Demonstration of PP/GF-Based LFT Composites Using Laboratory-Scale Coating Line

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Introduction

Thermoplastic composites draw attention among researchers and polymer processors, in industries such as automotive, military and aerospace. They are typically reinforced with fibers to enhance their performance e.g. high specific strength, design flexibility, light weight, corrosion resistance and ability to be recycled. These composites can be generally classified as:

- Short fiber (SF) reinforced (average fiber length of less than 1 mm)
- Long fiber (LF) reinforced (average fiber length in the 1-25 mm range) (Fig. 1)
- Continuous fiber reinforced (average fiber length equal to the part dimension)

Figure 1. Short fiber (SF) reinforced (left) vs long fiber (LF) reinforced (right) pellets

While, in continuous fiber reinforced thermoplastic composites, the fibers are aligned in the same direction and extend along the length of the part; in short and long fiber reinforced thermoplastic composites, the fibers are discontinuous and have random or preferred orientation.

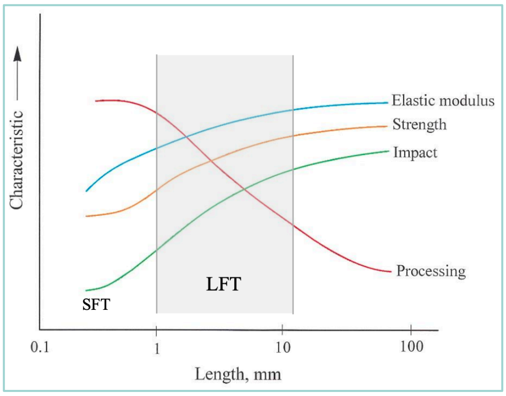

Figure 2. Effect of fiber length on the mechanical properties and processability [1]

For long fiber reinforced thermoplastics (LFTs), higher residual fiber length in composite specimens results in better thermal as well as mechanical properties, such as strength, impact resistance, wear resistance with respect to SF reinforced thermoplastics. Meanwhile, composite processing becomes more difficult (Fig. 2).

"Hot melt impregnation" is often utilized to produce LFT pellets. In this process, the continuous fiber tows enter the extrusion die under tension and are consequently surrounded by the extruded polymer. In the next step, the material is pulled and cooled and chopped into the desired pellet length.

LFTs offer various material choices for both resin and fiber reinforcements. As LFT matrices, a variety of thermoplastic polymers have been used in the industry. Currently, 65% of global market share for

LFT composites is held by PP-based LFTs, due to the good processability, commercial availability, low cost and mechanical performance of PP. And the rest 35% is governed by engineering polymers such as PA6, PA66 and high-temperature polymers e.g. PPS and PEEK. As reinforcement, most common options are glass fiber (GF), carbon fiber, natural and aramid fiber reinforcements [1].

There is a limited number of research studies in the literature on LFTs compared to conventional short fiber (SF) reinforced thermoplastics. This is primarily due to the significant infrastructure requirements for LFT research, including high initial installation costs, substantial operational expenses related to labor, and the need for large volumes of material. As a result, the economic barrier from concept to implementation is considerable. To address this challenge, Xplore developed a dedicated benchtop coating line to accelerate the early-stage development process of LFTs. Current LFT research studies primarily focus on the improvement of mechanical, thermal, electrical, flame retardancy, failure behaviours, and ability to resist loads (especially in car collision). The main aim is to find out the influencing factors such as: fiber type (carbon, glass, hybridized, etc), fiber surface modification, fiber dispersion, fiber orientation, fiber content (volume fraction), fiber aspect ratio (length / diameter), final fiber length, viscosity of the polymer, impregnation time, melt temperature, addition of compatibilizers, mineral fillers (as secondary reinforcement), process parameters, hybrid reinforcement and interfacial adhesion.

In this technical note, we have successfully demonstrated the LFT production process on a benchtop coating line at Xplore, using GF and PP and compared with conventional short glass fiber (SGF) reinforced PP.

