PA66 for Flame Retardant Large-Area D-LFT Components

Faster Process to Safe Battery Enclosures

Long fiber thermoplastic compression molding is suitable for the production of components with large surfaces such as battery enclosures for electric vehicles. However, these components place high demands on the material used. Not only must it have good mechanical properties, it must also be flame retardant. Two resin grades specially developed for the process meet these demands, thereby permitting the substitution of thermosetting SMC molding materials for the manufacture of such components.

Due to the expected quantities and component dimensions, plastics producers and processors view battery enclosures and covers for electric vehicles as extremely demanding items. Because of the high demands on mechanical and thermal resistance, these components belong to the e-mobility products that are most difficult to produce. Sizes up to 2 m² and weights up to 50 kg for battery enclosures represent great challenges for processors. In the thermoplastics field, direct long fiber thermoplastic compression molding (D-LFT process) is seen as a key manufacturing technology (**Fig. 1**).

Currently, most D-LFT plants are operated with two compounding units. The first compounder serves to melt and homogenize the material, and in the second unit, a mixing extruder, the long fibers – continuous or chopped – are introduced and wetted by the polymer. Material parameters such as flowability and compatibility with the fiber surface, as well as processing parameters such as screw speed, temperature, and screw geometry contribute decisively to the final fiber length in the component, and thereby to product quality. Via a nozzle with variable cross section, the polymer melt is extruded onto a heated conveyor belt, subsequently cut in accordance with component weight. Needle grippers pick it up and insert it into the mold so that the shortest flow path is created.

Large-area components, like the battery cover shown, can be produced very well using direct long fiber compression molding. Optimized materials such as PA66 Mobius NPD 555 FR GF50 from Invista are ideal for the process involved. © Invista

Increasing Demands for Battery Enclosures

Since the introduction of the UL 2596 standard (test method for thermal and mechanical performance of battery enclosure materials) early in 2022, the demands on materials for battery enclosures and covers have been increased with the requirement for flame retardant properties. However, the use of flame retardant agents usually leads to a serious impairment in wetting of the glass fibers by the polymer matrix, which in turn can result in severe reductions in the mechanical properties profile – mainly in terms of strength and impact resistance.

Invista, the US-American plastics producer, has developed two polyamide 66 (PA66) formulations specifically for the D-LFT process: Mobius NPD 555 and Mobius NPD 555 FR. They can be processed into compact polymer melts in the usual PA66 processing temperature range of 280 to 310 °C without problems, and using all conventionally configured D-LFT plants. The good properties of glass fiber-reinforced PA66 are also obtained with the D-LFT process. Moreover, in fully automatic processes, large volumes of the polymer melt can be inserted into the D-LFT molds with needle grippers, and compressed. This also applies for the flame retardant formulation Mobius NPD 555 FR. In addition, the newly developed types feature good wetting of the fibers. This makes a fiber content of at least 50 wt.% possible, and also leads to reproducible, balanced mechanical properties of the component.

Same Mechanical Properties in spite of Flame Retardants

For mechanical characterization, and for determining the fire properties of the newly developed material, highly oriented panels were produced at the Fraunhofer Institute for Chemical Technology (ICT) using the D-LFT process, and subsequently examined. Measurements were made with test specimens conditioned in accordance with the ISO 1110 standard, which were cut out of the panels parallel to the fiber direction. During the tests it was shown that even with temperature-dependent tensile tests no significant differences exist between the flame retardant Mobius NPD 555 FR and the non-flame retardant Mobius NPD 555 (**Fig. 2**). Mobius NPD 555 FR with 30 % and 50 % glass fiber-reinforcement and a wall thickness of 3 mm achieved a classification according to UL94 V-0.

For a comparative study, the same D-LFT plant was used to produce panels with PA6 and polypropylene (PP) resins – both non-flame retardant – and with flame retardant Mobius NPD 555 FR, to conduct mechanical tests. Glass fiber lengths and their distribution are mainly responsible for the mechanical performance of the D-LFT fiber compounds. Mobius NPD 555 FR with a glass fiber content of 30 wt. % achieves a weighted average of 3.3 mm, and Mobius NPD 555 FR with 50 % glass fibers still reaches a weighted average of 2.5 mm. Consequently, both versions are well above the average of 2.1 mm of a comparison sample made of PA6 with 30 % glass fibers produced in the same plant. However, the comparison sample made of PP with 30 % glass fibers achieves a clearly higher average of 5.3 mm. Glass fiber length mainly influences the impact properties (**Fig. 3**). Nonetheless, 50 % shorter fiber length compared with the PP only results in a 30 % reduction of notched impact strength. With a fiber content of 30 wt. %, the flame retardant Mobius NPD 555 FR surpasses the non-flame retardant PA6. Moreover, by increasing the fiber content to 50 %, the notched impact properties of Mobius NPD 555 FR can be brought up to the same level as PP.

