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Long Fiber Thermoplastics

SPECIALTY POLYMERS

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What are Long Fiber Thermoplastics (LFT)

Long Fiber reinforced Thermoplastics (LFT) are a range of materials that bridge the gap between traditional fiber reinforced compounds and composites. These products are easily processed in a standard injection molding process, yet achieve a far higher mechanical performance than traditional short fiber compounds.

High mechanical performance is achieved through a reinforcing fiber network that is formed during injection molding. This fiber network ensures an optimal transfer of forces from the polymer matrix to the reinforcing fibers themselves.

LFT is a range of injection moldable thermoplastics that are manufactured in a pultrusion process by which endless fiber bundles are impregnated and cut into granules. Fiber length is the same as pellet length. After injection molding the resulting fiber length in the end product is about 1–3 mm, compared to around 0,3 mm for traditional compounds.

The amount of stress that can be transferred from the relatively weak polymer matrix to the much stiffer reinforcing fiber depends on fiber length. So higher fiber lengths result in better mechanical performance of the molded parts.

Picture 1: *Piston Mountain bike brake Star-Therm® E C-3XC N7*

Picture 2: *Crank for door mechanism Strator® C-6 S7*

Advantages of Long Fiber Thermoplastics

Key advantages of the LFT fiber structure include:

High strength, particularly at high temperatures

Traditional reinforced thermoplastics loose significant levels of strength and stiffness as the polymer matrix weakens at higher temperatures. The LFT fiber network provides far better support to the weakened polymer matrix. As a result, the loss of strength and stiffness above the glass-transition temperature is far less significant.

Figure 1 and 2 compare the reduction of strength and stiffness versus temperature of the PA 6.6 based Omnix® LF-4062 to the equivalent short fiber grade.

Figure 1: Tensile modulus vs temperature, ISO 527, DAM

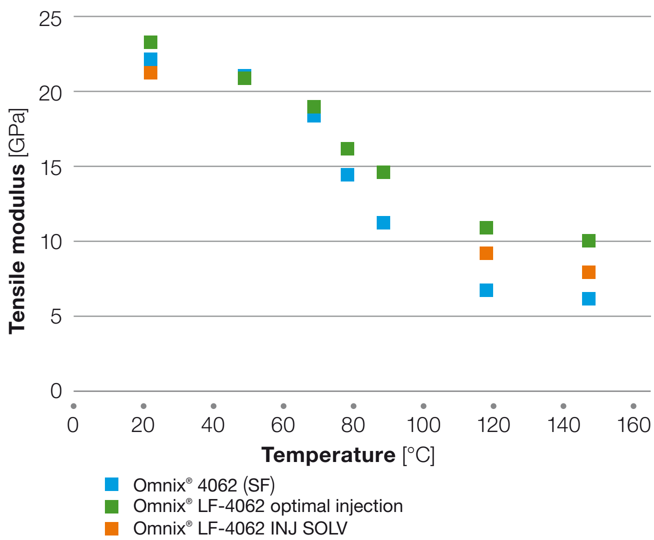
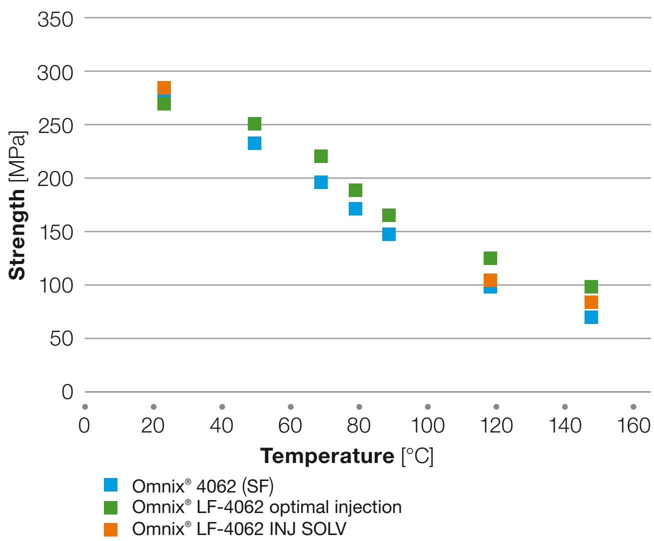


Figure 2: Tensile strength vs temperature, ISO 527, DAM



Excellent resistance to long-term loads and highly fatigue resistant

LFT grades have some of the best creep properties available from any thermoplastic on the market today. Figure 3 and 4 compare the creep resistance of Strator® C-6 (PA 6.6 LGF60) to various PPS, PEEK and PPA grades.

