THE LIGHTWEIGHT POTENTIAL OF NATURAL FIBER BASED COMPOSITES IN AUTOMOTIVE INTERIOR PARTS

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Introduction

Annually, the world-wide production rate of car industry comprises 56.1 Mio cars (see Table 1).

In all segments of automotive industry a great number of parts is used to furnish car interiors. Such parts are, e.g.

- *inside door coverage's,*
- *instrument panels,*
- *floor and trunk trim*
- *boot covers,*
- *headliners, etc.*

The demands on the properties and functions of interior parts are quite high, especially in view of their shape and surface design, stiffness, weight, heat insulation, sound absorption, odor emissions, application of further functional elements, security (in case of crash). Moreover, they shall be easy and fast to assemble/disassemble and at last they have to have a low price rate which is the most important parameter for industry.

At the present time, contrary demands and requirements in the properties of car interior parts are realized by means of multiple-layer fiber reinforced composite structures, that are laminated by textiles or plastic sheets on the visible side; often they also have a light layer (foam) on the backside, processed, e.g. by injection molding. Additionally, enclosed metal parts – in order to provide a suitable stiffness - increases the multiplicity of the material mix. The production processes of the supplying industry are material intensive and still have a high number of processing and production steps. The consumption rate of fossil resources for car interiors is also still very high. Due to the multiplicity of the material mix that is used and the special design of the composites, material recycling is almost impossible. In most cases interior parts are disposed off by waste incineration or will be deposited in garbage dumps.

Thereby 8 to 9 million tons of waste products in Europe are annually caused by used automobiles. Car interiors take a great part of this. Therefore, in April 1999 a change of the European guideline 70/156/EWG - was administered by the European commission. Hereafter, from the 1st January 2005, automobiles must have a potential of material recycling by a minimum of 85 %, later on by a minimum of 95 % of the material weight of the car. This regulation, which is addressed to the responsibility of automotive industry, has the consequence that thermal waste disposal is from this date on limited, which requires suitable concepts to recycle the construction material.

With the background outlined above, the project partners that are presenting this paper, started in April 1999 the "FVW-CAR" project. The intention of the project was an integral life-cycle orientated product development (Fig. 1) for car interior parts, envisaging also necessary environmental characteristics, high technical standards and additionally the specific cost levels of the OEMs

The basic strategy to achieve these goals was to reduce the multiplicity of material mixes by a natural fiber reinforced composite that can easily be recycled at the end of a cars life-cycle. This objective was accomplished by means of natural bast fibers, embedded in **only one binder material**. Visible surfaces have been formed as webs made from natural fibers. In view of the recycling properties required, the matrix material need to have thermoplastic characteristics. Bio-polymers (re-growing and/or bio-degradable) offer an additional approach for recycling and are currently under further investigation.

In a summarized form, the efforts of the FVW-CAR project intended to improve the technical properties by developing lightweight interior parts via composite structures and, as far as possible, also in terms of their acoustics.

The main objectives were:

- ***Recyclable interior parts as light weight structures with an advanced acoustic design***
- *Product development guidelines for interior parts and definition of process - production parameters with respect to the properties of the new material*
- *Recycling options*
- *A low number of technical processes and production steps*

Material Shares of Carriage Material for Door Panels in Western Europe 1997

Current State of the Art

Currently, a wide range of different materials and blends for the design of interior parts of vehicles (cars, trucks, railway wagons, etc.) are used. This is a result of the comprehensive demands and requirements on the parts for example shape and surface design, stiffness, lightweight, heat insulation, sound absorption, application of further functional element, security (in case of crash), and economical aspects. In Figure 2 the current material multiplicity that is applied, is demonstrated at the different carriage structures used for door panels. As one might derive from Fig. 2, natural bast fiber reinforced thermoplastic material have only a market share of currently 3%; whereas in nearly 42 % of the 19.2 Million cars, that are annually produced in Europe, plastics like Polyurethan (PU), Acrylnitrilbutadienstyrol (ABS) - mostly reinforced with glass fibers - are dominating the market. However, NF based material combinations becomes more and more important.

At the time being, in the supplying industry as well as at several research institutions, new attempts have been made to use various natural fibers because of their high tensile strength, that in some cases even surpasses the properties of fiber glass Today the new trend is to make new blend with natural fibers such as Sisal/Kenaf/Hemp or Flax/Sisal/Kenaf to take advantage of, e.g. the fineness (Flax) and strength (hemp) of the fibers.

