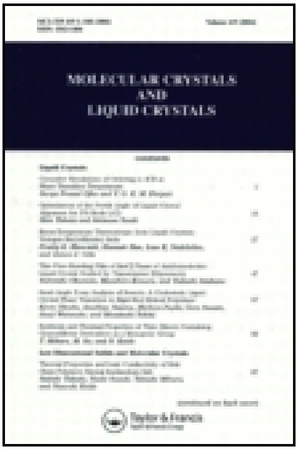

Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Production of Reinforced Composites with Natural Fibers for Industrial Applications - Extrusion and Injection WPC

Alcides Lopes Leão [a] , Rui Manuel Fernandes Teixeira [b] & Paulo Cadete Ferrão [b]

[a] UNESP - São Paulo State University, Botucatu, SP

[b] Universidade Técnica de Lisboa - Instituto Superior Técnico, Lisbon, Portugal

Version of record first published: 22 Sep 2010

To cite this article: Alcides Lopes Leão, Rui Manuel Fernandes Teixeira & Paulo Cadete Ferrão (2008): Production of Reinforced Composites with Natural Fibers for Industrial Applications - Extrusion and Injection WPC, Molecular Crystals and Liquid Crystals, 484:1, 157/[523]-166/[532]

To link to this article: http://dx.doi.org/10.1080/15421400801904393

Mol. Cryst. Liq. Cryst., Vol. 484, pp. 157/[523]–166/[532], 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400801904393

Production of Reinforced Composites with Natural Fibers for Industrial Applications – Extrusion and Injection WPC

Alcides Lopes Leão[1], Rui Manuel Fernandes Teixeira[2], and Paulo Cadete Ferrão[2]
[1]UNESP – São Paulo State University, Botucatu, SP
[2]Universidade Técnica de Lisboa – Instituto Superior Técnico, Lisbon, Portugal

The aim of this work is to study the replacement of currently used thermoplastics by composites reinforced with vegetable fibers with several advantages, mainly better mechanical properties, low weight and competitive cost compared to its counterparts. Extrusion and injection molding processes were studied using polypropylene (PP) matrix. The raw materials used were sugar cane bagasse, elephant grass, wood, milk cartons and recycled polypropylene. The composites were tested for bending, tension, hardness and impact resistance, following ASTM standards. The results obtained were extremely positive since they proved that natural fibers as reinforcement can be an important alternative to replace talc and other fillers.

Keywords: bagasse; composites; elephant grass; natural fibers

INTRODUCTION

Since ancient Egypt natural fibers are part of our civilization. The traditional applications are baskets, clothing, sacks, bags, ropes, rugs, paper, medicines, etc. Several articles are listed in the literature describing the advantages of natural fibers compared to its counterpart the man-made fibers, such as glass fiber and polyester in composites applications. Lightweight, strength with stiffness and mainly low-cost are specially poised to replace glass fibers and mineral fillers in the plastics industry.

We are thankful to CNPq, Brazilian Council for Research and Plastitech Indústria e Comércio Ltda. that made possible this research.
Address correspondence to Alcides Lopes Leão, UNESP – São Paulo State University, Botucatu, 18.603-970, SP. E-mail: alcidesleao@fca.unesp.br

The aim of this work is to demonstrate the advantages of composites based on natural fibers, mainly for the automotive industry, which represents the largest market niche in Brazil for these materials. The technique of injection molding is well known in the plastics industry and represents billions of dollars worldwide. However the injection molding of natural fibers reinforced materials represents a new segment in industry. Only 5% of the worldwide market of plastics reinforced with natural polymers (fibers/flour) is dedicated to injection molding applications, with the majority for extrusion of profiles, mainly for construction (decking, door and window frames, etc.) [1]. Several reasons are listed to motivate the utilization of the natural fibers in the composites industry, such as:

- Environmentalist pressure for more utilization of Natural Renewable Resources;
- Better efficiency in converting raw-materials in products compared to other man-made fibers;
- Products based on Life Cycle Analysis (ISO 14000);
- National strategy to create rural jobs in economically deprived areas;
- Good mechanical properties relations: Weight versus Resistance;
- Recyclability;
- Composites/Ecomenes;
- Reduction of the Greenhouse Effect;
- Renewable source of raw material;
- Excellent specific strength and high modulus. High flexural and tensile modulus – up to 5′ base resin, high notched impact strength – up to 2′ base resin;
- Reduced density of products;
- Lower price of polymer composites reinforced with natural fibers than those reinforced with glass fiber;
- Reduced tool wear; and
- Safe manufacturing processes, no airborne glass particles, relief from occupational hazards. Reduced dermal and respiratory irritation. No emission of toxic fumes when subjected to heat and incineration.

BACKGROUND

Combining natural fibers with fossil plastics is a great economical opportunity, since the price of virgin polypropylene in Brazil is around USD2.7/kg while its recycled counterpart costs about USD1.0/kg, which can result in economic gain for the transformer. This fact already was predicted by Rowell [2], since the lignocellulosics composites at level of 50% compares favorable to glass fiber-PP injection molded composite.

Several automotive companies have tried to introduce natural fibers composites in their models [3]. It is a trend that have grown at very high rates (25% per year) in Europe since 2000 [4]. One great discovery in the natural fibers composites is the sound insulation properties. Audi, in its model A6 is applying wood-polypropylene in the speakers box, since this material results in strong sound absorption [5]. The utilization of natural fibers in the automotive industry in increasing. An increase of 27% was observed last year just for the Mercedes auto C-Class, accounting for a remarkable consumption of 23 kg/auto/yr [6]. One of the most attractive points to use natural fibers in the car industry is the fact that parts are becoming lighter, about 20%, which will result in a large economy (100 kg extra weight account for 1 liter of fuel every 100 km). Another point is the matter of green carbon. In this case, the main competitor (glass fiber) requires 54,8 MJ/kg to produce the material and natural fiber only about 9,7 MJ/kg.

MATERIAL AND METHODS

The fibers tested were the most common in Brazil: sugar cane bagasse and wood flour. Another material tested was milk carton, that consists of low density polyethylene, aluminum and paper. The legend for the tested fibers are:

- PP: Polypropylene; polypropylene virgin, co-polymer, with melting flow index of 29;
- PPBDE: blend of PP and sugar cane bagasse without pith;
- PPBIN: blend of PP and sugar cane bagasse in nature, with pith;
- PPCAP: blend of PP and elephant grass;
- PPM90: blend of PP and wood flour, mesh 90;
- PPMAD: blend of PP and wood flour, mesh 40;
- PPTET: blend of PP and milk cartoon; and
- PPTal: virgin polypropylene with talc as filler.

The fibers were grinded at 2 mm size particles, dried up to less than 1 percent moisture content and blended with polypropylene. The material was compounded through extrusion process and samples were prepared in a injection molding machine. 1% maleic anhydride grafted polypropylene (MAPP) modifier, Epolene G-3002 (Eastman Chemical Products, USA), with an average molecular weight of

60,000 were added. The addition of a coupling agent (MAPP) helps to promote the bondability between the thermoplastics and the natural fibers. The fibers ratio in the tested composites were 15, 25 and 40% by weight, while the talc ratio were 20 and 40%. The compound was carried out in a twin screw extruder. The fibers were fed at the final third of the barrel through a side feeder and a gravimetric loader.

The extruded pellets were dried at 105°C for 4 hours to eliminate residual humidity from the fiber before the injection molding of the samples. The samples were produced through injection molding process at 190°C, according to ASTM standards, in an automatic injection molding machine, Sandretto, 65 Micro. Prior to mechanical testing, the samples were conditioned at $(40 \pm 5)\%$ relative humidity, (25 ± 2)°C for 40 hours. Unnotched Izod Impact tests were made in ten specimens using a CEAST Resil 25 pendulum type impact machine according to ASTM Standard D-256. Tests were performed using an EMIC DL 3000 testing machine, following ASTM standards: tensile testing (ASTM D638); flexural testing (ASTM D790). For flexural and tensile tests five specimens were used.

