THE ECONOMICAL PERFORMANCE OF LONG GLASS REINFORCED POLYPROPYLENE CONCENTRATES

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Abstract

Long glass fiber reinforced polypropylene (LGF PP) has generated significant interest in the automotive industry over the past several years. With increasing emphasis on cost reduction, part consolidation, reduction in total assembly cycle time, and recyclables, this versatile material offers many benefits. To provide these solutions, while considering (improving) the economics required in the automotive structural large part segment, LNP has introduced a highly loaded LGF PP concentrate.

This paper will first discuss the industry trends that are driving tremendous growth potential in LGF PP. This brief overview will address the evolution of LGF PP materials and components in the vehicle, and market pressures driving the need for a more cost effective material approach.

The cost reduction potential of LGF PP concentrate blends will be illustrated along with the mechanical property performance, and other specific benefits of this masterbatch concept. A study of impact-enhanced blends will also be reviewed.

Introduction

It is no secret that PP has experienced rapid growth in many markets over the last several years – especially automotive. It is the world's fastest growing and most versatile thermoplastic resin, according to Dr. Salvatore Ali, Montell Italia S.p.A.[1] (See Figure 1*)*. Within the automotive sector PP has found a new home in many interior, exterior, and underhood applications at the expense of high cost engineering resins such as ABS, Polyurethane, and Nylon. With improvements in catalysts and processes, PP can compete in more demanding applications, according to Dr. Ali.

One of the driving forces in polypropylene's growth in automotive is the "mono material construction" approach. This concept offers many advantages such as recycling, part consolidation, volume purchases, weight reduction and reduced complexity. Consider door systems, where the substrate, skin, and trim are all molded out of polypropylene based materials. Other multiple component applications include IP's, FEM's, and Cargo Management Systems.

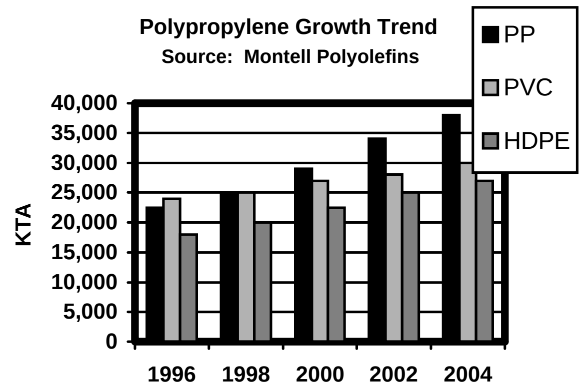

Figure 1.

LGF PP has also experienced rapid growth potential in the last several years for many of these same reasons. It offers the designers and engineers a low cost material, with exceptional impact, stiffness, and chemical resistance, while eliminating the need to select resins outside of the olefin family.

As these trends have become more evident, an increased number of suppliers have entered the LGF PP supply arena. This has increased market recognition and acceptance of these products. For example, prior to 1996 there were two major domestic producers of LGF PP compounds for the automotive market. Today there are an increasing number of suppliers of LGF PP pellets and direct compounding systems worldwide.

Furthermore, the marriage of low pressure molding equipment and LGF materials has opened the door for system integrators to cost effectively produce large structural parts.

With this trend in mind, LNP recently introduced a more cost effective LGF PP product, while maintaining the mechanical property performance of fully compounded LGF PP material.

[1] Blanco, A., *Plastics Engineering*, (May 2000).

Masterbatch Approach

Most people in the automotive community realize that economics is the single most important force in a products success. However, the integrity or performance of a product cannot be jeopardized at the expense of cost alone. Responsible engineers must find a balance between performance and cost. LGF PP concentrate is an excellent choice to achieve this goal.

The material studied in this paper is a long glass-fiber reinforced polypropylene masterbatch. It is specifically formulated for machine-side blending using neat polypropylene. This product is based on commingled[2] fiber technology whereby, polypropylene resin fiber and glass fiber filaments are commingled into one roving. (See figure 2) This roving is then processed under heat and pressure and pelletized into 13mm or 25mm lengths, depending on processing method and end-use application.