In tensile tests with samples produced and conditioned in the same way, PP-GF30, PA6-GF30, and the flame retardant PA66 Mobius NPD 555 FR GF30 achieved a similar elastic modulus at room temperature. In contrast, at a temperature of 80 °C, the elastic modulus of Mobius NPD 555 FR GF30 is already 25 % higher than that of PP-GF30 (**Fig. 4**). Even at room temperature, the material's strength is 30 % above that of PP-GF30, and at a similar value as that of »

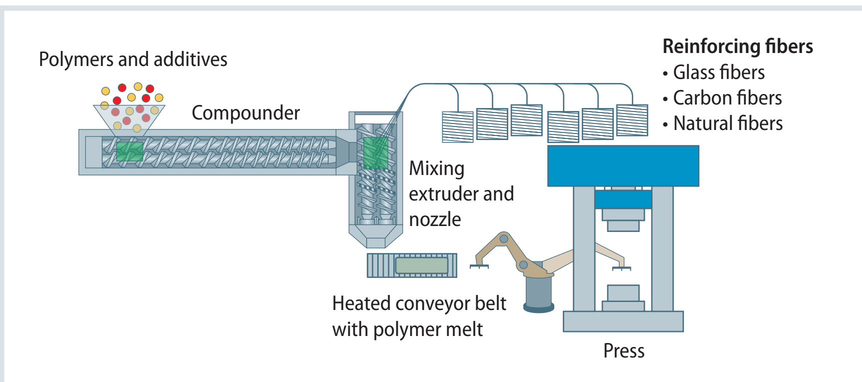

Fig. 1. During the D-LFT process, polymer and additives are mixed in the first compounder, and reinforcing fibers are introduced and wetted by the polymer melt in the second compounder.
Source: Navraj Singh Heer, Fraunhofer Innovation Platform for Composites Research at Western University; graphic: © Hanser

Info

Text

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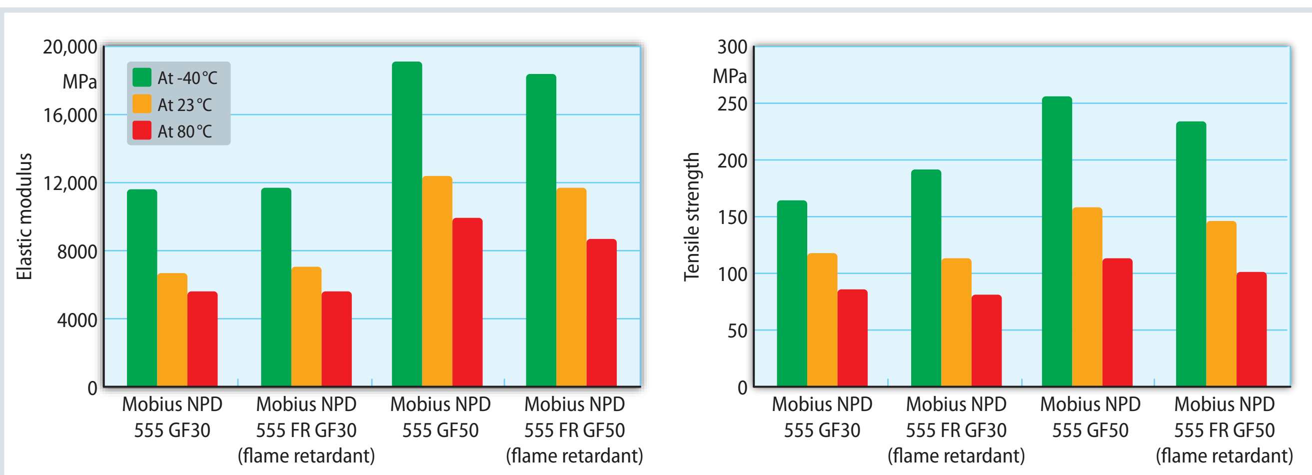

Fig. 2. Tensile elastic modulus and tensile strength of PA66 Mobius NPD 555 GF30 and GF50 compared with the flame retardant Mobius NPD 555 FR GF30 and GF50 at –40 °C, room temperature, and 80 °C: the values of the two versions only differ slightly. Source: Invista; graphic: © Hanser

PA6-GF30. Because the flame retardant formulation of Mobius NPD 555 FR wets the glass fibers very well, a reliable increase of glass fiber content to at least 50 wt. % is possible. With an equal value for notched impact strength compared with PP-GF30, the tensile strength of Mobius NPD 555 FR GF50 achieves up to 65 % higher values, and stiffness – represented by the tensile elastic modulus – was practically doubled (**Fig. 4**). Thanks to these properties, it is possible to produce D-LFT components with significantly thinner walls that are optimized in terms of installation space and material consumption, and which also comply with fire protection standards.