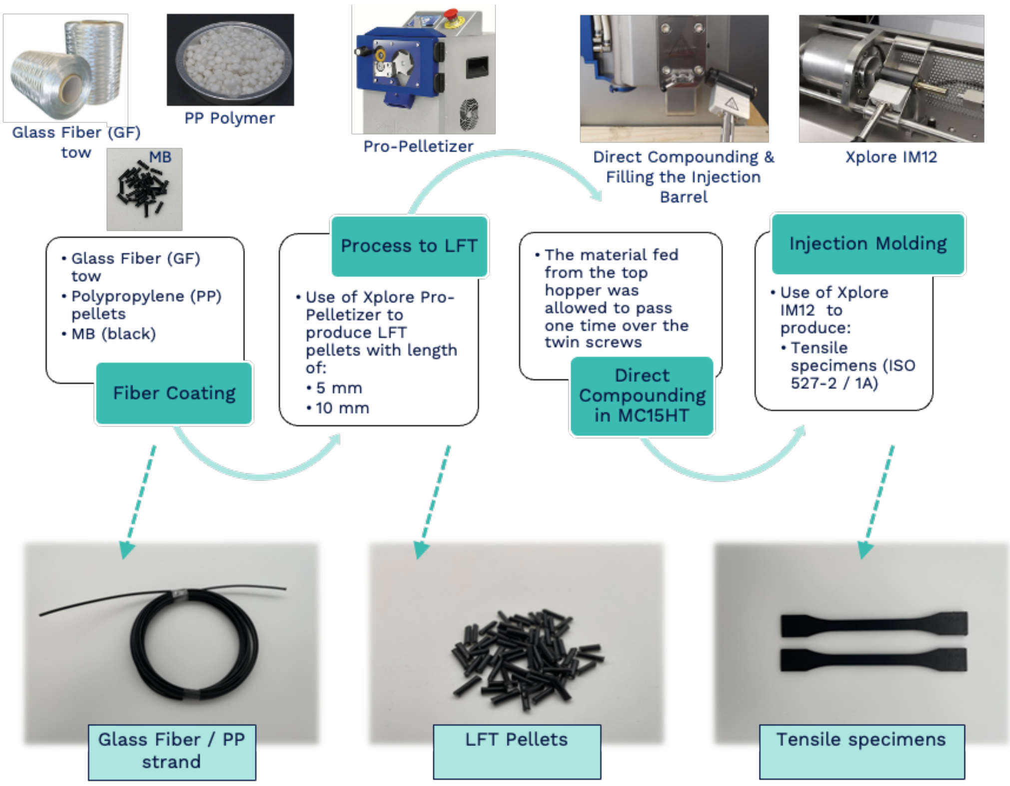

Figure 3. Preparation steps of LFT samples

Materials and Methods

The LFT production process had multiple steps (Figure 3). The preparation of glass fiber reinforced PP-based LFT strands was conducted using a laboratory-scale Xplore MC40 40 mL micro-compounder and the fiber coating line. Processing was performed in continuous extrusion mode, at 25 rpm screw speed, 230°C barrel temperature, facilitating subsequent pelletization with Xplore Pro-Pelletizer (refer to Figure 4).

To enable stable throughput, PP (Sabic PP 515A with MFI of 24) and black masterbatch (MB) was fed continuously bu using double automatic feeders (Figure 4).

Within this setup, GF (2400 tex) was directed through the fiber coating die (230°C) ensuring uniform coating by PP. The resulting strands with an average diameter of 2575 µm were drawn at a winding speed of 0.8 m/min, and subsequently chopped into 10 mm pellet length using Xplore Pro-Pelletizer operating at 50 rpm blade speed.