Thereby automotive trim parts are fabricated based on natural fibers as flax, sisal, cotton, etc. embedded in epoxy, phenolic, polyurethane, unsaturated resins (approx. 10% market share) or in PP (3% market share). Today, in the car industry we can find the following main products:

- Mats 70/30 % Flax/Sisal or 100% hemp with Phenolic resin or Polyurethane
- Mats 50/50 Flax/Polypropylene

If fibers are embedded into a thermoplastic matrix, e.g. Polypropylene (PP), the capacity of material recycling will be increased whereas most of the physical properties that are required can be achieved. Some disadvantages like missing form stability and stiffness under higher temperatures (e.g. stability tests at 115^{0}C for headliners) give reason to the at last still small amount of interior parts that are made from PP. However, NF´s itself offer a high potential for lightweight construction due to their high tensile

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strength (Fig.3) and they provide the same stiffness in composites whereas the part has in general a lower weight compared to glass fiber reinforced parts (Fig. 4).

Current Gaps in Research and Development of Interior Parts

A review of the literature shows that there is a general acceptance in automotive industry to use natural fibers as reinforcement fibers in interior parts as an important strategy for technical, economical and environmental improvements. However, the following gaps remain:

- A decided concept to use only one material in composites that fulfil the high demands of material recycability, with respect to the European legislation and in view of a sustainable and resource saving product design and production
- Utilization of quality ensured natural fibers for more sophisticated composite structures to realize lightweight interior parts
- Lack in economical viable binder materials with tailored properties (e.g. high temperature profile)
- Lack in research and development of acoustic properties (damping characteristics) of interior parts, due to the increasing customer demands on the ride comfort of all vehicles, especially passenger cars. A weak point of acoustic design is the weight reduction of the cars and it's parts, because lightweight constructions are much more susceptible to vibrations.
- Lack in a real "concurrent design and engineering" for all stages of life cycle for interior parts as a co-operative work of all parties concerned. Often, a so-called "Throw over the wall" mentality is still dominating in the design organization and management.

Natural Fiber Markets for Car Interior Parts

Since the beginning of 1990 an annual increase of fiber consumption for automotive interior parts can be observed. Data of the latest surveys are given in Fig. 5-6.

Trend in the German Automotive Industry

Results of the FVW-CAR Project

By the FVW-CAR project, recycability, lightweight and advanced acoustics were envisaged in order to develop interior parts that provides better technical, environmental and economical performances compared to series parts that are currently in use.

Based on an actual request of automotive industry we started our attempt to save weight by developing a sandwich structure for a trunk trim part made by means of two flax fiber polypropylene based layers (mats) covering an expanded polypropylene (EPP) particle foam core (Fig. 7-8).

Normally, a stiff lightweight part can be made from a NF-PP 50-50% mat, e.g. as a blow molded part with a total weight per area of, e.g. 2000 g/m^2. In order to minimize the weight of a trunk trim part, we used two NF mats covering an EPP core. Additionally we varied the weight per area of the natural fiber based mats as well as the density of the EPP core, as long as we obtained the same stiffness, requested by the series part. The optimized version was formed in a single step into a rigid three dimensional automotive trim component (Fig. 9) by means of solution 2 in Fig.8. A comparison of the results is given in Table 3 and Fig. 10.

From the results one can derive, that a three layer sandwich structure as shown above, offers an enhanced lightweight potential whereby one might save about 40% of weight compared to blow molded natural fiber based parts. Surely these savings were paid by a surcharge of approx. $ 0,20 per kg, since the EPP foam core adds additional costs to the part. Hence, the direction of our recent research is heading towards the development of new fiber blends providing enhanced stiffness in order to allow us to reduce the density of the EPP within the sandwich structure.

Summary

Natural fiber embedded in PP can be used with technical, environmental and economical advantage to produce light weight trim components for automotive industry. Moreover, the weight of the parts might be additionally reduced by implementing an EPP core into the composite, thereby the same stiffens might be achieved whereas the weight of the trim component might be reduced by 40%. Flax-PP-EPP parts show excellent mechanical properties that justifies their use as interior part material. In terms of recycling issues, even those sandwich structures consists of only two components (natural fiber and PP) which gives access to an easy way for material recycling. Currently, the Molan Group is able to produce waste free automotive trim car components, as all the natural fiber-PP residues can be recycled into part production or can be re-used as a granulate for the production of buckets that were fabricated by injection molding.

