AFFORDABLE, LIGHTWEIGHT LOAD FLOORS USING 100% POLYPROPYLENE MATERIALS

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Abstract

The marine, aircraft and heavy truck transport industries have long used structural and semi-structural sandwich panels for their excellent performance/weight ratio. More recently, the automotive industry has also discovered the advantages of lightweight sandwich constructions, mainly for interior applications such as load floors and rear parcel shelves. However, for high-volume applications there are the additional demands of low cost and, for European markets in particular, full recyclability.

A new sandwich construction based on a 100% PP solution could be the answer. A combination of an extruded PP hollow structure covered in-line with a self-reinforced PP skin offers light weight, good mechanical performance, resistance to moisture and chemicals, good thermoformability, full recyclability using existing channels and a good cost/performance ratio.

Introduction

New legislation on materials recycling has caused a rethink in materials for vehicle interior and exterior parts whilst, at the same time, weight reduction is key to improving performance and engine efficiency. The use of the new generation of thermoplastic composite materials offers a cost-effective alternative for low- and high-volume car producers alike.

Several raw material suppliers now offer polypropylene composites with properties exceeding those of traditional materials. Production can be geared to high volume with fast cycling presses and low-cost tooling can be used as an alternative to GRP in a process of vacuum consolidation.

Polypropylene composites are perhaps the most developed thermoplastic materials for automotive use. The base material offers many benefits from its polyolefin matrix. The energy content in production means that it is increasingly competitive against traditional materials, it has a high impact strength and chemical resistance together with a low density. An added advantage in production is a wide 'processing window'.

Polypropylene composites are offered in self-reinforced and continuous unidirectional and random glass-reinforced forms. The glass-reinforced materials allow material stability similar to steel and thermoset materials. This offers real alternatives to steel and thermosets for exterior body panels. The self-reinforced polypropylenes, which comprise highly drawn polypropylene fibres or tapes held together by polypropylene matrix, can be processed using low moulding pressures with the resultant low-cost tooling.

Many initial developments in these materials have been for vehicle interiors, with applications ranging from engine covers to roof headliners. The low-pressure processing also allows 'in-mould' finishing with fabrics, foils or carpet, and sandwich structures can be created with honeycomb materials, all of which can be based on the single polymer for recycling.

Load Floors

Load floors, sometimes also known as spare tire covers, can present quite a challenge for the automotive designer. Different manufacturers have different requirements – indeed different models within a particular range can have widely differing needs. In the simplest case, the load floor is simply a cosmetic trim, supported from below by the bodywork and the spare tire. In the worst case, the load floor may be required to support loads of several hundred pounds, at high temperatures, whilst being supported only on two edges. As a consequence, over the years, many materials have been used running from steel to stiffened carpet.

As already indicated, the search for lightweight cost-effective solutions has led to the increasing use of polypropylene-based materials. Perhaps one of the first was the Ford Taurus Wagon, which replaced a steel part with Azdel in 1986. The use of glass-reinforced polypropylene gave a lighter weight, corrosion-resistant part with adequate stiffness at an acceptable cost.

However, when looking for a good stiffness-to-weight ratio, sandwich structures provide the highest performance especially when using skins with a high modulus and a light core with a good shear resistance. For a long time, economic constraints limited such structures to aeronautical applications but the introduction of lower cost core materials, such as thermoplastic foams and honeycombs, opened the opportunity for the automotive designer. One of the first examples was the load floor of the Nissan Primera Break (Wagon) for which Peguform produces a complete load floor comprising polypropylene honeycomb panel, Twintex (continuous co-mingled glass/PP) skins and full carpeting in a single moulding process. This solution has since been used in a number of other vehicles but it has to be said that polypropylene honeycomb is not a particularly cheap material and to some extent there has been a compromise between performance, cost and recyclability.

More recently, there have been moves by a number of OEMs to eliminate glass fibres from vehicle interior parts, which puts an even greater strain on Tier suppliers in their attempts to meet performance/weight/cost targets. One material, which offers the potential of meeting many of the performance targets without the use of glass fibre reinforcement, is self-reinforced polypropylene. Much has been written about these 100%-polypropylene composites but essentially they comprise highly drawn PP tapes held together in a matrix of the same material. Benefits include light weight and simple recyclability, but they fall a little behind glass products in terms of overall stiffness, hence the need to look at sandwich structures.