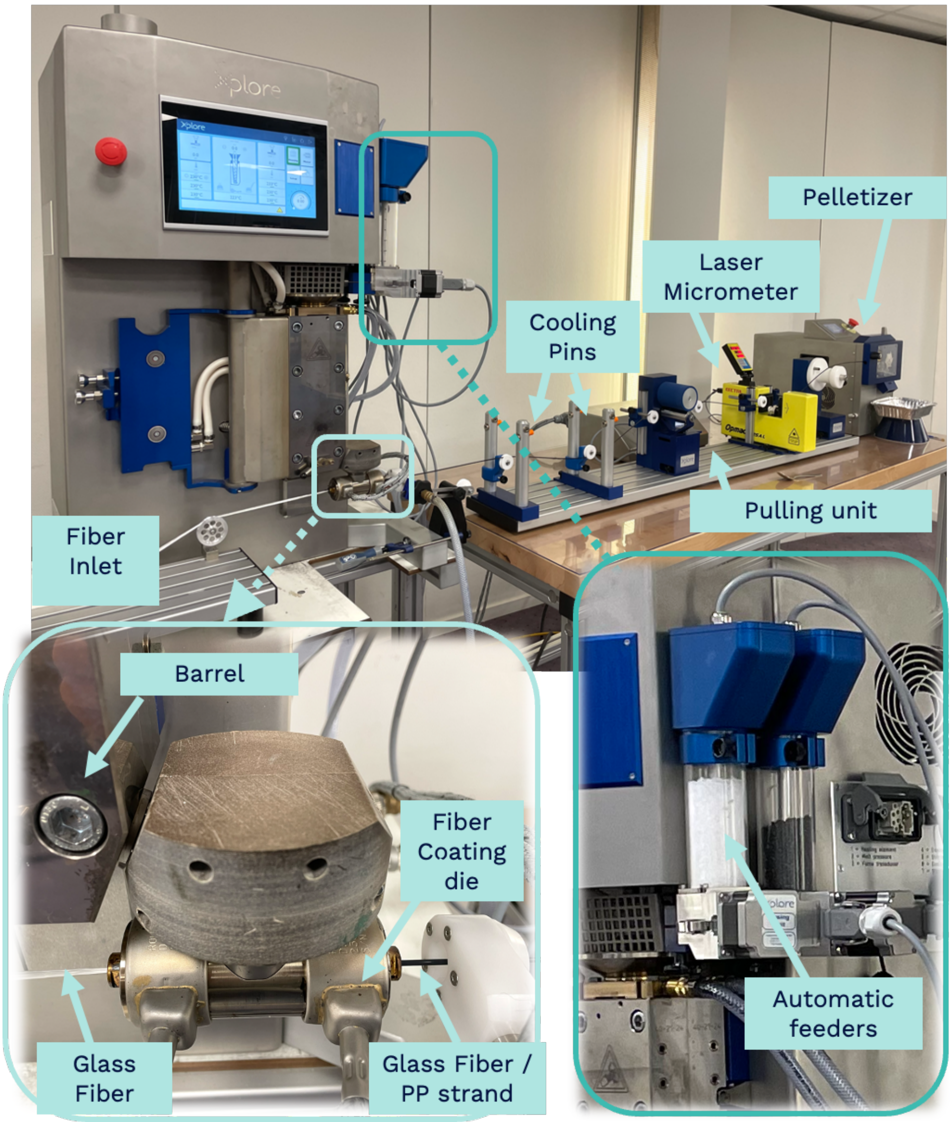

Figure 4. Xplore MC40 micro-compounder and the fiber coating line details

In the final processing stage, the prepared LFT pellets were melt-mixed using the MC 15 HT 15 ml micro-compounder by using the following processing parameters: 230°C, 50 rpm, direct compounding (single-pass). The residual glass fiber length is a critical factor for the final mechanical properties. Therefore, micro compounding was done through “direct compounding” where the recirculation valve was kept open. The material fed from the top hopper was allowed to pass one time over the twin screws and directly extruded from the die to the transfer cylinder of the IM12.

The molten material was then directly transferred to a micro-injection molder (IM12, Xplore Instruments) for the fabrication of ISO 527-2 Type 1A tensile test specimens (Figure 3), using the following processing conditions: mold temperature of 40°C, injection and holding air pressure at 6 bar, and the cycle time of 15 sec.

To compare the properties of the LFTs (group is designated as LGF-10) with the conventional short glass fiber (SGF) reinforced composites, PP was compounded with chopped glass fibers in MC15HT micro-compounder at a fiber loading of 50%, matching that of LGF-10.

The resulting compounds were then directly transferred to the IM12 injection molding machine and molded under similar conditions as previously described. This group is referred to as PP-SGF throughout this document.

Using the same processing parameters, neat PP was blended with masterbatch (MB) to produce a reference sample, designated as PP-MB.

Mechanical and rheological properties of the samples were evaluated using an Instron Model 3345 universal testing machine and an Anton Paar MCR 102 rheometer, respectively.