Figure 3: Creep strain vs time, 120 °C, 50 MPa

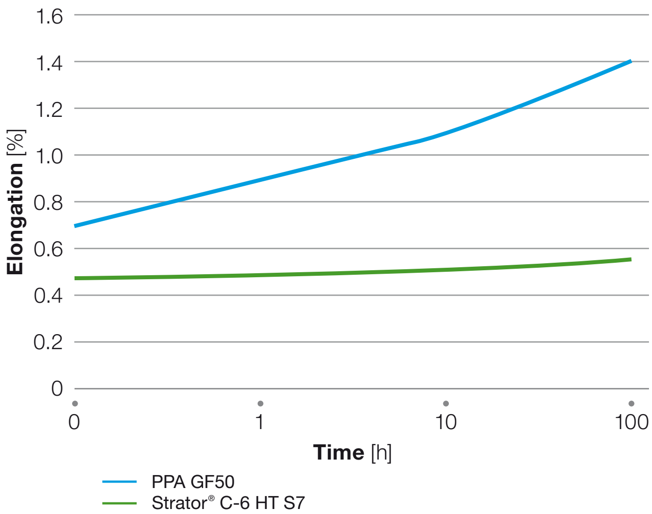
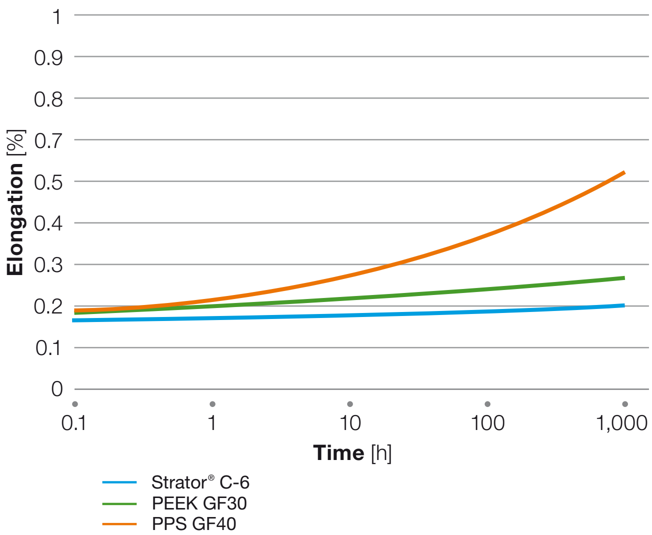


Figure 4: Creep strain vs time, 120 °C, 20 MPa



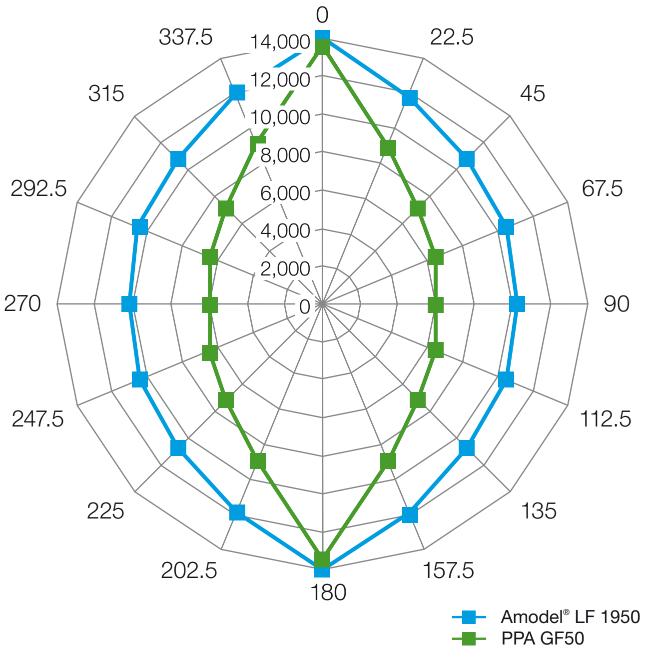
One example is represented by the carrier of a planetary gear drive which was originally manufactured in Zamak. A thermoplastic carrier represented a significant cost reduction. Products like glass fiber reinforced PPA and PA failed because at the operating temperature of 120 °C the bolts supporting the planetary gears deformed under the creep load. Strator® C solved the problem, providing the required mechanical performance as well as excellent moldability.