In keeping with the need for an all polypropylene solution, to aid weight restrictions and recyclability issues, two types of core have been investigated in recent times – expanded polypropylene (EPP) foam and polypropylene honeycomb. Foam has the advantage of having ultra light weight and it is possible to bond a PP skin to the core without the use of additional adhesive layers. However, the mechanical performance of an EPP cored panel is not so good, especially at elevated temperatures. Polypropylene honeycomb, on the other hand, is capable of giving reasonable mechanical performance. However, it is not so easy to achieve good bonding between skin and core because of the small contact surface area afforded by the honeycomb cells. Furthermore, polypropylene honeycomb has so far failed to become the low-cost material it was once predicted to be.

A new approach to an all-PP sandwich construction has recently been developed in Europe through the combination of a low-cost twin-wall polypropylene extrusion, more commonly associated with the packaging industry, with additional outer skins of self-reinforced polypropylene. Figure 1 shows the basic structure.

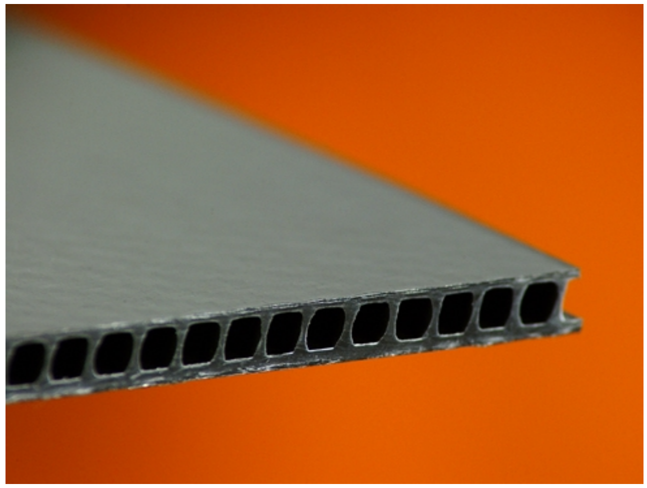
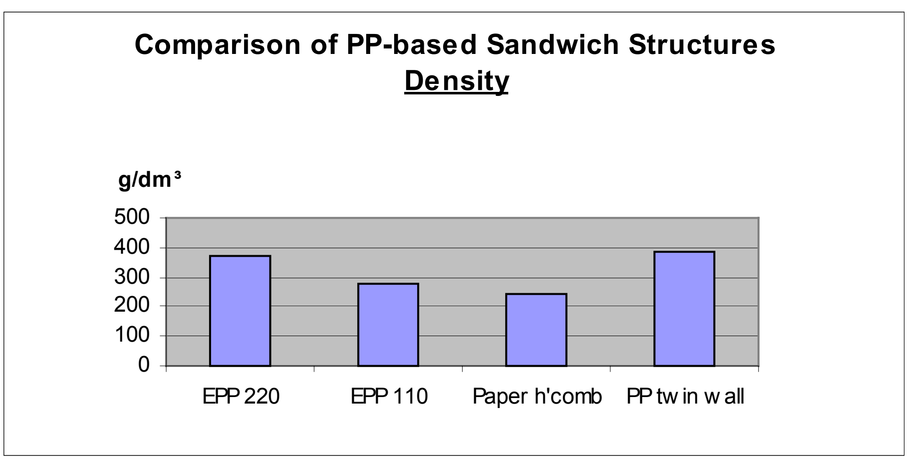
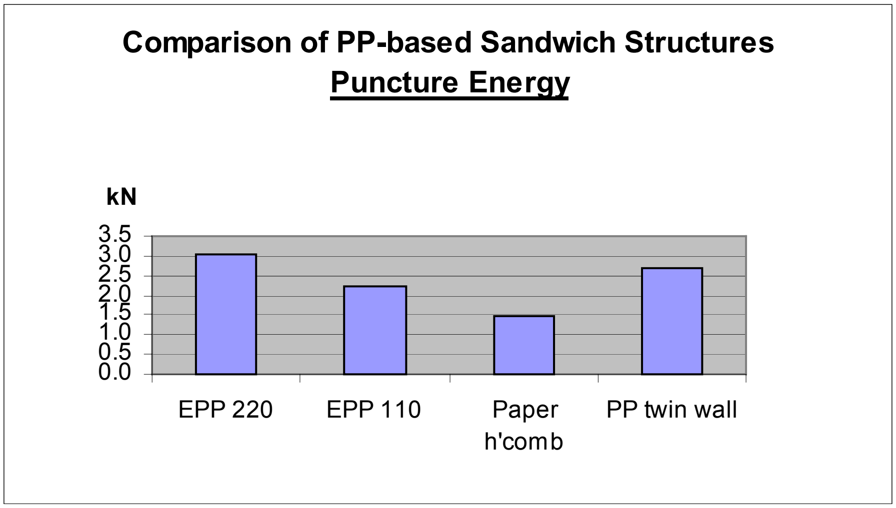