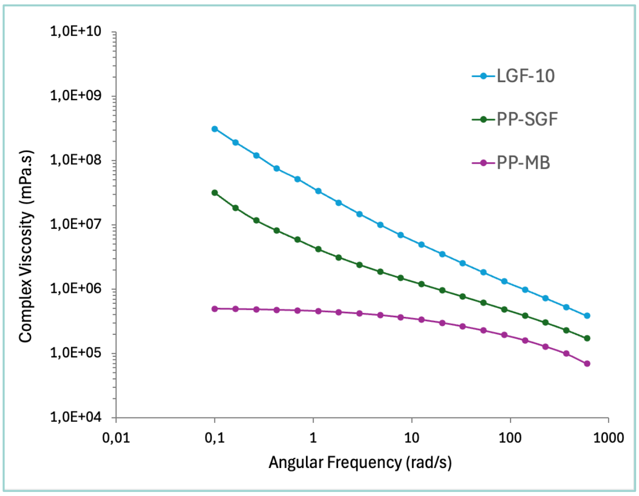

Figure 5. Complex viscosity versus angular frequency of samples

Results

Figure 5 represents the complex viscosty variation with respect to the fiber length (short or long). The rheological response highlights how fiber reinforcement strongly affects polymer processability. The long glass fiber (LGF-10) system exhibits the highest viscosity and most pronounced shear-thinning, indicating strong fiber–fiber interactions and efficient stress transfer within the melt. In contrast, the short glass fiber (PP-SGF) formulation shows lower viscosity, reflecting reduced entanglement and easier flow. The PP-MB system, with minimal reinforcement, flows most readily.

Batch micro-compounding enables precise control of shear forces and residence time, ensuring homogeneous fiber dispersion even in high-viscosity systems like LGF-10. This capability allows researchers to balance processability and performance, while generating rheological data that reliably predict behavior in larger-scale extrusion or molding processes.

The tensile test results, presented in Table 1, indicate that the LGF-10 sample exhibits significantly higher mechanical performance. Specifically, when compared to PP-SGF, LGF-10 shows approximately 13% increase in tensile strength and a 32% increase in tensile modulus. These findings demonstrate that mechanical properties, particularly tensile strength and modulus, improve with increasing fiber length.

As expected, the elongation at break decreased with the incorporation of glass fibers. This reduction in ductility is primarily due to the formation of stress concentration zones at the fiber ends and along the fiber-matrix interfaces. These localized stress concentrations restrict the mobility of polymer chains, limiting the ability of the thermoplastic composite to undergo plastic deformation.

Table 1. Tensile test results of samples

Sample	Tensile Strength (MPa)	Elongation at Break (%)	Modulus (GPa)
PP-MB	29.3 ± 2.1	18.1 ± 1.6	2.5 ± 0.2
PP-SGF	31.3 ± 3.4	0.6 ± 0.04	7.1 ± 0.6
LGF-10	35.5 ± 3.8	1.3 ± 0.11	9.4 ± 0.7

Summary

LFTs attract considerable attention in industrial applications due to their excellent mechanical strength, design versatility, lightweight nature, resistance to corrosion, and recyclability. However, research in this area remains limited, primarily because of the high costs and infrastructure requirements associated with conventional processing methods.

In this application note, polypropylene (PP)-based LFT composites reinforced with glass fiber were successfully developed using a novel microprocessing approach: the Xplore fiber coating line. This lab-scale system provides a practical and efficient platform for researchers to rapidly develop and screen LFT composites. It enables LFT research studies with minimal material consumption and substantially reduced processing times compared to conventional techniques.

This new system opens up opportunities to expand LFT research into a broader range of domains, including bio-based and natural fiber-reinforced LFTs, hybrid composite architectures, high-performance composites with tailored fiber-matrix interfaces, functionalized materials incorporating additives or nanofillers, and advanced sustainable composites utilizing recycled thermoplastics, thereby enabling comprehensive investigations into structure & property relationships and process optimization.

For further information, contact our experts at Xplore Instruments BV.

References

[1] Ning H, Lu N, Hassen AA, Chawla K, Selim M, Pillay S. A review of Long fibre thermoplastic (LFT) composites. International Materials Reviews. 2020; 65(3): 164-188.

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