Another example showing the fatigue performance of Strator® C was based on an industrial claw coupling originally made in aluminum. At 10 million cycles, the aluminum clutch failed at a torque of 100 Nm. Strator® C provided the solution: at 10 million cycles the transmitted torque rose to 125 Nm. Moreover, the cost of the component was significantly lower.

Isotropic mechanical properties and isotropic shrinkage

The LFT fiber network in the molded part has far less orientation than traditional engineering plastics. This means less difference in mechanical properties in and across flow direction as well as a more isotropic mold shrinkage. Figure 5 shows the Stiffness of Amodel® LF-1950 compared to an equivalent short fiber grade.

Figure 5: E modulus MPa vs angle with direction of flow



High shear strength and high burst pressure

As a result of the more isotropic behavior, the shear strength of LFT grades is 30–50 % higher than that of traditional reinforced plastics. For instance, for screw threads this allows for far greater loading. An example of this is the back plate for a door lock (picture 3). The parts manufactured in Strator® C have a pull-out load of the bold 3,500 N, whereas in an equivalent standard grade, the pull-out force reaches a maximum of 2,500 N.

Excellent surface finish

The LFT fiber network is oriented parallel to the surface, so that few fibers break through the surface. This results in an excellent surface finish.

High notched impact, even at minus temperatures

The fiber network results in a far higher crack-propagation energy, even at low temperatures. This makes LFT grades ideally suited for components that are subjected to low temperature impact, like ski bindings or airport conveyor belt components.

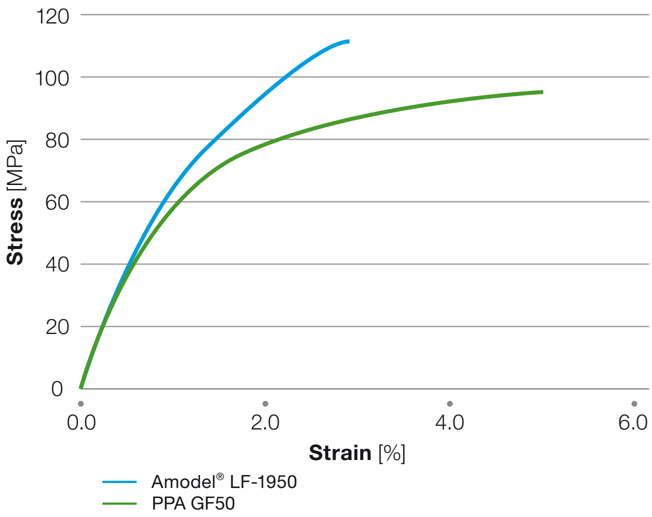
***Picture 3:** Door fitting Strator® C-6 S7*

Product Range

Amodel® LF: Extremely High Stiffness

The Amodel® LF range is based on PPA, giving it extreme stiffness and a high melting point. Compared to the standard PPA-based compounds, the stiffness and strength of the product drop is far less when the base polymer passes through the glass transition temperature at approximately 125 °C. Also, the creep resistance at high temperatures is by far superior. Figure 6 compares the stress strain curve at 150 °C of standard PPA GF50 and Amodel® LF-1950; it has a far more linear response than the traditional short fiber reinforced PPA.