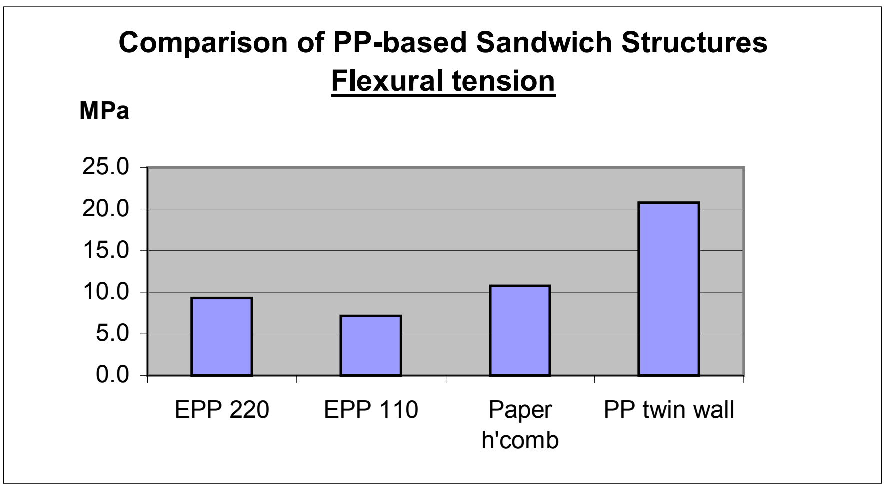
Figure 1: Twin-wall PP extrusion with self-reinforced PP outer skins