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Table 1. Worldwide forecasted production rate of automotive industry in 2001

2001 Market	Forecasted production
North America	16.7 Mio cars
Europe	19.2 Mio cars
South America	2.2 Mio cars
Asia	18.0 Mio cars
Total	56.1 Mio cars

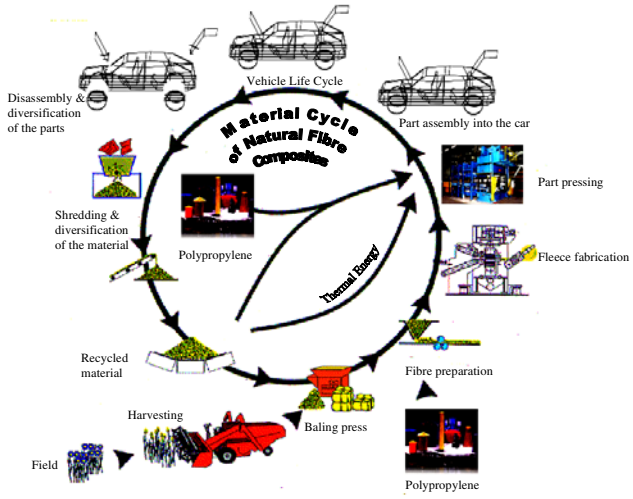


Figure 1. The range of topics of recycling.

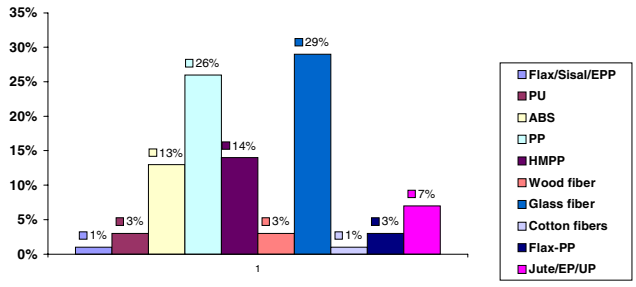
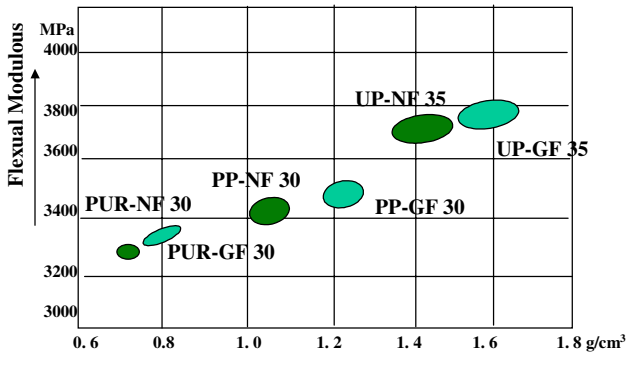


Figure 2. Material shares of carrier materials used for door panels.

Fiber	Density [g/cm³]	Tensile Strength of Single Fiber [cN/tex]	Strain at max. Tensile Force [%]	Young's Modulus [kN/mm²]
Cotton	1,52	55	48,0	11
Flax	1,48	60	4,0	35
Jute	1,49	40	1,5	10
Glass	2,54	138	4,0	65

Figure 3. Mechanical properties of natural fibers compared with glass fibers /Flemming 1995/.



NF=natural fiber; GF= Glass fiber; PUR=Polyurethane
UP= unsaturated Polyester resin; PP=Polypropylene

Figure 4. The lightweight potential of natural fibers.

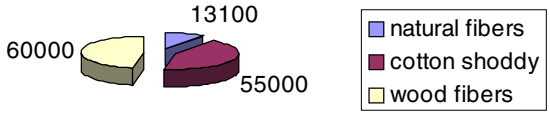


Figure 5. Consumption of fibers in the German automotive industry ´98 (mt/y).

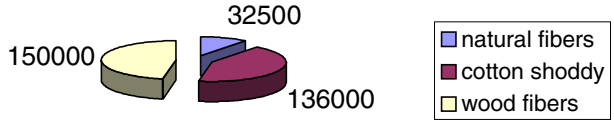


Figure 6. Consumption of fibers in the West European automotive industry ´98 (mt/y).

Table 2. Tendency of fiber consumption rates.

