Better Part Properties thanks to Fewer Fiber Breakage

Plastification System Optimized for Processing Long Glass Fiber Materials

Long glass-fiber-reinforced polypropylene and polyamide are used in automotive lightweight construction especially where high impact toughness, very good crash behavior and low weight are required. However, care must be taken during injection molding, since not every screw is suitable for these materials. To maintain the fiber length reliably and obtain a uniform distribution of the fibers, Engel has developed a new plastification system especially for processing long glass-fiber-reinforced materials.

Plastics are filled with fibers in order to improve the properties of the composite material through the high strength and stiffness of the fibers. The addition of fibers significantly increases the mechanical characteristics, such as tensile strength, stiffness, impact strength, thermostability and wear resistance. Long glass-fiber-reinforced (LGF) materials with a fiber length of at least 10 mm are gaining ever increasing importance in automotive applications and have superior properties, in comparison to short glass-fiber-reinforced (SGF) materials. However, if the plastification screw is not specifically designed for these materials, the long glass fibers may be reduced in length too much during plastification and the properties obtained may only correspond to those of short glass-fiber-reinforced materials.

Long glass fiber materials are available on the market in different qualities. The manufacturing process for rod-shaped pellets determines the quality. In pultrusion, a long glass fiber strand is pulled through a melt bath and then fed to a chopping system. The advantages of this process are good impregnation as well as a uniform distribution of the individual glass fiber filaments in the rod-shaped pellets, and therefore in the later part. Alternatively, the long glass fiber strand is only enveloped with polymer from the outside. Impregnation thus only takes place during processing.

A Screw for Different Materials

Engel Austria GmbH has the aim of developing a new plastification system that can be universally used for a wide range of long glass-fiber-reinforced materials. For processing long glass-fiber-reinforced rod-shaped pellets, the company has so far offered a single-flight 3-zone screw with a special screw-on LGF mixing head. The LGF mixing head is designed to be pressure-neutral as a result of the relatively large flow cross-sections, allowing gentle plastification.

Since the demand for injection molding machines for these applications is increasing. Engel decided to produce the screw and mixing head in one piece and to further optimize the screw geometry. The newly developed long glass fiber screw (LFS), in contrast to the standard screw, has a lengthened feed zone, a high channel depth in the feed area and a longer compression zone, as well as a shorter metering zone and an optimized feed channel in the mixing head (**Title figure**).

The greater channel depth in the feed zone prevents feeding problems with the rod-shaped pellets (© Engel)

The deeper channel in the feed zone prevents feeding problems and the associated dosing time fluctuations, since the rod-shaped pellets do not flow so easily into the screw as standard pellets. A highly effective flight welding gives the screw the necessary wear and corrosion resistance. The LFS is available with diameters from 80 to 170 mm.

Comparison of the Different Screw Concepts

Within the development project, Engel processed different PP-LGF grades, varying according to fiber content and viscosity, with the new LFS and with a standard screw, with and without LGF mixing head respectively, with constant process settings. In the series of trials, the Engel engineers assessed process parameters such as dosing time, melt temperature and torque, as well as the quality of the specimen parts produced. They investigated the specimen parts for optically identifiable fiber bundles, and determined the impact strength. In addition, individual strands were removed to determine the fiber length distribution. To compare the different screw concepts, the experts chose a process setting that would preserve the fibers as far as possible, with 0.2 m/s circumferential speed and 10 bar back pressure.

With the standard screw without LGF mixing head, with each long glass fiber material, the fiber bundles are visible with the naked eye, while the LGF mixing head breaks up these fiber bundles and the back pressure can consequently be reduced. The studies also show that increasing the back pressure shortens the fibers to a greater extent than the use of an LGF mixing head (**Fig. 1**).