Figure 6: Stress strain curve of PPA GF50 and Amodel® LF-1950 at 150 °C



An application that required the improved creep performance is a E-gas gear segment. This gear is under a high continuous spring load for safety reasons: in the event of an electronic failure the valve controlled by the gear segment must close automatically. Standard PPA GF50 showed significant creep at high temperatures under continuous load from the spring; use of Amodel® LF-1950 solved these problems.

Picture 4: *Frame for electrical switch mechanism Strator® C-6 S7*

Ixef® LF: Ideal for Thin Wall Sections

Ixef® LF is based on PARA, which provides a unique combination of strength and aesthetics. The flow characteristics of Ixef® PARA protect the fiber length, even when injected into extremely thin wall sections of 0,6 mm.

Ixef® LF-1050 has a remarkably high strength and stiffness as well as delivering a high gloss surface finish that is ideal for painting and metalizing. Even when molded in extremely thin wall sections, these properties are maintained, making this a prime candidate for light weighting and miniaturization.

Ixef® LF has low moisture absorption, making it dimensionally stable even in high humidity environments. Furthermore, Ixef® LF has low thermal expansion, which is often a requirement when replacing high precision metal components.

Omnix® LF: The Metal Replacement Solution

The Omnix® LF range is based on a HPPA, which exhibits higher stiffness, less moisture absorption and a better surface finish then standard PA grades.

These grades are particularly suited for metal replacement, for which stiffness and dimensional stability are key requirements. These grades also have excellent heat stability and can be used for applications with long-term temperatures at around 140 °C.

Omnix® LF is extremely easy to process and has an excellent surface finish, even when reinforced with a glass fiber level of 60 %.

Strator®

Strator® consists of PA 6.6 based LFT grades. These are general-purpose LFT grades that can be used for a wide variety of applications with long-term use temperatures of up to 120 °C.

The Strator® A Range is based on PA 6.6, the Strator® C range is based on PA 6.6/6 co-polymers, which exhibit higher flow and better surface finish.

Specialty Grades

For specific application areas, Solvay has developed a grade with enhanced properties such as improved wear and friction as well as electrical conductivity. A number of standard grades are showcased here; if the standard grades do not meet the needs of your application, Solvay can develop a special grade to suit your requirements.

- Star-Therm® E C-3XC: high strength and electrical conductivity
- Tribocomp® wear and friction grades based on Strator® technology

Particularly for highly loaded gears and bearings, our LFT Technology coupled with our Tribocomp® lubricated systems yield extraordinary results. Parts function at far higher temperatures and allow more torque to be transmitted.

Picture 5: *Sun gear for planetary gear system Tribocomp® PA 6.6 LGF30 TS0 S8*

Picture 6: *Planetary gears Tribocomp® PA 6.6 LGF30 TS0 S8*

Metal Substitution with LFT

Many components that are currently manufactured in metal can be produced at lower cost and lower weight in high strength plastics. Compared to metals, plastics offer a number of significant advantages:

- Faster production cycles
- Lower investment in equipment and tooling
- Elimination of finishing operations, such as machining or painting
- No corrosion problems
- Tighter tolerances
- Easier assembly

In order to establish whether it makes commercial sense to switch a part over to plastic, each part needs to be assessed on an individual basis. Tooling, processing and post processing tend to cost far less for plastic parts; how the raw material cost works out depends on the metal as well as the plastic involved. Thermoplastics allow for more design freedom than metals, so additional cost-saving can result from integrating functions.

Solvay has a wide range of experience in the field of metal replacement and is able to provide you with support in assessing potential cost-saving opportunities.

The three key groups of die-cast metal are zinc, magnesium and aluminum-based alloys.

Compared to zinc alloy, LFT compounds offer a 70 % reduction in weight, better creep performance and better strength at high temperatures. Also, LFT compounds do not suffer from the low temperature brittleness that afflicts zinc alloys.