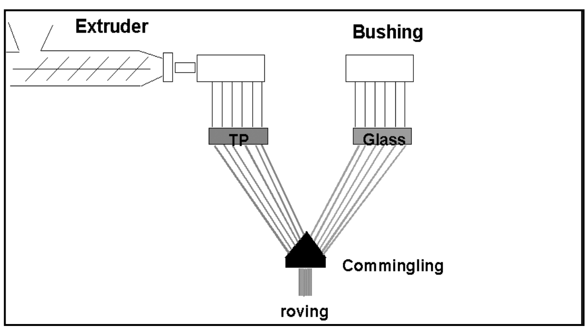

Figure 2.

This commingling process is different from existing manufacturing methods for LGF PP pellets, including pultrusion/melt-impregnation and wire-coating technologies. The technology allows the glass and polypropylene fibers to be intermixed, giving the system excellent glass-to-resin dispersion within the consolidated pellets. Figure 3 is an illustration of a pellet cross-section, which shows the resin distribution throughout the pellet. This efficient method of combining the resin and glass in the composite matrix provides for higher glass loadings (up to 75% by weight) than previously possible in melt impregnation or wire-coating technologies. Furthermore, similar physical properties to fully pultruded LGF PP materials (discussed in the following section) are achieved.

While the performance characteristics of this masterbatch approach are similar to fully pultruded LGF PP materials, the cost is up to 20% less. There are two primary reasons for this savings.

First, the cost of neat PP can be leveraged based on volume buys by tier 1's or system integrators. They can use their existing unfilled polypropylene material as the "B" component for their structural applications. This allows them to increase their buying position in polypropylene while avoiding the need to inventory "special" compounds. Furthermore, if they have several structural applications, which require different glass loadings, they can simply inventory the masterbatch and blend it according to the applications specific requirements.

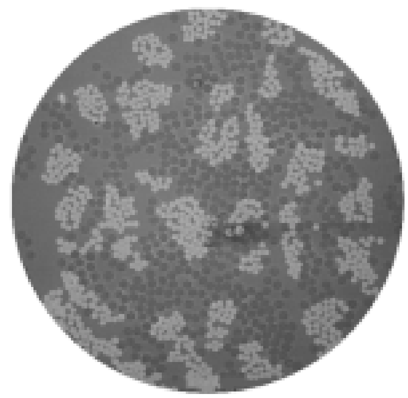

Figure 3.

Secondly, conversion costs are reduced by eliminating the need to fully compound 100% of the overall resin system. For example, a 1 million lb./yr. application requiring 30% long glass in the final part would use 40% LGF PP concentrate and 60% neat polypropylene (based on 75% loaded masterbatch). In this example, only 40% (400,000 lbs.) of material would need to be pre-compounded. This would result in conversion cost savings based on 600,000 lbs of material. In the case of a fully pultruded product however, 100% of the material (1 Million lbs.) would need to be pre-compounded.

Property Performance

To verify that key performance characteristics of LGF PP were not compromised using the masterbatch approach, LNP performed the following studies.

First, an experiment was run to test LNP's fully compounded 30% LGF PP vs. LNP's 75% LGF PP Concentrate diluted to 30% glass fiber. For this experiment a 30 MFI homopolymer PP was used as the dilution resin (component B). A masterbatch compound (referred to hereafter as component C) consisting of additional compatibilizer and heat

[2] Commingling : Based on Twintex® technology

stabilizer, was added to the blend to match the final loadings of these additives in the fully compounded LGF product. Properties were tested with and without the addition of component C to determine the effect of lower contents of HS and compatibilizer on mechanical properties.

The blends were performed manually (drum tumbled) in small batches (approximately 5 lbs each) and manually transferred to the injection molding machine hopper. This was to ensure a consistent blend between the unfilled short PP pellets and the 13mm LGF PP pellets.

ASTM mechanical property specimens were molded on a 220T press with a 40mm diameter barrel, a 20:1 L:D screw, and an 8oz shot. The following mechanical properties were tested in accordance with ASTM standards: Tensile Strength, Tensile Elongation, Flexural Strength & Modulus, Notched Izod Impact Strength, and Falling Dart Impact Strength.

