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MECHANICALLY EXPANDED PRODUCTS USED AS CORES IN SANDWICH PANELS

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Abstract: *Many types of periodic cellular structures have been proposed to be used as cores in sandwich assemblies due to the performance obtained by applying the sandwich concept in structural engineering applications. The aim of the perpetuated research in this field is to increase the structural properties while lowering the weight, to reduce the production costs by simplifying the fabrication methods and also to develop such core topologies that allow integrating multiple functions in a sandwich assembly. A novel cellular structure has been proposed to be used as a core in sandwich structures, trying to respond to such requirements and needs. The principle of the fabrication method and its potential are presented and discussed.*

Key words: *sandwich panel, cellular core, expanded structure.*

1. Introduction

The idea of using the sandwich concept in mechanical engineering applications has been born from the human kind desire to create materials with special mechanical properties, for example to obtain materials characterized by high bending stiffness and strength to weight ratios. This need has been driven mainly by the aeronautical industry in the early 40, and the first industrial application was the construction of the Mosquito airplane fuselage, during the Second World War.

A sandwich structure usually consists of three principal components: two thin, stiff and strong face materials, separated by a thicker and lightweight cellular structure [12], Figure 1. However, more components may be added, in terms of the application.

These elements are forced to act as a unit by a joint layer which may be a result of different joint methods, in terms of the type of the materials' components; the most known examples are: adhesive bonding, bonding based on brazing methods, point welding, laser welding, resistance welding, ultrasonic welding etc. The joint layer must be able to transfer axial and transversal loads from and to the cellular structure, making this assembly to act as a continuum structure.

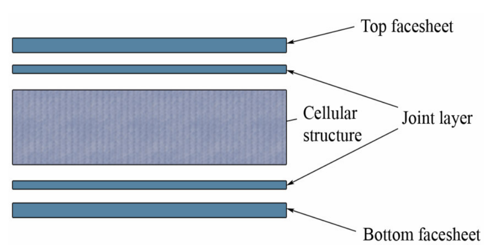

Fig. 1. *The components of a sandwich assembly*

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The cellular structure must be enough rigid in order to keep constant the distance between the lateral face sheets. From the structural point of view, the main function of the cellular structure is to stabilize the lateral face sheets in order to avoid buckling and wrinkling and to carry shear forces over its thickness.

The lateral face sheets support tension and compression stresses. Their main role is to give flexural and shear rigidity and to support lateral and bending loads. In addition, the lateral face sheets support also the localised loads.

One important thing that has to be observed is that, by assuming a perfect joint, the cellular structure must fulfil the most important requirements in a sandwich assembly. In addition to the main required mechanical properties (low density, high in-plane shear strengths and high out-of-plane compressive strengths), a cellular structure most often has to contribute to other properties of the sandwich assembly such as thermal and acoustic insulation, impact energy absorption etc.

2. The Sandwich Effect and Currently Used Cellular Cores in Sandwich Assemblies

The word "core" is often used to describe a cellular structure in sandwich theory, due to its middle position between the exterior sheet faces.

Nowadays, the sandwich concept plays an important role in the development of efficient engineering systems, due to the special characteristics and advantages that it may offer. Among these, the most important are: high bending stiffness and bending strength to weight ratios, high shock and vibration absorption rates, good acoustic and thermal insulation properties etc. Each of these properties are prone to improvements in terms of the application, in terms of the type of the used cellular structure, the manufacturing methods and the properties of each separate material which is part of the assembly.

An exemplification of the sandwich concept effect, considering the bending stiffness and strength only, is given in Figure 2. While the weight of the sandwich assembly remains almost unchanged with respect to the thickness increase of the cellular structure (due to its low density), the flexural rigidity and the bending strength is considerably increased.

The research conducted along the years in order to obtain cellular topologies that satisfy the imposed requirements by their functional role in sandwich assemblies, allow us to separate them in two categories, in terms of the cells geometry: stochastic and periodic cellular structures.

Stochastic cellular structures may have relatively low production costs but they are characterized by low mechanical perform-

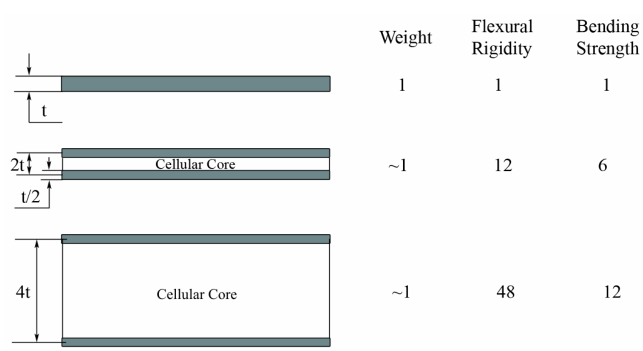


Fig. 2. *Comparison between homogeneous and sandwich cross-sections* [12]

ances. A stochastic material with high mechanical performances will also imply high production costs [9].