The composites were prepared in a twin-screw extruder, model ZSK-25, Werner & Pfleiderer, L/D ratio of 25, at 180 rpm. The screw design is closely related to a better mixing and transporting the blends preventing thermal degradation damage or excessive shear [7].

RESULTS AND DISCUSSION

Figure 1 shows the sharp reduction in the melting flow index with the addition of natural fibers. It was observed in other experiment that with a PP of a melting flow index, with 50% wood flour, the final MFI was reduced to around 12. With an increase in the level of natural fibers, the final MFI were around 2 to 8, ideal for injection molding in parts without small channels or with higher flow area. In this case hot mold is a solution. The size of the particles is also important. Bigger particles reduce the MFI of the composites, as can be seen for both wood flour studied, mesh 40 and mesh 90. For extrusion blends, the reduction in the MFI is not a problem, since a commercial profile such as decking requires a initial MFI around 6. Therefore, in molds with special requirements, higher level of natural fibers can represent a limitation.

In Figure 2 the density reduction of natural fibers composites is shown compared to talc at 20 and 40%, the usual levels used in the automotive industry. The average density for natural fiber composite is around 1.05–1.08, versus 1.20 to 1.32 with talc. This is important

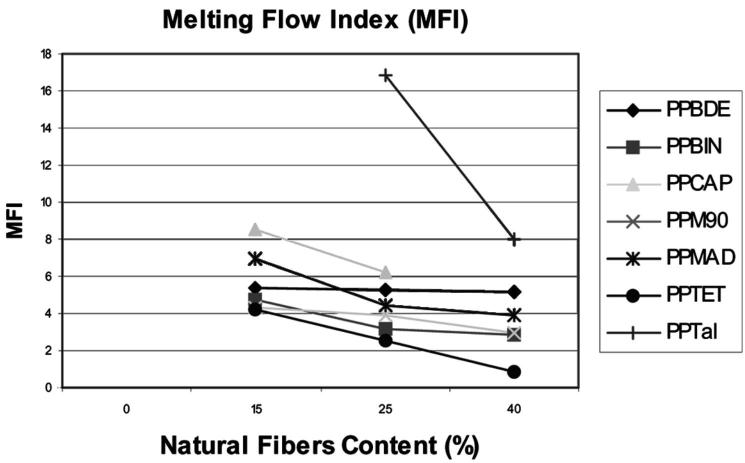

FIGURE 1 Melting flow index for composites.

as described early. When compared with PP and glass fibers this advantage is much more accentuated. Basically there are no significant differences among the several fibers tested.

Another characteristic important in many sectors, mainly for injected parts in the automotive industry, is the surface hardness as seen in Figure 3. Many parts require scratch resistance, such as front and door panels. In this case an increase in the natural fiber levels results in better hardness. This behavior is followed by all the tested fibers. The milk carton due the presence of LDPE (low density

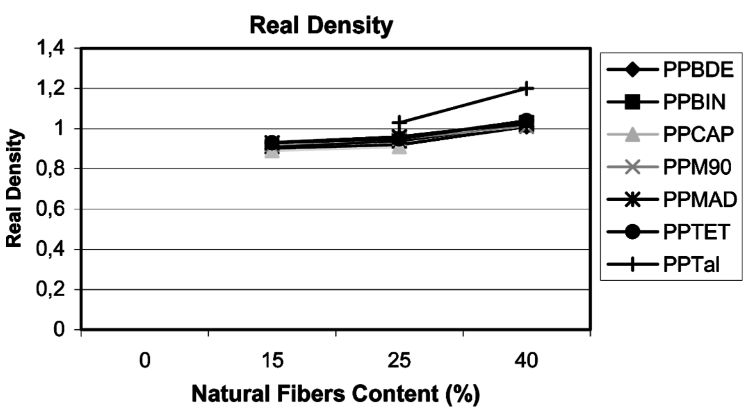

FIGURE 2 Density reduction with addition of natural fibers.