Whereas with the standard screw, without LGF mixing head at 10 bar, fiber bundles are clearly visible for each long glass-fiber material, these fiber bundles disappear when the back pressure is increased to 100 bar, provided that materials with high flow rate (PP matrix with MFR = 250 g/10 min at 230 °C/2.16 kg) are used. If the material has low flow rate (PP matrix with MFR = 50 g/10 min at 230 °C/2.16 kg), the back pressure must be increased to 150 or 200 bar so that fiber bundles can no longer be identified. With the use of the new LFS, hardly any fiber bundles are identifiable at all at a backpressure of 50 bar, in the case of high-flow materials, while with low-flow materials isolated fiber bundles occur at only 100 bar. These fiber bundles are only visible with naturally colored materials and are used as an indicator that the long glass fiber properties are retained.

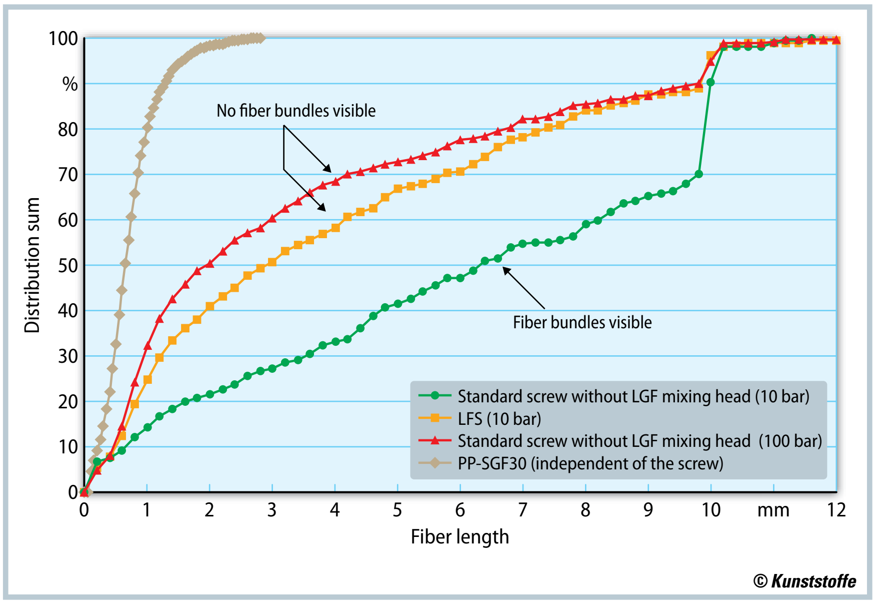

Fig. 1. With the standard screw without LGF mixing head, the average fiber length is greatest, however with a low back pressure of 10 bar, fiber bundles are clearly visible. With the new LFS and 10 bar back pressure, the measured fiber lengths are somewhat higher than with the standard screw and 100 bar. Note: the distribution curve is a distribution of different fiber lengths and not a spot measurement (source: Engel)

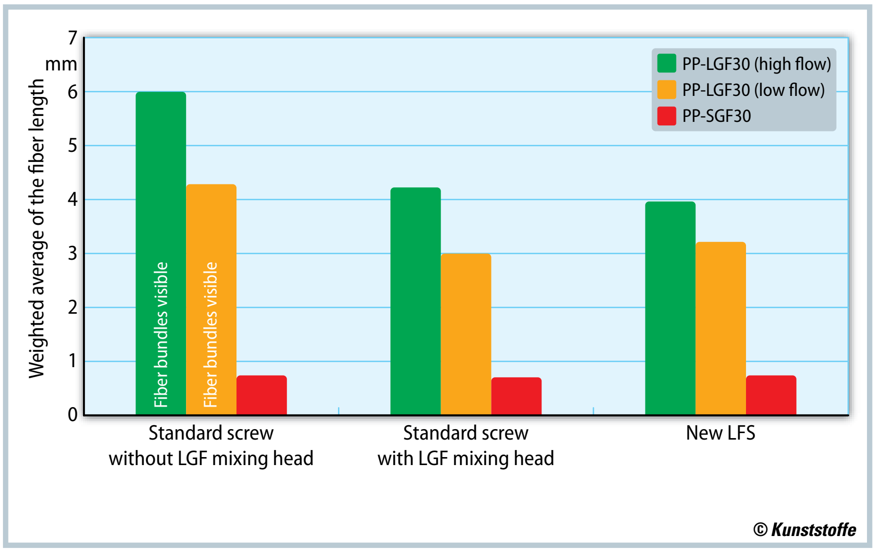

Fig. 2. High flowability (low viscosity) results in lower fiber length reduction (less friction). The standard screw with LGF mixing head and the new LFS yield comparable fiber lengths. All trials were performed at 10 bar holding pressure (source: Engel)