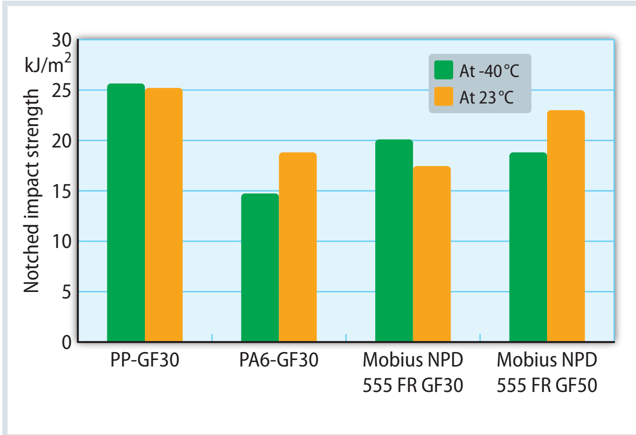

Fig. 3. Notched impact strength of two PA66's compared with PP-GF30 and PA6-GF30: at 23 °C, the flame retardant PA66-GF50 achieved similar values as the non-flame retardant PP-GF30. Source: Invista; graphic: © Hanser

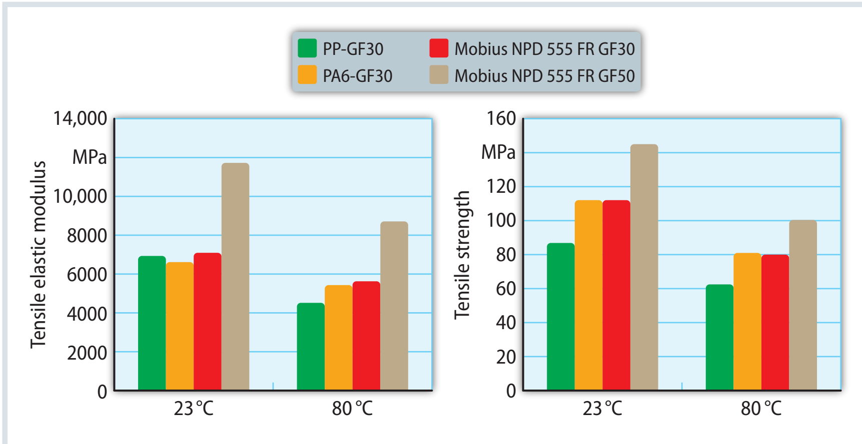

Fig. 4. Tensile elastic modulus and tensile strength of Mobius NPD 555 FR GF30 and GF50 compared with PP-GF30 and PA6-GF30 at 23 °C and 80 °C: the GF30 version achieves values that are at least as good as the other two polymers – the GF50 version exceeds them clearly.

Source: Invista; graphic: © Hanser

Tensile Strength Remains at Same Level after Aging

Decisive for the use of plastics in automotive applications is the aging behavior. In typical tests, samples are stored for 1000 h at 85 °C and 85 % rel. air humidity, and then evaluated in a tensile test. With PA66 Mobius NPD 555 GF30, tensile strength remains at the same level during the entire aging procedure, while the tensile strength of comparison material PA6-GF30 is reduced by some 15 % (**Fig. 5**).

Competitor for SMC Molding Materials

With the development of the PA66 formulation Mobius NPD 555, and in particular the flame retardant version Mobius NPD 555 FR, polymers are available for use in the D-LFT process, which exhibit very good mechanical properties across a wide application temperature range, also under aging conditions. Furthermore, they offer the possibility of using glass fiber contents above 50 wt.% in the D-LFT process reliably. Moreover, classification according to UL94 V-0 can be achieved with Mobius NPD 555 FR. Thanks to this holistic properties profile, the gap between D-LFT materials and thermosetting SMC (sheet molding compound) materials is closed. Mobius NPD 555 allows the manufacture of recyclable voluminous components in up to five times shorter cycle times than with the SMC process.

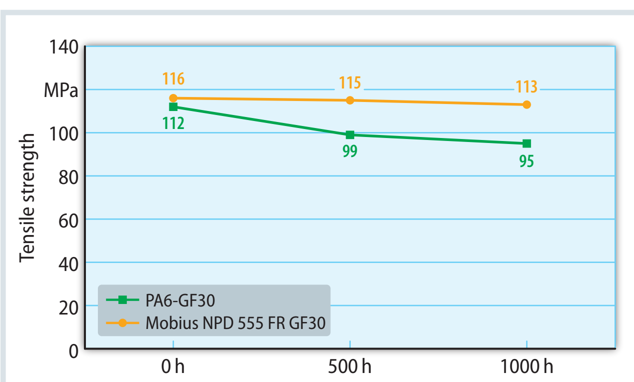

Fig. 5. Tensile strength of Mobius NPD 555 FR GF30 compared with a PA6-GF30 after aging at 85 °C and 85 % rel. humidity: contrary to PA6, the values of PA66 are only reduced slightly. Source: Invista; graphic: © Hanser

Due to the low water absorption of the newly developed PA66, only slight dimensional changes in the envisaged battery enclosures and covers with lengths up to 2 m occur during operation. This enables the available installation space to be used in the best way possible. The very good mechanical performance permits a reduction of wall thicknesses and thereby the design of thin-walled components. This ensures economic advantages due to shorter cycle times and less material consumption. The use of reinforcing elements such as UD laminates or organic sheets can be implemented more cost effectively and in another way – mainly because warping tendency is reduced significantly thanks to the similarly high glass fiber content of the D-LFT material and the fiber matrix preforms. Furthermore, promising pre-trials with thermal runaway tests are being carried out at present. ■