THERMOFORMING TECHNOLOGY OF HYBRID SANDWICH STRUCTURES

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ABSTRACT: The most interesting and promising ways to obtain composite material consisting of polymeric resins and fiber-glass structures are hybrid sandwich structures. The faces of the sandwich structure can be metallic materials (such as aluminum alloys or stainless-steel) and non-metallic materials (polymeric laminates with glass-fiber or carbon-fiber). For special applications in the field of aircrafts or shipbuilding, where the main priority is the strength/weight ratio, honeycomb core sandwich materials are used. In these materials, the core can be made of paper that`s pre-impregnated with resin and especially of aluminum alloys or polymers reinforced with glass-fibers.

KEY WORDS: composite, hybrid, structures, fibre, automobiles

1. Introduction

Hybrid Sandwich Structures

Sandwich materials with fiberglass-reinforced thermosetting polymers are widely used for applications where the main requirement is bending. An ideal sandwich material has thin, rigid, high-strength faces, a low-density core, and a low cost price [1].

The following Table 1 [1] shows the mechanical properties of the faces of sandwich-type materials made of glass-fiber-reinforced polymers, compared to metal materials.

Hybrid structures are such that the dynamic design of lightweight structures allows the use of the most advantegeous properties of materials of different degrees of origin and their incorporation into a single structure. A typical and ideal combination of desired material properties of hybrid structures is the low weight merging with good mechanical properties. The number of beneficial combinations is very large, since the constituent materials of a hybrid structure may have substantially different properties than those of the material itself [2].

The manufacturing step of a structure is usually challenging. Especially in laminated hybrid structures, where macroscopic mechanical interlocking between layers is impossible, the level of adhesion between the constituent materials may be insufficient.

Table 1. – Mechanical properties regarding Hybrid Structure Faces compared to metals [1]

Material	Resistance (Mpa)	Modulus of elasticity (Gpa)	The weight of the structure with the surface of $1m^2$ and thickness of 1mm,kg
Fiber-glass composite and:			
Polyester resin	769	56	1,92
Epoxy resin	1009	56	1,83
Phenolic resin	769	56	1,81
Aluminum:			
2024 – T3	800	160	2,69
5052 – H34	416	160	2,69
6061 – T6	560	160	2,69
7075 – T6	1169	160	2,69
Stainless-steel:			
316	961	480	7,68
17-7	3200	480	7,68

2. Current stage

Non-metallic and metallic honeycombs introduced in the unconventional technologies in the late 1960s revolutionized the performance of composite materials. The represent hybrid cellular structures, similar to natural honeycombs in Figure 1 [1], having the following characteristics:

- Extremely low specific gravity (sub 100 kg/m^3);
- Good flexural strength and stabilized compression;
- Excellent properties in the fields of thermal and sound insulation;

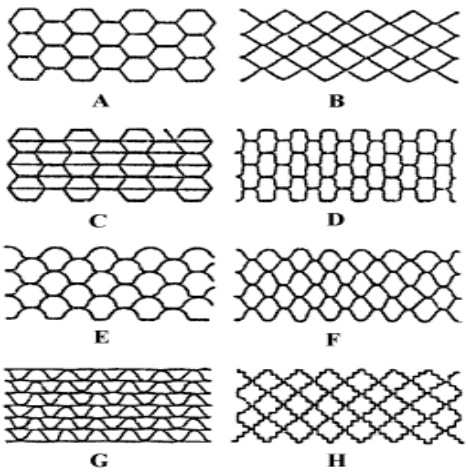

Figure 1 – Hybrid structures for metallic honeycombs [1]
A–hexagonal; B–rhombic; C–reinforced hexagonal; D-rectangular; E–flexible; F–sinusoidal shape; G – multistrat; H-rhombic wavy;

Metal honeycombs are made of aluminum foil with a thickness of 10-80 μ, while for non-metallic variants special fireproof paper is used. Metal / non-metal honeycombs with different dimensions of the base cell are obtained depending on the specific weight and strength of the required parts (4,7 ; 6,3 ; 9,5 ; 12,7 mm etc.), depending on the specific weight and strength of the required part [3].

After removing the ornagic solvents by passing through a tunnel kiln with a maximum temperature of 130°C, the foil is cut with a guillotine-type device, according to the dimensions of the thermoforming die, reaching stage B. The resulting sheets are placed in the thermoforming die in such a way so that the adhesive tapes of one are evenly spaced.

After superimposing 100-300 sheets, it reaches stage C. The package is placed in a press with hot platters, at a temperature of $170 - 210^0$C and a pressure of $150 - 300\ daN/mm^2$. This leads to the unexpanded block stage. The resulting block is then cut longitudinally using special cutters, without the use of cooling/lubricating fluids, at low machine speeds (in order to avoid the appearance of micro-welds between the component aluminum foils).