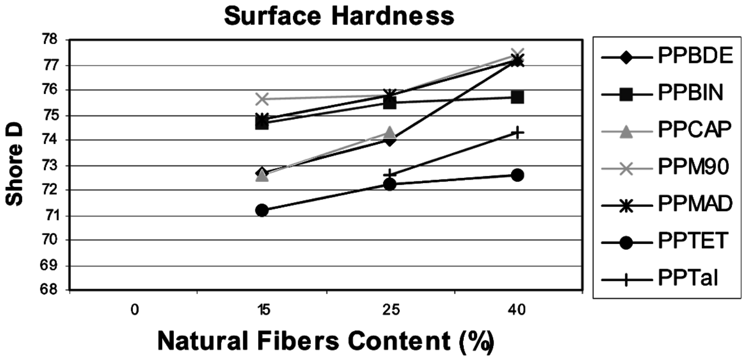

FIGURE 3 Hardness increase due to natural fibers addition.

polyethylene) reduces its hardness. Sugar cane bagasse in nature and without pith resulted in better performances.

The elongation reduction occurs for all the tested materials, including milk carton. An increase in the natural fibers levels results in a sharp decrease in the elongation. In this case the particle size had no effect on this property (Fig. 4).

The results for flexural resistance (modulus) is shown in Figure 5, where wood flour gave values similar to those obtained with talc at

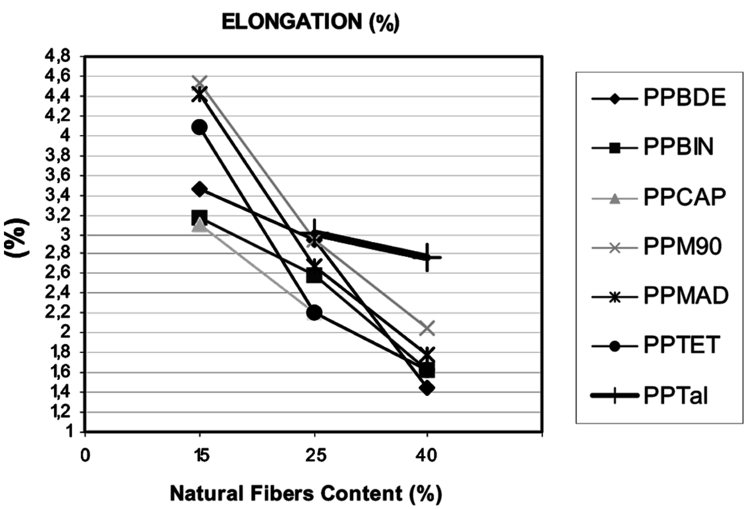

FIGURE 4 Elongation reduction due to natural fibers addition.

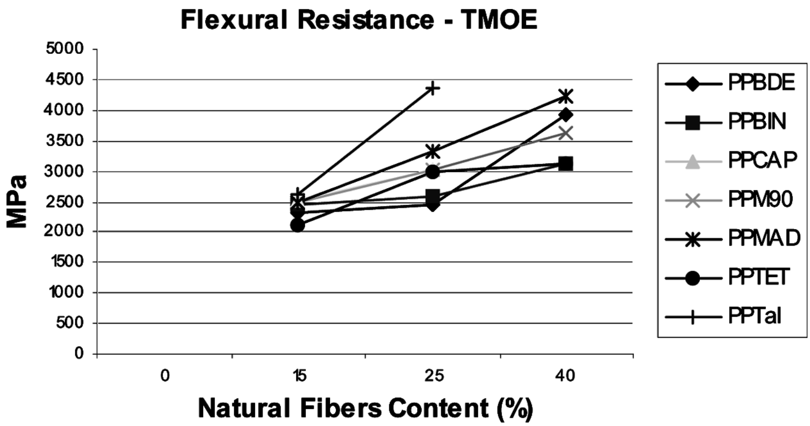

FIGURE 5 Flexural resistance for different fiber content (modulus).