Picture 7: *Electrical switch mechanism*

In comparison to Magnesium alloys, LFT compounds have similar load bearing capabilities over a wide temperature range. The key advantages are improved creep resistance and a far better resistance to corrosion and stress cracking, thereby eliminating the need for expensive surface treatments. Also, tool life tends to be approximately 5 times longer.

Comparison of mechanical properties

In comparison to die-cast metal alloys, LFT grades have similar mechanical performance over a temperature range from –30 to 200°C, depending on the base polymer used. For instance, Omnix® LF 4062 has similar load bearing capabilities as magnesium and zinc alloys, and even approaches the performance of die-cast aluminum up to 180 °C. The stiffness of metals as such is superior; however Omnix® LF 4062 affords greater design freedom, allowing parts to reach similar stiffness through strategic placement of thin-walled ribs.

Figure 7: Comparison of strength vs temperature of Strator® C-6 and various die casting alloys

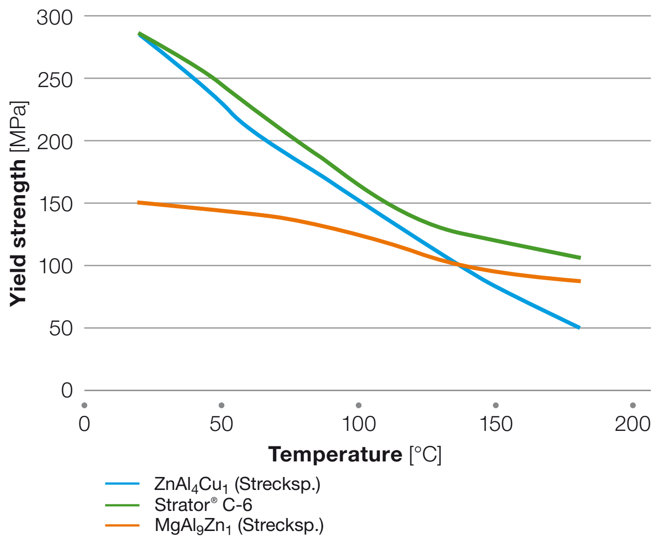


Figure 8: Impact Izod ISO 180 notched and unotched, 23 °C, DAM

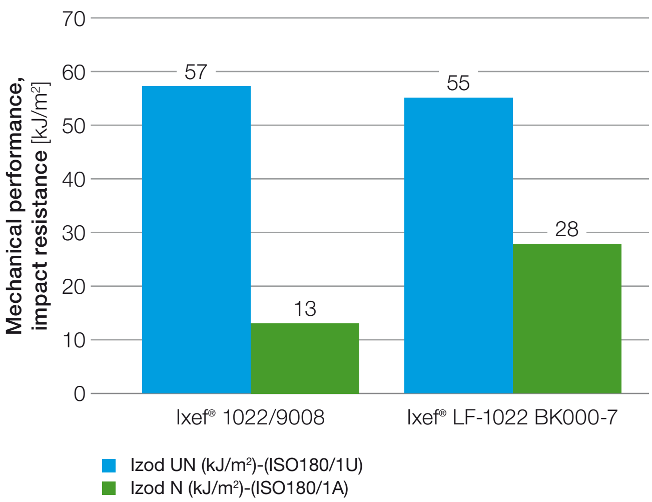
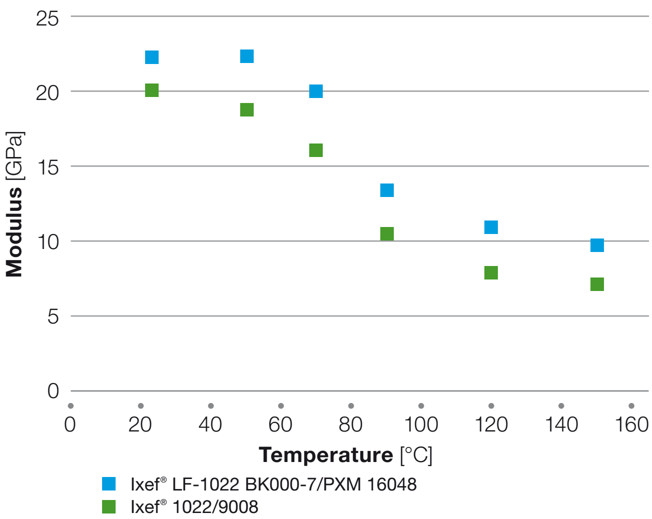