Natural fiber	Consumption rate in mt/y	Tendency
Flax	10.000	slight increase
Kenaf		Slight increase
Hemp	1.100	increase
Jute	800	stable
Sisal	700	stable
Cotton shoddy		substantial decrease for the benefit of natural fibers

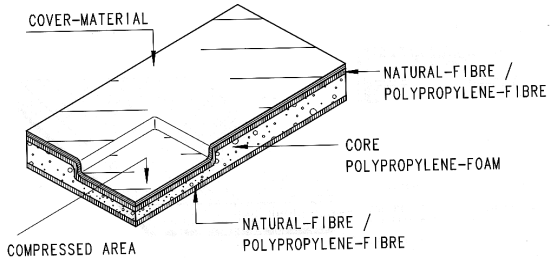


Figure 7. Flax-PP-EPP Sandwich construction.

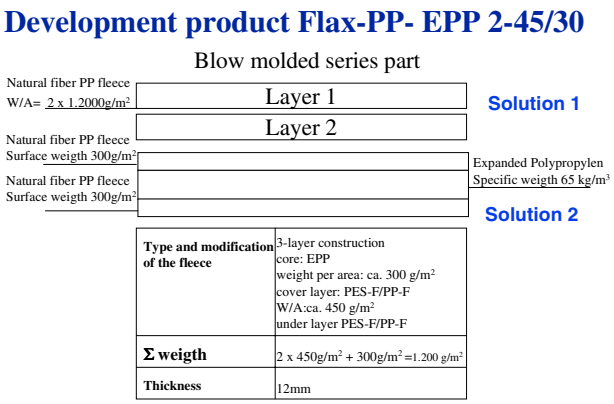


Figure 8. Flax –EPP Sandwich construction.

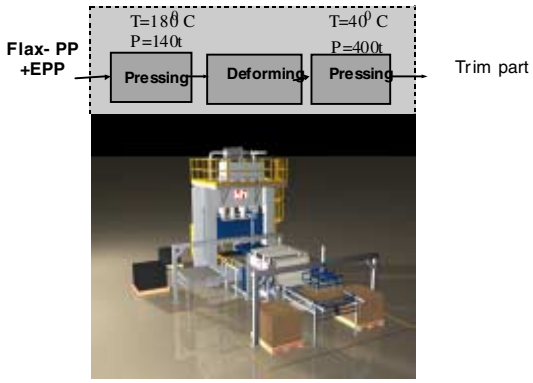


Figure 9. Production process for natural fiber PP based trim parts.

Table 3. Comparison of trunk trim parts made from Flax-PP or Flax-PP-EPP-Flax-PP.

Designation	Trunk trim part left & right	Trunk shutter
Solution 1 Flax-PP blow molded)	Size = 0.53 qm	Size = 0.36 qm
Carrier weight	2[2x1000g/qm x 0.53 qm] = 2.120g	
∑ Weight per car	2.840 g	
Solution 2 (Flax-PP/EPP/Flax-PP)		
Carrier weight	2[2x600g/qm x 0.53qm]= 1.272g	1[2x600g/qm x 0.36qm]=432g
∑ Weight per car	1.704g	
Δ of weight between sol.1 & sol.2	1136g = 40% of weight savings	
Price	$ 4.39	$ 4.46
Δ price between sol. 1 & sol. 2	$ 0.25	

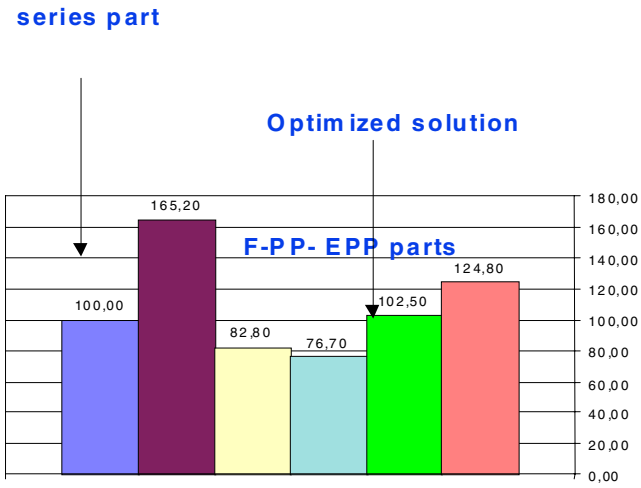


Figure 10. The optimization process of solution 2.