- The great advantage of this technology is that the combs can be transported in the form of compact blocks, thus achieving large space saving and also avoiding cell damage, pre-expansion and expansion operations can be performed directly by beneficiary clients [3];
- The technology of obtaining honeycombs from paper or cardboard is similar, the place of degreasing/pickling operations being taken by the impregnation of the material with flame retardant resins [3];
- Note that the thermoforming operation is conducted at lower temperatures (max. 140^0C), to avoid degradation of cellulosic material [1];

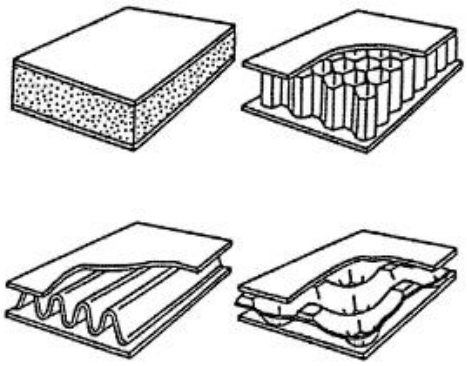

Figure 2 – Hybrid sandwich structures with non-metal faces [1]

Hybrid structures with fiber-glass and carbon/polymer foil

Widely used for automobiles, these types of structures are commonly used with fiber-glass combined with carbon and aramid fibers, but all are non-degradable and difficult to recycle; It has been found that natural plant fibers are viable alternatives to synthetic fibers to increase the economy, recycled thermoplastic resisns are usually used, especially in the manufacture of body-secondary elements or other components that are not fundamental in ensuring the functionality of the vehicle. For example, Mercedes-Benz has in the past initiated the use of jute fiber reinforced plastics for the interior cladding of class E doors [4].These will be the main aspects of the composite structures for future research.

Below is shown in Image 4 and Image 5 a model used by Alseca [5 - https://alseca.com/] where one of the polymer plates of the structure type carbon fiber and glass for automobiles is used.

Advantages:

- The ability to print even very thin thicknesses, which injection molding technology does not allow (due to technical limitations);

- Being able to build a mold with many cavities depending on the size of the machine table, production times can be significantly reduced compared to injection molding;

Disadvantages:

- Low production speed for plate machines, high speed for digital web machines;
- The inconsistent and uneven spread of the plastic on the sinuosity of the mold;

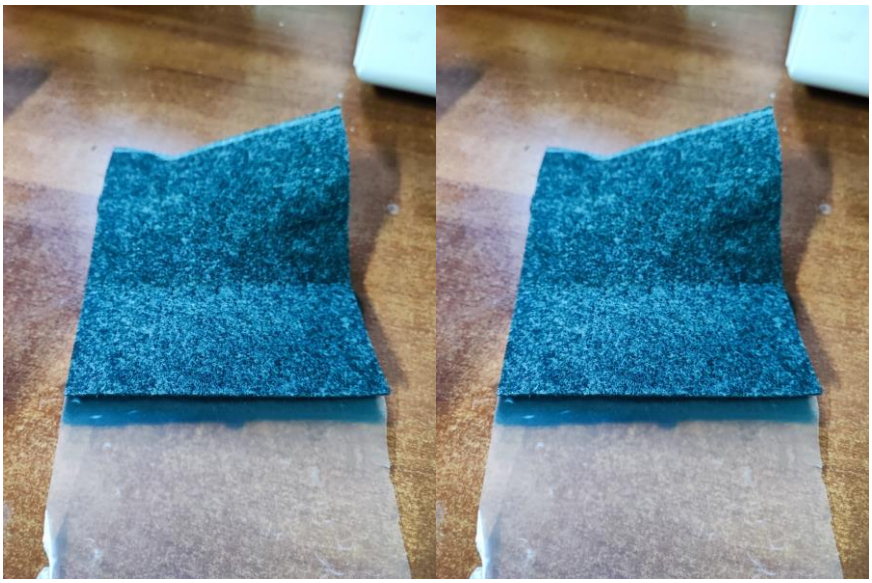

Figure 3 and Figure 4 – Hybrid structures used in structural applications

For this component to serve it`s purpose, a layer of polymer foil is used that will be between two films of the same structure. The polymer film will aim to bond the layers togheter using the thermoforming process. The foil is pushed onto the mold due to the high pressure exerted by the outside air, which also facilitates cooling.

After bonding, a thicker layer of fiber is formed which is then used for placement on the car components (bars, doors, etc.). This layer of fiber structure also benefits from the ability to absorb sound and vibration.

3. Marketing Strategy

In other words, the production process and the forming behavior of the local reinforced steel/polymer/steel area (316L/PP/316L), also known as Sandwich Hybrid Composite Materials (SMS) was investigated in detail because the traditional structures had disadvantages related to by their modulus, and slightly deformed when applied in civil engineering. The effect of simple reinforcements with plates of different sizes, shapes and geometries was studied for new development, where as local reinforcement, simple inlays made of simple solid steel and steel mesh with central edge positions were chosen instead of a polymer core laminated sandwich. Given the increased strength by moving the tested surfaces, this "wafer" method was favored thanks to it`s efficiency and low cost [6].

4. Conclusion

The increasing use of laminated composites and sandwich structures in various fields of engineering has required the development of various refined theories that predict the precise dynamic behavior of such structures. The main purpose of this research is to present various methods available for the analysis of "Rolled metal fiber composites and sandwich panels' and to guide researchers for future research. Many theories have been reported in the literature for vibration analysis [7].

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