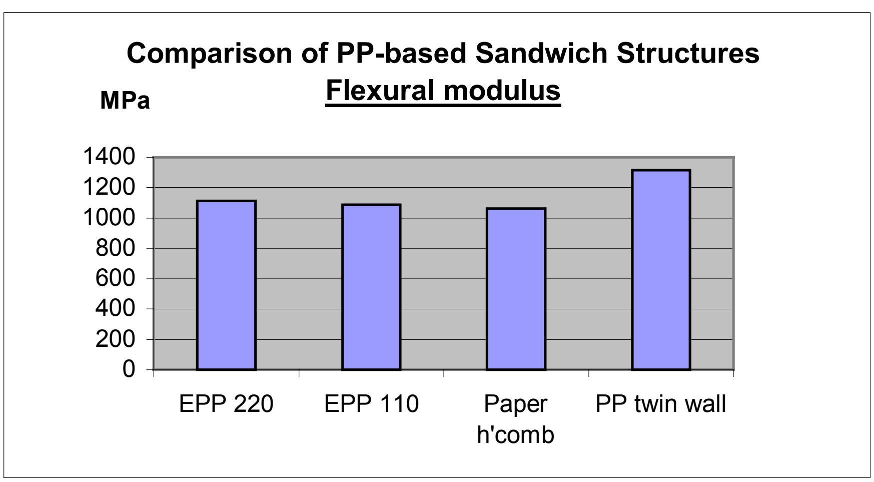
Mechanical Testing Data

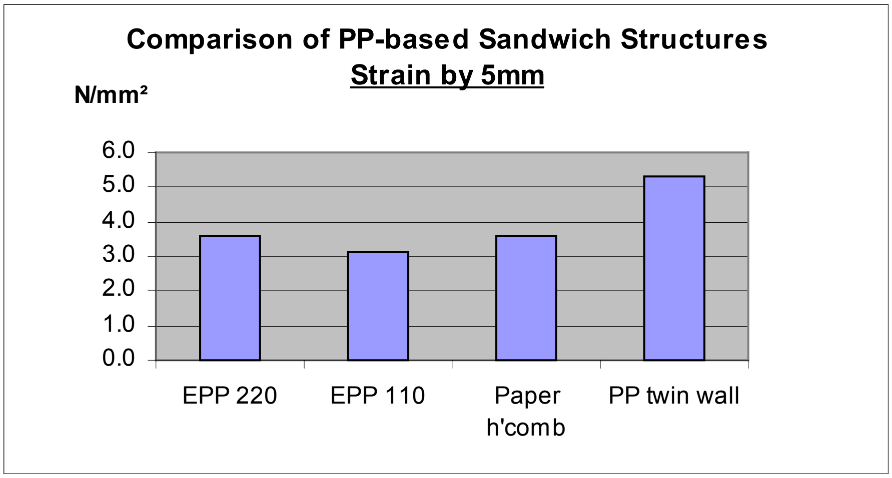
The fact that the panel is somewhat unbalanced, with reinforcement ribs running in one direction only, similar to corrugated card, is not a real issue; the only key requirement is stiffness and resistance to deflection under load and this is a function of how the panel is supported. A whole series of mechanical tests have been carried out to make comparisons with the alternative EPP and honeycomb solutions. The results are shown below. The materials used for comparison are EPP foam with a density of 220 kg/m^3 (EPP 220), EPP foam with a density of 110 kg/m^3 (EPP 110), paper honeycomb and PP-twin wall sheet. In all cases, the panel was a nominal 6 mm overall thickness with skins of 0.3 mm. For ease of comparison, and where appropriate, an average value of machine direction and cross machine direction is shown.

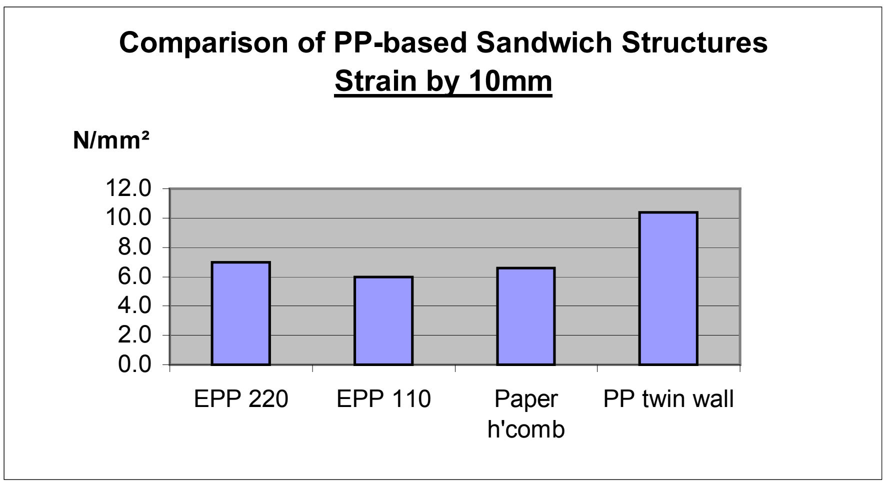



Comparison of PP-based Sandwich Structures
Puncture Energy
kN
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
EPP 220
EPP 110
Paper h'comb
PP twin wall


Comparison of PP-based Sandwich Structures
Flexural tension
MPa
25.0
20.0
15.0
10.0
5.0
0.0
EPP 220
EPP 110
Paper h'comb
PP twin wall


Comparison of PP-based Sandwich Structures
Flexural modulus
MPa
1400
1200
1000
800
600
400
200
0
EPP 220
EPP 110
Paper h'comb
PP twin wall





Deflection (strain) testing was carried out at room temperature (20ºC) using a point load centrally placed on a fully supported panel measuring some 900 x 900 mm. Elevated-temperature testing (80ºC) showed the EPP foam materials were incapable of sustaining any significant load. Results for the other two materials are yet to be released but are known to meet OEM requirements.

Summary

Self-reinforced / twin-sheet extruded polypropylene load floors are not the solution for heavy duty, high load demands such as those seen in commercial vehicles and certain SUV's. However, for light to medium duty applications, by far the greatest market segment in terms of volume, panels made in this way appear to meet the demands of OEMs in terms of performance, weight, recyclability, and above all, cost. The material is currently undergoing final testing by several major vehicle manufacturers with first commercial applications expected before the end of 2004. Further applications, now passing the feasibility stage and entering prototype testing, include sliding roofs, panels in tonneau covers and parcel shelves.