On the other hand, many types of periodic cellular cores have been proposed, among which the most known being the honeycombs [2], [10]. Other periodic cellular architectures are lattice truss structures [5], [7], [11], corrugated structures [8], egg-box materials [3]. These kind of cellular structures are characterized by superior mechanical properties but still with a relatively high production cost, mainly due to the manufacturing process.

Currently, there is an interest in developing new core topologies that allows for reducing the production costs by simple and flexible manufacturing processes and by the quantity of the base material used, in the same time with keeping high mechanical performances and allowing implementing multiple functions. It has been proved [10] that the periodic cellular structures are favorable to be used in multifunctional applications of sandwich structures (the sandwich structure has to carry different type of loads in the same time: mechanical, thermal or acoustic).

3. Mechanically Expanded Products

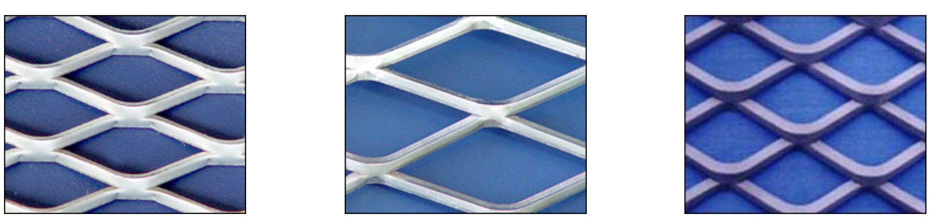
Although the first methods for expanding metal sheets by mechanical means have been proposed before the first use of a sandwich panel [4], [6], the expanded products have never been considered to be used as core materials in sandwich structures.

Nowadays, many companies produce expanded metals in different patterns and from different metallic materials, Figure 3. The resulted products are used in a variety of applications as protective materials, decorative materials, in lithium battery applications, in filtration applications or anti-slide protection for stairs. Such an expanded structure is characterized by a low bending stiffness and it cannot be used alone in load carrying applications. In addition, following the current manufacturing process of such expanded products, the mesh profile of the expanded metal sheet is obtained by copying the profile of a mobile cutter of the machine [1] and thus, although it is an automated production process, it still presents an inflexibility degree when required to change the aspect ratios of the structures, in terms of the customer needs.

However, its low relative density make it attractive for being used as a core in sandwich structures where the bending stiffness of the cellular structure itself is not mandatory but still, by reconsidering the manufacturing process and by adapting the cellular topology to the requirements that a cellular core must fulfill.

4. Proposed Method for Producing Mechanical Expanded Cellular Cores for Sandwich Structures

By considering the above presented requirements and needs, a novel cellular core have been proposed at *Transilvania* University of Braşov to be used as a core in



a) b) c)

Fig. 3. *Mechanically expanded products with different aspect ratios* [13]

sandwich structures. This cellular core is produced by the mechanical expansion of a continuous sheet material that previously suffered intercalated cuts and perforations in such a way that a pattern of opened cells is formed.

Such a pattern is given as an example in Figure 4, where *l* represents the length of the cell wall that one wants to obtain and *c* represents the distance between two transversal cuts. In the same figure it may be noticed the principle of the proposed method for the expansion of metal sheets which may be described shortly as it follows: a force *F* is applied on the ends numbered 7, Figure 4, in the plane of the metal sheet and oriented in a direction perpendicular to the transversal cuts and perforations already created; in the same time, the opposite ends numbered 6 will remain fixed in the direction of the applied force. Due to the stresses that appear in the sheet material and also due to the way the transversal cuts are positioned, the material starts do deform in space by torsion. The resulted geometry is represented in Figure 6.

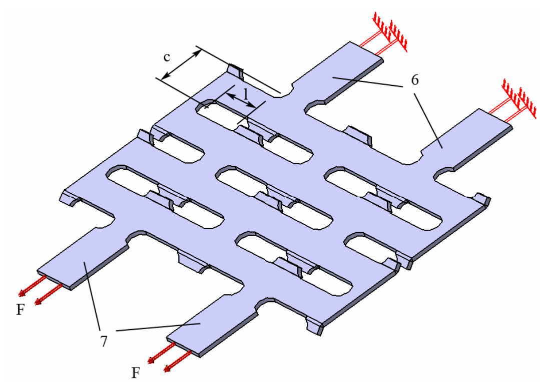


Fig. 4. *The perforated sheet material before the expansion process*

The expansion degree, which represents at the same time the inclination angle of the cells, is defined by the value of *G*, Figure 6, and it is calculated using Equation 1:

$$G = \tan^{-1}\left(\frac{l \sin A}{c}\right), \quad (1)$$

where: *A* is the internal angle of the cells, Figure 6.