40%, followed by sugar cane bagasse. Sugar cane bagasse without pith resulted in better performance, demonstrating that pith reduces the mechanical properties of sugar cane bagasse. In Figure 6, a similar result was observed with all the natural fibers with values above the polypropylene/talc blends.

Tension modulus is shown in Figure 7. Analyzing the tension stress the most promissory result was obtained for the wood composites in both granulometry, when compared with the other natural fibers. In Figure 8, the same trend was observed, except that for this property the sugar cane bagasse had a better behavior.

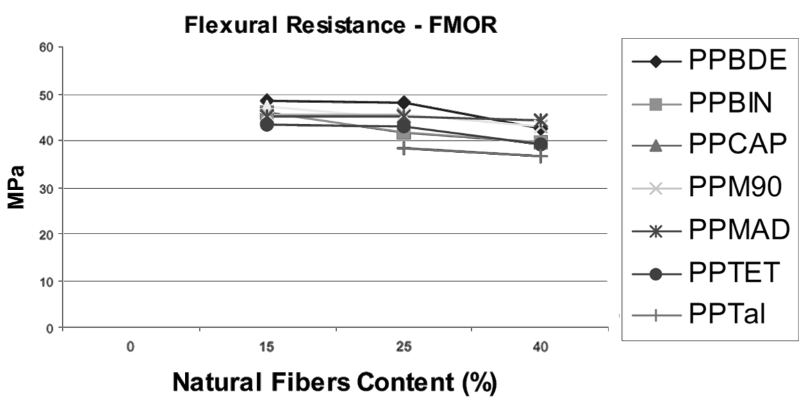

FIGURE 6 Flexural strength.

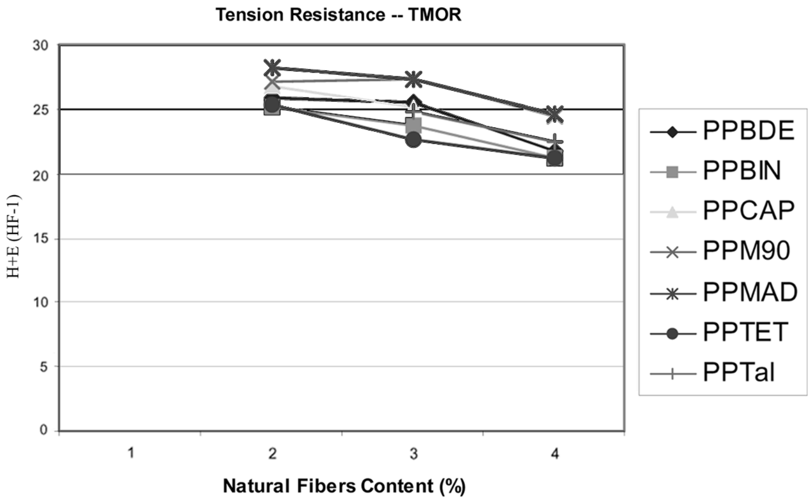

FIGURE 7 Tension resistance.

In Figure 9 the results for impact resistance are shown, since in some external applications, such as bumpers and coatings in civil construction it is a limiting factor [6].

Wood flour as reinforcement agent gave the best results when compared to other natural fibers, although with the increase of natural fibers content all the natural fibers level off with a decrease in impact resistance. Wood flour resulted in better performance. Proved improvements of treated PP with maleic anhydride, the commonly known MAPP, only comes to confirm the effectiveness of this treatment for PP and natural fibers.