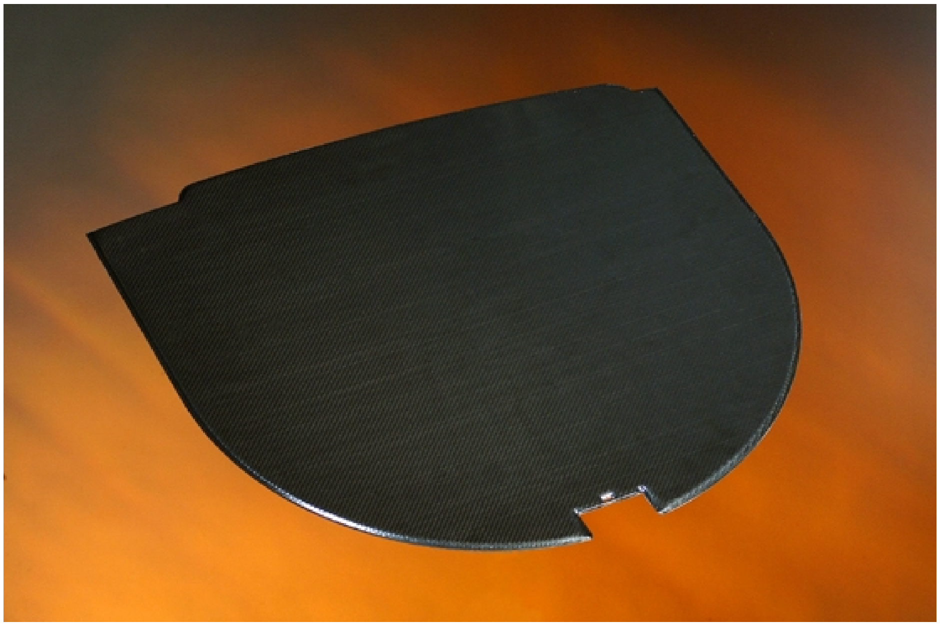


Figure 2: Prototype all-PP load floor

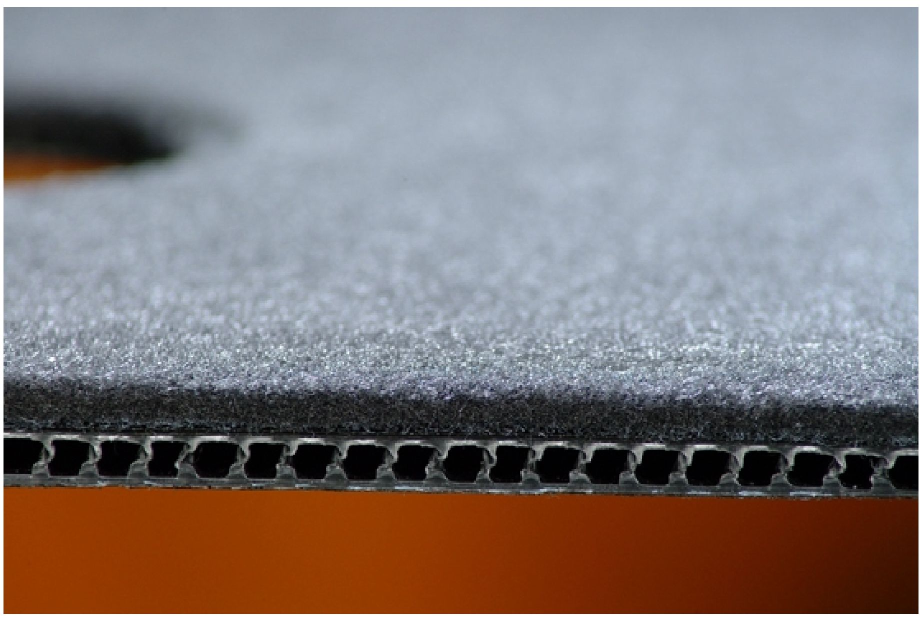


Figure 3: Prototype all-PP load floor with PP carpet