RECYCLING OF LANDFILL-BOUND AUTOMOTIVE HEADLINERS INTO USEFUL COMPOSITE PANELS

Jean-Jacques Katz
TrimaBond, LLC

Abstract

Automotive headliner scrap is comprised of post-industrial recyclates (production rejects, trim offal) (PIR) and post-consumer recyclates (PCR), i.e. headliners discarded from vehicles that have reached the end of their useful lives (End of Life Vehicles or ELVs). This waste stream exceeds 100 million pounds yearly in the United States and is currently 100% disposed in landfills. This paper describes an innovative process that converts headliner scrap into finished composite panels using VOC-free adhesives. The resulting product has unique physical properties and can be used as vertical decorative panels in the transportation industry, such as automobiles, recreational vehicles, refrigerated trucks and tractor trailers. The boards’ physical properties will be compared to targeted competitive products, i.e. Luan plywood or polypropylene/glass fiber composites. Luan, also known as Meranti or Philippine mahogany, is a wood material glued with urea-formaldehyde (UF) resins, that is imported from South East Asia. It is extensively used by the North American recreational vehicle industry for interior wall panels. Unlike the new composites described in this publication, Luan emits formaldehyde which is rated as a carcinogen by the U.S. EPA. Customers using Luan are now under pressure to drastically reduce VOC emissions, especially formaldehyde, under current CARB II regulations from the California Air Resources Board.

Background

The automotive parts recycling industry produces goods based on components recovered from end-of-life products, known as PCR - post-consumer recyclates - or manufacturing scrap, known as PIR - post-industrial recyclates. The overall process converts recovered components into “like-new” goods, thereby yielding important economic and environmental benefits. Remanufactured/recycled goods generally have the appearance, performance, and life expectancy of new goods; they meet the same performance standards as, and enjoy warranties similar or identical to, new goods. In short, they are identical to products manufactured from raw materials and/or new parts.

Automotive remanufacturing/recycling was roughly a $40 billion market in the U.S. in 2008 [1]. Total vehicle scarpage rate, i.e. ratio of vehicles reaching end-of-life (ELV) to number of registered vehicles, was 5.6 percent in 2008, and 6.1 percent in 2009 [2], based on 249 million
officially registered vehicles. As a result, nearly 14 million vehicles reach the end of their useful life and are discarded, yearly.

Automotive recyclers can now recover nearly 80 percent of the total materials by weight from vehicles [3] that today contain around 8-10 percent by weight of “plastics” (about 257-322 lbs/vehicle). However, the proportion of plastic materials being recycled is still extremely low. One key reason is the wide range of polymers used by the automotive industry: there are about 39 different types of basic plastics in a vehicle. About 75 percent of the plastic grades (by weight) encompasses 10 plastic types [4]. Although these polymers are technically recyclable, costs to separate and clean each individual polymer stream would be much higher, in the vast majority of cases, than purchasing and processing virgin polymers [5].

**Description and Discussion of Composite Production Process**

**Headliner Feedstock Characterization**

Among automotive interior trim parts, headliners, or more accurately headliner substrates, are very representative of the recycling challenges facing the industry. These thermo-formable, multi-layer, multi-material constructions (Figure 1) do not lend themselves to straight recycling processes; they would require complex, expensive, and uncompetitive disassembly and separation operations. This explains why today there are no commercial recycling processes able to convert PIR/PCR automotive headliners into parts or components for re-use in motor vehicles or other industrial applications.

![Figure 1: Typical Dry Polyurethane Automotive Headliner Substrate Construction](image)

These parts are ultimately disposed and discarded in landfills. Although PCR volumes are generally constant, as described above, PIR waste volumes fluctuate and are highly dependent on light vehicles production in North America. Figure 2 provides a breakdown of headliner scrap by category, i.e. PIR and PCR scrap, headliner production and total yearly scrap volume; from the reported data, it is estimated that in excess of 100 million pounds of automotive headliner scrap are land-filled every year [6].
Figure 2: Projected Headliner Substrate Material Volume

PCR Feedstock Analysis

All experimentation described in this paper relies on post-industrial scrap, because of ready availability from manufacturing plants. However, since the highest scrap volume originates from the disposal of end-of-life vehicles, a recycling infrastructure must be developed in order to access and manage this feedstock. As with most complex opportunities, identifying, collecting, sorting and shipping the feedstock is the key to efficiency and commercial success [7]. Other raw materials (steel and aluminum) have a long history of being recycled, despite material recovery and logistics challenges. As solid waste disposal costs and oil price continue to increase and global environmental issues become more prevalent, recycling efforts and investment to recover automotive trim scrap composite feed-stocks will be given higher priority.

