood and bones [3]. The polymeric foams are currently the most used in engineering applications, but they do not guarantee a good level of passive safety because of their poor impact energy absorption capability. Even metals and alloy can be foamed, by letting the liquid solidify but, at the same time, preserving the morphology of the foam. The metallic nature of the matrix and the porosity behaviour provide an excellent combination of properties, which strongly depend on the morphology of the pores, such as: average size, shape and spatial distribution of

* Corresponding author.
E-mail address: giuseppe.petrone@unina.it (G. Petrone).

http://dx.doi.org/10.1016/j.compstruct.2014.07.031
0263-8223/

the pores; thickness, intersections and defects of the cell-walls; density of the gas bubbles [4,5]. However, the use of open cell foams is limited to functional applications for their poor mechanical properties, whereas the closed cell ones can be designed to have both structural and functional properties [4]. In Fig. 1, the applications of the metal foam are grouped, according to the type of porosity [6].

Metal foams are actually used as bare component to manufacture energy absorber and silencers. Their characteristics make them attractive also to be used as core for sandwich structures, especially for the case of aluminium foam (Aluminium Foam Sandwich or AFS panel). At this moment, there are not large-scale industrial applications for this kind of sandwich panels, but many prototypes and studies showed their great potential in the automotive [7], aerospace [8], railway [9,10] and marine [11] fields.

The potential of metal foams, especially made of aluminium alloy, has driven the research in the last few years, leading to an extension of the knowledge and the related literature. The well known works made by Gibson and Ashby [3,4] and Degischer and Kriszt [5], has been completed with a substantial effort by Banhart and others [6,7,13,12,14–18].

Just few researches have investigated the acoustics of closed-cell metal foam, despite its special structure has a great potential in the fields such as sound insulation and noise reduction. The first available works report some experimental analyses regarding the influence of several parameters (morphology of pores, temperature, density) on the sound absorption capability of closed cell aluminium foams [19–21]. The main results, obtained through measurements made with an impedance tube, highlight that: (i) the absorption behaviour strongly depends on the flow resistance, but it has an uncertain relation with its porosity [19]; this is also confirmed by Wang and Lu [22], who numerically investigate the effect of cell size on the absorption coefficient; (ii) the sound absorption capability can be enhanced by open (partially or completely) the closed cells of the foam through mechanical processing, resulting also in a reduction of the mechanical properties [20].

While a wide literature on the acoustic behaviour of sandwich panels with traditional configurations is available [23], the work made by Yu et al. [24] is the first (and according to the authors' knowledge the only) one reporting some measurements of the transmission loss of several closed-cell Aluminium Foam Sandwich panels. All the specimens have aluminium face sheets 1 mm thick, whereas the cores have different thickness and density. The results display that the transmission loss increases as thickness and density increase, but the increasing trend becomes mitigated when the thickness and density are added equivalently.

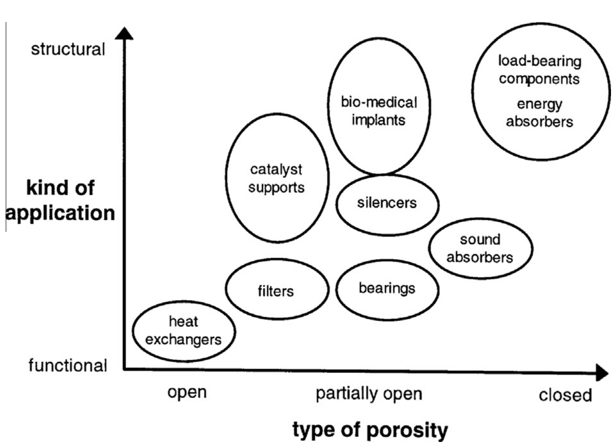

Fig. 1. Applications of cellular metals [6].

Furthermore, metal foams present a strongly randomised distribution both of mass and stiffness, since the manufacturing process is not fully controlled yet.

Previous works of the authors [25,26] demonstrate that a sandwich panel with a randomised core can lead to an improvement of the vibro-acoustic behaviour of a sandwich panel subjected to a distributed pressure load.

This work is thus the straightforward continuation of a previous one [27], in which modal characteristics and dynamic behaviour of AFS panels were investigated both numerically and experimentally. In the present work, the radiated acoustic power intensity of the same Aluminium Foam Sandwich panels is experimentally and numerically investigated. The test specimens are described in Section 2. An overview of the theoretical basis is provided in Section 3, where the acoustic power radiated by an elastic surface is defined first in continuous coordinates and, then, in discrete ones. Hence, the numerical model is described. In Section 4, the experimental set-up is shown, whereas the achieved results are summarised in Section 5. Some remarks, given in Section 6, close the work.

2. Test specimens

Aluminium Foam Sandwich (AFS) panels, depicted in Fig. 2, consist in a three-layer composite comprising a foamable (containing TiH_2 as a blowing agent) aluminium alloy sheet as a core layer and two face sheets still in aluminium alloy on both sides. The AFS panels under investigation are designed, manufactured and sold by the Austrian company Mepura Metallpulver GmbH with the commercial name Alulight®. The manufacturing process uses the decomposition of foaming agents into semisolids [5,6].

Two different AFS panels, having the same in-plane dimensions (0.476 m by 0.656 m) and average cell size of the foam bubbles (2 mm), are investigated. The density and the thickness of the foams of the two panels are different, as well as the thickness of the face sheets.

The characteristics of the panels are summarised in Table 1, where the subscript "s" and "f" are used to indicate the skins and the foam, respectively.

The face sheets are made of aluminium alloy EN AW 6082, which is a high strength alloy, according to the formula $AlSi_1$ MgMn. The mechanical properties are summarised in Table 2. The mechanical properties of metal foam were estimated in a previous authors' work [27], by means of a sensitivity analysis. In fact, no detailed information about the Young's modulus and damping coefficient of aluminium foam $AlMg_3Si_6$ are available. These properties strongly depend on the material which is foamed and on the percentage of porosity. In particular, the relative density ρ_r, defined as the ratio of the foam density ρ_f over the metal density ρ_s, plays a fundamental role: the higher is the relative density, the higher are the mechanical properties [3].

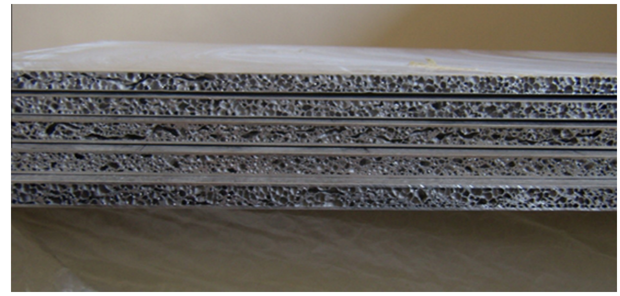

Fig. 2. Aluminium Foam Sandwich panels.