Figure 5 represents a detail of the bended extremities 4 and 5, at an angle equal the value of the expansion degree *G*; those edges are bended before the expansion process and their role is to increase the contact area between the core and the face sheets. The contact area will vary in terms of the cell wall length *l* and the value of *b*, Figure 6.

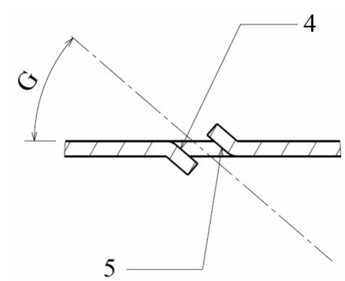


Fig. 5. *The contact surfaces of the core with the face sheets*

5. The Resulted Sandwich Panel

A sandwich assembly is obtained further by attaching two lateral face sheets, 1 and 2, to the above described cellular core, denoted as 3, Figure 7, by means of a joint

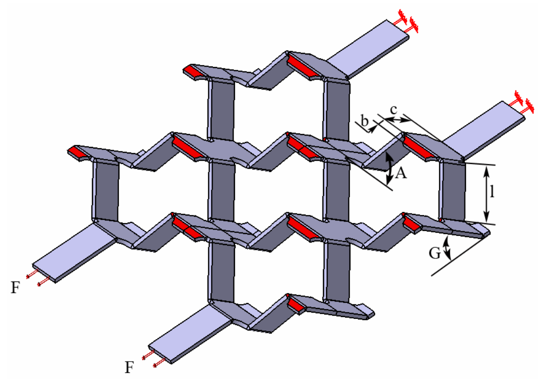


Fig. 6. *The resulted cellular core, after the expansion process*

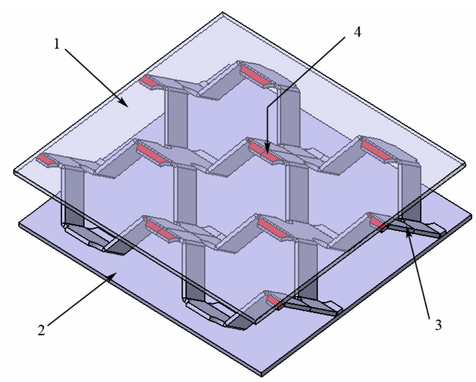


Fig. 7. *Model of the resulted sandwich structure*

method. The contact areas with the top face material have been numbered with 4.

Such a sandwich assembly benefits of the advantages of a very lightweight core with low relative density. Moreover, being a periodic open-cells structure, the intercellular space may be used for implementing additional functions like those discussed in the second paragraph.

Following the above described method, samples of the expanded cellular structure have been prepared using stainless steel type 304 metals sheets. Further on, the sandwich assembly has been created by using epoxy-based adhesive joints between the expanded core and the lateral face sheets, Figure 8.

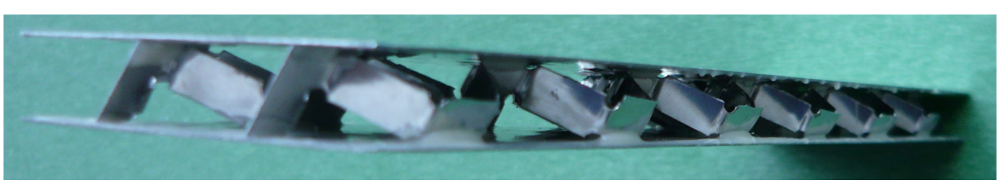


Fig. 8. *Sample of the resulted sandwich structure with the proposed cellular core made of stainless steel type 304 metal sheets*

6. Conclusions

Due to its relatively simple fabrication principle and the reduction of the consumed base material implied, this type of core may represent a cheaply and easily produced alternative to the already known cellular structures used in sandwich assemblies.

The topology of the expanded cellular core may be easily changed, in terms of the customer needs, by simply creating the transversal cuts and perforations at different values for l and c respectively, and by applying the desired expanding degree G. Different types of joint methods may be applied in terms of the type of the materials used. Further research should be carried on in order to find the optimal topology that adequately responds to given type of loads. The preliminary tests showed that the cellular structure presents a high in-plane stiffness comparing to other topologies, due to the inclination of the walls. This will contribute to the overall flexural stiffness of the sandwich panel.

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