Headliner Feedstock Processing

The composite material production process starts with shredding/granulating of PIR or PCR vehicles' headliner scrap: this scrap is converted in a shredder or granulator, into smaller particles referred to as fluff. Average fluff particle size ranges from 3/8 to ½ inch pieces based on current plastics recycling protocols. Shredded PIR fluff can be used as such and does not require further gravimetric or magnetic sorting; it has not yet been established, however, whether PCR fluff would require additional sorting. Liquid polyurethane adhesive is then metered into the fluff in an agitated vessel, with the resulting blend mechanically mixed at room temperature for 2-3 minutes. Binder levels, used as adhesive to produce flat panels or shaped articles, will vary depending upon finished part’s targeted physicals, fluff size and composition,
i.e., type and amount of polymers and fillers present in the fluff. The process is depicted in Figures 3 and 4.

**Figure 3: Shredding of PIR/PCR Streams to Fluff**

The binder mixture is then placed into a heated mold or a mold heated via hot press platens around 320°F and compressed under pressure in the 3000 to 4000 psi range. An appropriate, water-based mold release is applied to prevent sticking of the material to the metal surfaces; alternatively Kevlar sheets can be used on a development/pilot scale to provide self-release from metal surfaces, thereby removing any potential for panel surface modification or contamination. Chrome-plated steel tooling could be considered for production quantities, negating the need for Kevlar sheeting. Material residence times in the tool vary from 2 to 4 minutes. Curing takes place when the isocyanate prepolymer which comprises the adhesive composition reacts with moisture contained in the atmosphere or the fluff to form a cured adhesive [8] (see Figure 5).

**Figure 4: Binder Addition to Fluff**

**Figure 5. Fluff Molding Process**
Physical Properties of Molded Composite Panels

A summary of physical properties of the boards produced through the process described in Figure 5 is reported in Table 1. In addition to the headliner scrap composite board, the table includes data on typical 3-ply wood Luan composite panels (regular and low density grades), (Figure 6) and polypropylene/glass fiber composites under evaluation as a potential Luan replacement.

Figure 6. 3-Ply Wood Composite Board

Table I: Physical Properties of Headliner Composite Panels and Competitive Materials

<table>
<thead>
<tr>
<th>Volume Density</th>
<th>Panel Thickness</th>
<th>Static Bending Parallel</th>
<th>Static Bending Perpendicular</th>
<th>Internal Bond</th>
<th>Thickness Swell</th>
<th>Water Absorption</th>
<th>Tensile Strength (ASTM D-1037)</th>
<th>Thermal Conductivity (4) (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/m³</td>
<td>mm</td>
<td>MOE</td>
<td>MOR</td>
<td>MOE</td>
<td>MOR</td>
<td>IB</td>
<td>%</td>
<td>k</td>
</tr>
<tr>
<td>Headliner Waste Stream + 20% Binder</td>
<td>550</td>
<td>2.5</td>
<td>400</td>
<td>9.0</td>
<td>400</td>
<td>9.0</td>
<td>0.589</td>
<td>2.1</td>
</tr>
<tr>
<td>3-Ply Light Weight Luan (1)</td>
<td>480</td>
<td>2.9</td>
<td>9020</td>
<td>60.8</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>3-Ply Standard Luan (2)</td>
<td>510</td>
<td>2.74</td>
<td>7500</td>
<td>66.8</td>
<td>2700</td>
<td>36.3</td>
<td>1.173</td>
<td>5.5</td>
</tr>
<tr>
<td>SymaLITE Thermoplastic Composite (3)</td>
<td>410</td>
<td>2.60</td>
<td>1600</td>
<td>11.6</td>
<td>1000</td>
<td>7.9</td>
<td>2.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

NA= Not Available

1. PT. Kutai Timber Indonesia - Falcata core (1.7 mm) and Meranti faces (0.6 mm each)
2. Standard Luan plywood (Meranti faces/Luan core) has an average density of 500-650 kg/m³
3. Thermoplastic substrate comprised of polypropylene resin reinforced with continuous bidirectional long glass fiber mats available from TekModo, LLC
4. Average value for hardwood panels is 1.04. Other values are actual measurements
5. For comparison purposes, average k values for Styrofoam panels are 0.229 and 0.139 for rigid polyurethane foam
The headliner composite board, by design, has low stiffness and rigidity to enable installation as a RV decorative, non-structural interior panel. Its mechanical properties are therefore lower than those of corresponding standard and lightweight, structural Luan boards. However, its high degree of flexibility allows it to bend without breaking, unlike Luan boards, or even SymaLITE panels which crease easily. It is worth noting that Luan and SymaLITE boards exhibit directionality (different MOR and MOE values in machine and cross-machine directions), unlike the headliner composite board.