Loading of the Fibers in the Melt

Besides the feed and compression zone, where unmelted material is still present, and projecting fibers can be easily broken, the loading of the fibers in the melt also results in shorter fibers in the area of the LGF mixing head. Fiber bundles can be further separated by the shear energy. The lower the viscosity, the easier is the impregnation and the lower is the fiber breakage (**Fig. 2**).

For determining the fiber length distribution, Engel collaborated with the Wood K plus competence center in Linz, Austria. Here, the fibers were separat- »

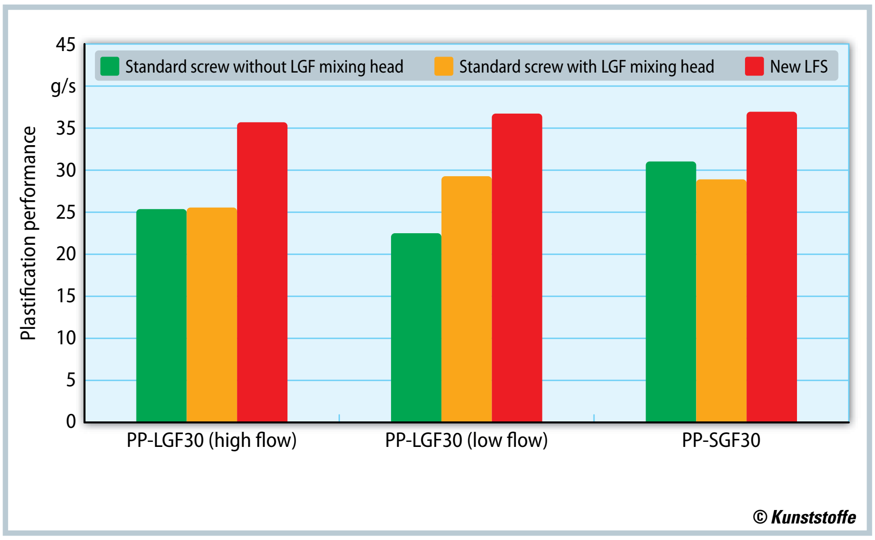

Fig. 3. The plastification performances are greatest with the newly developed LFS. For the same cycle time, it offers the advantage of a lower rotational speed and therefore also less fiber size reduction. The trials were performed with screws with a diameter of 90 mm in each case (source: Engel)

ed out of the composite material without damage, and micrographs of the fiber structure were taken. After image processing and analysis, complete statistics of the fiber length distribution could be determined [1].

With the aid of the determined fiber-length distribution, it can be seen that a high flowability of the matrix material counteracts the fiber damage. The high-flow material has significantly longer fibers. Because of its greater channel depth in the feed zone, the new screw also provides higher plastification rates with lower fluctuations in dosing time. The rotational speed can therefore be reduced for the same cycle time (**Fig. 3**). The dosing behavior is more stable than with other designs.

The cooperation partner for determining the part properties and testing the parts by means of impact tests was Johannes Kepler University (JKU) in Linz. The impact energy necessary to penetrate the part was determined. The impact values of the specimen parts correlate with the average fiber length. The use of an LGF-mixing head made it possible to reduce the measured standard deviations, and consequently also the associated unreliability of the failure.

Summary

Engel's studies demonstrate the advantages of the new LFS. Due to the stable conveying behavior, dosing time fluctuations no longer occur. The screw ensures a higher plastification performance and low fiber length reduction together with good fiber distribution and dissipation. Taken together, that all means a significant improvement in the part properties. ■

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