The data shown in Table 1 illustrates the following: First, the ash contents were ± 2% (2 percentage points) of nominal 30%, in both of the masterbatch blends. This indicates an accurate blend between the unfilled PP and the 13mm LGF PP pellets. Customer trials utilizing airveying equipment to transfer pre-mixed batches have resulted in ash contents of ± 4%. For this reason it is highly recommended that accurate, gravimetric dosing units be installed directly on the molding machine hopper to limit pellet segregation/settling in a production setting.

Secondly, the tensile strength, flexural strength, and flexural modulus values in the 3 component masterbatch blend, differed less than 5% vs. fully compounded 30% LGF PP. The blend without component C had a tensile strength 11% lower than the control.

Impact testing showed that the 3-component masterbatch blend varied less than 1% vs. the fully compounded LGF PP in notched izod and less than 8% on falling dart total energy. Both notched izod and falling dart impact increased slightly with the omission of component C.

Further property characterization was done with blends targeting 20, 30, and 40% by wgt. glass (Table 2). These test specimens were molded on a 220T press with a 40mm diameter barrel, a 20:1 L:D, and a 8oz shot. In this experiment the 40% glass blend was run with and without component C. Although, LNP did not test vs. controls for each glass %, the property values showed consistency with published data sheets and brochure values for fully compounded product (reference LNP bulletin 270-498).

Like the earlier test the 40% masterbatch compounds showed higher tensile properties with the addition of component C. However, once again impact strengths improved with the omission of component C.

Based on this experiment LNP concluded that the masterbatch blends maintained the mechanical properties typical of fully compounded LGF PP. Furthermore, it was determined that the lower levels of compatibilizer and HS were detrimental to tensile performance but improved impact strength.

Product Customization

The economic value of the LGF PP masterbatch concept has been demonstrated. However, additional benefits have been confirmed by altering the component "B" in the masterbatch blend. More specifically, LNP has have proven certain property enhancements by diluting LGF PP Concentrates with various unfilled types of PP resin. This paper will concentrate on impact performance enhancement.

A study was performed to compare the strength and impact differences between a 50% LGF PP Concentrate diluted with a homopolymer PP vs. dilution with high impact copolymer PPs.

This study targeted a final ash content of 30%. The homopolymer based LGF PP concentrate was diluted with a 30 MFI homopolymer PP (control), and two copolymer PP resins, including: A 65 MFI, heat stabilized, nucleated, high impact copolymer, and a 100 MFI nucleated, high impact copolymer.

The same key mechanical properties mentioned earlier were to be tested. Blending was also done in small manual batches as indicated above. ASTM property specimens were molded on a 150T press with a 50mm barrel diameter, 20:1 L:D, and a 12oz shot.

The data (Table 3) revealed that the copolymer blends showed a 30-40% improvement in notched izod impact strength over the homopolymer blends. A 14% improvement in falling dart impact energy was realized using the copolymer blending resin.

The data table illustrates that strength and stiffness properties were maintained at levels equivalent to the homopolymer blend.

From this experiment LNP concluded that impact performance can be enhanced in a LGF PP masterbatch blend by utilizing an impact copolymer PP resin for the "B" component. This can be done with minimal effect to the strength and stiffness characteristics typical of a LGF PP composite.

Summary

In summary, PP has experienced significant growth in the automotive market over the last several years. LGF PP is following in its tracks as a good candidate for large structural automotive applications.

With increased demand for LGF PP in larger structural systems, LNP introduced a more cost effective material approach – LGF PP masterbatch. This composite results in material cost reductions of up to 20% compared to conventional LGF PP while exhibiting similar physical properties.

Based on the enclosed property performance experiments, LNP concluded that the masterbatch blends maintained the mechanical properties typical of fully compounded LGF PP. Furthermore, the lab results demonstrated that the lower levels of compatibilizer and HS were detrimental to tensile performance but improved impact strength.