As seen from the physical test results outlined above, thermoset composites produced from recycled headliner scrap exhibit excellent thermal insulation properties, almost four times better than regular wood composites and almost twice as much as polypropylene/glass composites. They also come quite close to matching k values from well-known insulating materials, such as Styrofoam and rigid polyurethane foam.

Finally, the headliner composite has good thickness swell and water absorption values, an improvement over wood composite panels.

Applications of Composite Panels

Main targeted applications in the transportation industry include structural or non-structural parts such as bulk heads, roofs, floors or vertical walls used in tractor trailers, marine vessels, and recreational vehicles (RVs). In this paper, we will focus on non-structural, decorative applications of these new composite materials in RVs.

Because the bonding process does not use any formaldehyde-based adhesives and that the substrate itself does not naturally emit formaldehyde, headliner composites can be classified as formaldehyde-free or NAF (No Formaldehyde Added products demonstrate a 90% or better compliance with a 0.04 PPM ASTM E1333 limit), with a formaldehyde level E0 rating (no emission). When manufactured as flat panels, headliner composite boards can replace wood composite panels such as Luan or wood composite panels currently adhered with urea-formaldehyde (UF) resins. Since formaldehyde is classified as a carcinogen by the U.S. EPA (Environmental Protection Agency), there is now a growing demand by recreational vehicle manufacturers for panels with low, or no, formaldehyde emissions. The need for these panels is expected to substantially grow within the next few years, driven by State of California regulations (CARB II) severely restricting, and eventually, eliminating any formaldehyde emission.

The boards' low stiffness and ability to bend without breaking are especially useful in applications where RV wall design is curved, an area where current available materials are not suitable. Thermal insulation properties, as reported in Table I, should make the headliner composite board a material of choice in transportation applications where heat loss/insulation is a concern, such as in refrigerated trucks. Similarly, good performance related to water swell and absorption could qualify the material for exterior applications.

An additional advantage of the present composite is the ability to apply on either or both sides of the fluff and binder mixture placed in the compression mold, a decorative textile cover-stock or other polymeric film, sheet or scrim, without additional adhesive. This allows the production of a laminated trim panel with decorative textile cover-stock adhered either on one side or both sides of the trim panel. Processing conditions can be selected from the range
supplied for the formation of a panel, as described above. When the molded article is manufactured at room temperature, another benefit of the process is the possibility to laminate temperature-sensitive films, sheets or scrims to the molded article without detrimental effects on their integrity.

Lamination of decorative textile cover-stock, polymeric film, scrim, or insulating foam can also take place after the mixture of fluff and binder has been molded. In that case, lamination consists of dispensing adhesive onto one or both surfaces of the molded panel, placing the cover-stock or other materials onto one or both surfaces of the molded article, and locating this composite part in a press under pressure or vacuum.

Unlike thermoplastic sheets based on polypropylene resins and long chopped glass fibers or glass fiber mats, which require polymeric scrims, films or additional surface treatments, headliner composite panels exhibit excellent adhesion to glues and other materials required for lamination to other substrates, without additional costly and time-consuming processing steps. Whereas thermoplastic composite materials tend to delaminate under mechanical stress, headliner scrap composite panels do not require metal reinforcements to secure anchoring of screws for panel assembly. Figure 6 shows an example of a block of expanded polystyrene foam laminated between two panels.

![Composite Panel Lamination to EPS](image)

**Figure 6. Composite Panel Lamination to EPS**

**Conclusions**

Automotive headliner post-industrial scrap has been converted into composite boards by a thermal compression molding process using VOC-free, moisture-cure isocyanate adhesives. These formaldehyde-free panels exhibit excellent physical properties that make them a
competitive and viable domestic replacement for imported

Luan plywood boards in transportation applications, such as recreational vehicle interior trim panels. The relative simplicity of this innovative material recycling process and the product’s unique attributes make such composites a material of choice for the automotive industry. In particular, these composite boards - at higher densities and thicknesses - could be targeted at structural applications where wood composites are currently used, such as load floors or package trays.

Because automotive headliner waste is plentiful and available from land-fills, redirecting and recycling this feed stream through the proposed process has a high potential to substantially contribute to waste remediation, and improving, through recycling, material sustainability and mitigating adverse environmental impacts. However, full realization of this potential will depend upon a working infrastructure that will facilitate headliner removal and collection from vehicles, prior to their disposal into land-fills or shredding during recycling operations.

References

1. Estimates by the Automotive Parts Remanufacturers Association (APRA), cited in “U.S. Automotive Parts Industry Annual Assessment, Office of Transportation and Machinery, U.S. Department of Commerce, April 2009”


3. EPA web-site http://www.epa.gov/epawaste/conserve/materials/auto.htm#recycle

4. Automotive Learning Center


6. Estimates based on volumes of ELV vehicles/year (~14 million) and average headliner weight (7.5 lbs)