Figure 8: Tensile strength vs temperature, ISO 527, DAM



Creep resistance

LFT grades based on Solvay's polymers have better high temperature creep resistance than many metal alloys such as, for instance, Zamak 3 or Magnesium AZ91D. Special creep resistant alloys like Magnesium AE42 or Aluminum A380 do resist somewhat higher creep loads. Compared to metals, LFT grades can absorb higher creep strains before creep rupture occurs. For instance, for most metals a creep strain of 0.1 % is considered to be the limit, whereas Strator® C-6 can absorb around 0.8–1.0 % in overall strain.

Fatigue resistance

For die-cast metals as well as for thermoplastics in general, fatigue data need careful analysis as they depend on wall thickness, gating, notches, molding conditions and the operating conditions of the part.

As a general rule, the fatigue strength of LFT compounds is competitive or even slightly better than die-cast metals. Fatigue limits for die-cast metals are:

- Mg alloys: ca. 40–50 MPa
- Zn Alloys: ca. 50–60 MPa
- Aluminum alloys: ca. 150 MPa

For PA and HPPA grades with 50 % long fiber, the fatigue limit is generally measured at around 100 MPa.

Processing

LF grades are easily processed on most standard injection molding machines.

To ensure optimal properties in the end product, granule length should be carefully chosen.

- Machines 30–45 mm: 7 mm
- Machines 45–60 mm: 7 or 9 mm
- Machines >60 mm: 7, 9 or 11 mm

Storage and Pre–drying

The LFT materials are supplied in octabins. It is recommended that the material be stored in a cool, dry place with no direct sunlight. Damage to the packaging should be avoided.

Pre–drying these materials is essential; it is recommended that a dessicated air dryer be used. The following drying conditions are recommended:

- Amodel® LF: 4–8 hours at 120 °C
- Ixef® LF: 4–8 hours at 120 °C
- Omnix® LF: 4–8 hours at 80 °C
- Strator®: 4–8 hours at 80 °C

Temperature Settings and Injection Molding

To minimize fiber damage, shear during melting should be kept to a minimum. Therefore, it is recommend that back pressure be kept at minimum in order to maintain a low screw speed and to run with a relatively flat temperature profile.

	Hopper Zone 1	Zone 2	Zone 3	Nozzle Zone 4
Amodel® LF	315–330 °C	320–335 °C	325–335 °C	325–345 °C
Ixef® LF	260–280 °C	260–290 °C	260–290 °C	260–290 °C
Omnix® LF	280–300 °C	280–310 °C	290–320 °C	295–320 °C
Strator®	280–300 °C	280–300 °C	280–300 °C	290–300 °C

In general, it recommend that fast injection speeds be used

Tool Temperature

Tool temperature is a compromise between cycle time and the reaching of maximum properties. LFT has excellent stiffness at elevated temperatures, so these materials can be molded efficiently at high tool temperatures. The following temperatures are recommended:

- Amodel® LF: 135–155 °C
- Ixef® LF: 120–140 °C
- Omnix® LF: 120–140 °C
- Strator®: 80–120 °C

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Specialty Polymers

Worldwide Headquarters
SpecialtyPolymers.EMEA@solvay.com
Viale Lombardia, 20
20021 Bollate (MI), Italy

Americas Headquarters
SpecialtyPolymers.Americas@solvay.com
4500 McGinnis Ferry Road
Alpharetta, GA 30005, USA

Asia Headquarters
SpecialtyPolymers.Asia@solvay.com
No.3966 Jindu Road
Shanghai, China 201108

www.solvay.com

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