As discussed, impact performance can be increased in a LGF PP masterbatch blend by utilizing an impact copolymer PP resin for the "B" component. This can be done with little or no effect to the strength and stiffness properties of a typical LGF PP composite.

Acknowledgments

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References:

Figure 1. Source: Montell Polyolefins
Figure 2. Source: LNP Engineering Plastics
Figure 3. Source: LNP Engineering Plastics
Table 1: Source: LNP LWR (lab work request) 2000-747
Table 2: Source: LNP LWR 2001-0018-34
Table 3: Source: LNP LWR 1999-0624-15
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<u>Table 1</u>.

30 % LGF PP – Direct Pultruded vs. Concentrate Blends
Reference - LNP LWR 2000-747

Injection Molded ASTM Properties

Property	Direct Pultruded, UV BK Lot 4071619	LGF PP Concentrate Blend without Component C	LGF PP Concentrate Blend with Component C
Tensile strength (psi)	17,984	15,974	17,145
Tensile elongation (%)	2.47	2.41	2.49
Flexural strength (psi)	23,510	24,542	24,124
Flexural modulus (psi)	950,900	962,000	951,400
Izod impact (ft-lbs/in)	3.52	4.22	3.28
DTUL °C	160.2	158.2	157.8
Dynatup falling dart instrumented impact crack initiation energy ASTM - D 3763 (J)	7.7	5.3	5.1
Dynatup falling dart instrumented impact crack propagation energy (J)	6.4	7.6	7.4
Dynatup falling dart instrumented impact total energy (J)	14.1	12.9	12.5
Air burn out (% FG)	29.1	31.2	30.2

Table 2.

75% LGF PP Concentrate Blended to 20, 30, & 40% Fiber Glass
30MFI Hompolymer PP used as dilution resin
LNP LWR 2001-0018-34

Injection Molded ASTM Properties

	20% GF Blend with Component C	30% GF Blend with Component C	40% GF Blend without Component C	40% GF Blend with Component C
Tensile (psi) strength	14,894 ± 850	16,813 ± 919	16,399 ± 1075	18,779 ± 504
tensile (%) elongation	2.8 ± .1	2.5 ± .1	1.9 ± .1	2.3 ± .1
tensile (ksi) modulus	734 ± 39	900 ± 29	1123 ± 62	1152 ± 48
flexural (psi) strength	19,794 ± 1126	24,431 ± 465	28,014 ± 2000	29,062 ± 1683
flexural (ksi) modulus	674 ± 41	923 ± 15	1225 ± 85	1197 ± 18
Izod impact (ft.lb/in)	2.2 ± .3	3.5 ± .5	7.0 ± 2.1	4.8 ± .8
HDTUL F 264 psi	314.8 ± 0.7	315.4 ± .45	317.8 ± .25	315.3 ± 0.3
Falling dart impact (I,p)	6.0, 5.6	7.6, 7.6	8.3, 10.5	7.1, 9.3
Dart (total)	11.7 ± 2.5	15.2 ± 2.1	18.8 ± 2.0	16.4 ± 2.4
ash content	20.2	30.1	40.1	40.8

± indicates standard deviation

Table 3.

Mechanical Properties for High Impact LGF PP
50% LGF PP Concentrate Diluted to 30% Glass Final
LNP LWR-1999-0624-15

Injection Molded ASTM Properties

	LGF Homopolymer PP Blend	LGF Compolymer PP Blend #1*	LGF Compolymer PP Blend #2**
Tensile Strength (PSI)	17,489	18,622	19,481
elongation %	3.29	3.23	3.33
Flexural Strength (PSI)	26,218	27,555	26,567
Flexural Modulus (PSI)	846,215	874,910	880,295
Falling Dart Crack In(J)	7.15	5.96	6.62
Falling Dart Crack Prop	7.08	10.31	9.54
Falling Dart Total (J)	14.23	16.27	16.16
Izod (ft-lb/in)	5.22	7.08	6.62
Ash (%)	31.5	30.9	30.9

*Diluted with 65 MFI, heat stabilized, nucleated, impact copolymer

**Diluted with 100 MFI, nucleated, impact copolymer