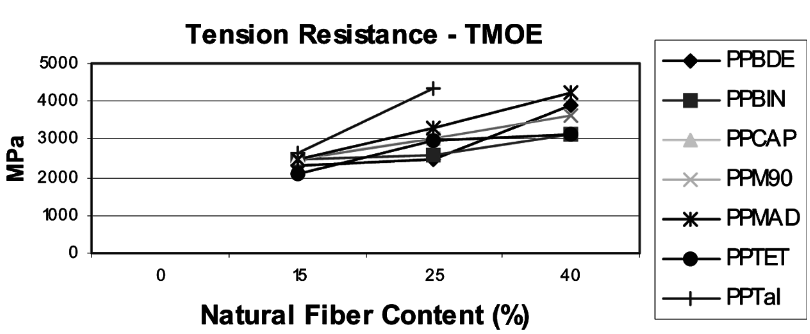

FIGURE 8 Tension resistance (modulus).

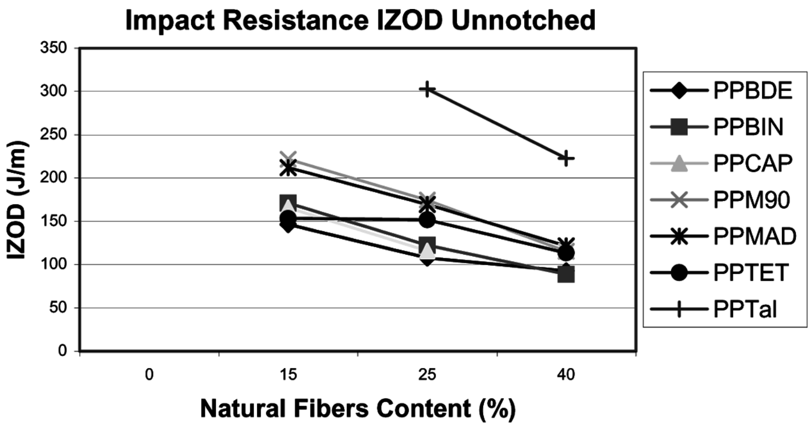

FIGURE 9 Impact resistance.

CONCLUSIONS AND RECOMENDATIONS

The composites properties made with natural fibers and polypropylene are extremely favorable and competitive to polypropylene with inorganic fillers. Considering its low density compared to its counterparts, natural fibers will imply in cost reduction for the consumers that inject the parts and for the tier suppliers that makes the pellets, since it is replacing polypropylene costing around 1.4 Euros/kg worldwide with a fiber that costs around 0.1–0.2 Euros/kg. Meanwhile the low density and high specific modulus result in a positive reduction of fuel consumption in the automotive industry, making bodies lighter. It is important to point out that natural fibers are not confined to automotive industry, having an enormous potential in other sectors such as electro-electronics, appliances, packaging, furniture, etc...

REFERENCES

[1] Zah, R., Hischier, R., & Leão, A. L. (2007). *Journal of Cleaner Production*, *15*, 1032–1040.

[2] Rowell, R. M. (1998). Economic opportunities in natural fiber-thermoplastic composites. *Science and Technology of Polymers and Advanced Materials*, 869–872.

[■] Kalanda, N. (1999). Trends in Automotive Plastics. In: ANTEC'99. 5p.

[3] Wühhlbauer, W. & Hutter, C. P. (2002). Utilization of abaca fiber as industrial raw material. In: *Workshop Sustainable Development, Natural Fibers For Modern Technology, Subsistence and Biodiversity Improvements Projects in the Philippines*, 6p.

[4] Sherman, L. M. Natural fibers: The fashion in automotive plastics. In: *Plastics Technology. On line article*.

[5] Mueller, D. H. & Krobjilowski, A. (2003). New discovery in the properties of composites reinforced with natural fibers. *Journal of Industrial Textiles*, *33*(2), 111–130.
[6] Leão, A. L. (1997). Produção de Compósitos Não-Estruturais à Base de Lignocelulósicos. Tese de Livre-Docência. UNESP, Campus de Botucatu.
[7] Mueller, D. H. & Krobjilowski, A. (2004). Improving the impact strength of natural fiber reinforced composites by specifically designed material and process parameters. *International Nonwovens Journal*, *13*(4), 31–38.