

LONG GLASS FIBER POLYPROPYLENE TECHNOLOGY FOR AUTOMOTIVE APPLICATIONS

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ABSTRACT

The use of long glass fiber reinforced polypropylene (PP) in injection molded parts has found new applications due to ease of processing, attractive economics, and good balance of properties. The glass fiber provides mechanical strength and dimensional stability. Part performance is influenced by glass fiber length, processing technique, and resin formulation including coupling chemistry, additives and colorants.

The balance of material properties may allow substitution from engineered resins like PC/ABS blends, ABS, SAN, SMA to lower cost resin options, like polypropylene. The demonstrated property balance may allow reduction of wall thickness. Applications for long fiber reinforced thermoplastics continue to grow with new automotive applications in development such as front end carriers, instrument panels, door modules, lower and overhead console reinforcements.

Dow Automotive has been developing Long Glass Fiber Reinforced Polypropylene systems for various applications including instrument panels and front end systems. Dow has developed a fundamental understanding of the effect of additives and different processing methodologies and their effect on property performance. This paper reviews the mechanical properties for the various LGF processes from fully formulated granulates to direct processes as well as the impact of additives on performance.

INTRODUCTION

The LGF PP market could be ranked in three product families. The biggest and oldest product family is GMT (Glass Mat Technology). These products have had their biggest market growth in the 80's and 90's but volumes are now flat to declining apparently because of the cost and performance balance provided by the PP LGF products. The fastest growth is now seen in the LGF PP pellets and direct LGF PP product families and is targeted to grow further in the future, shown in Figure 1.

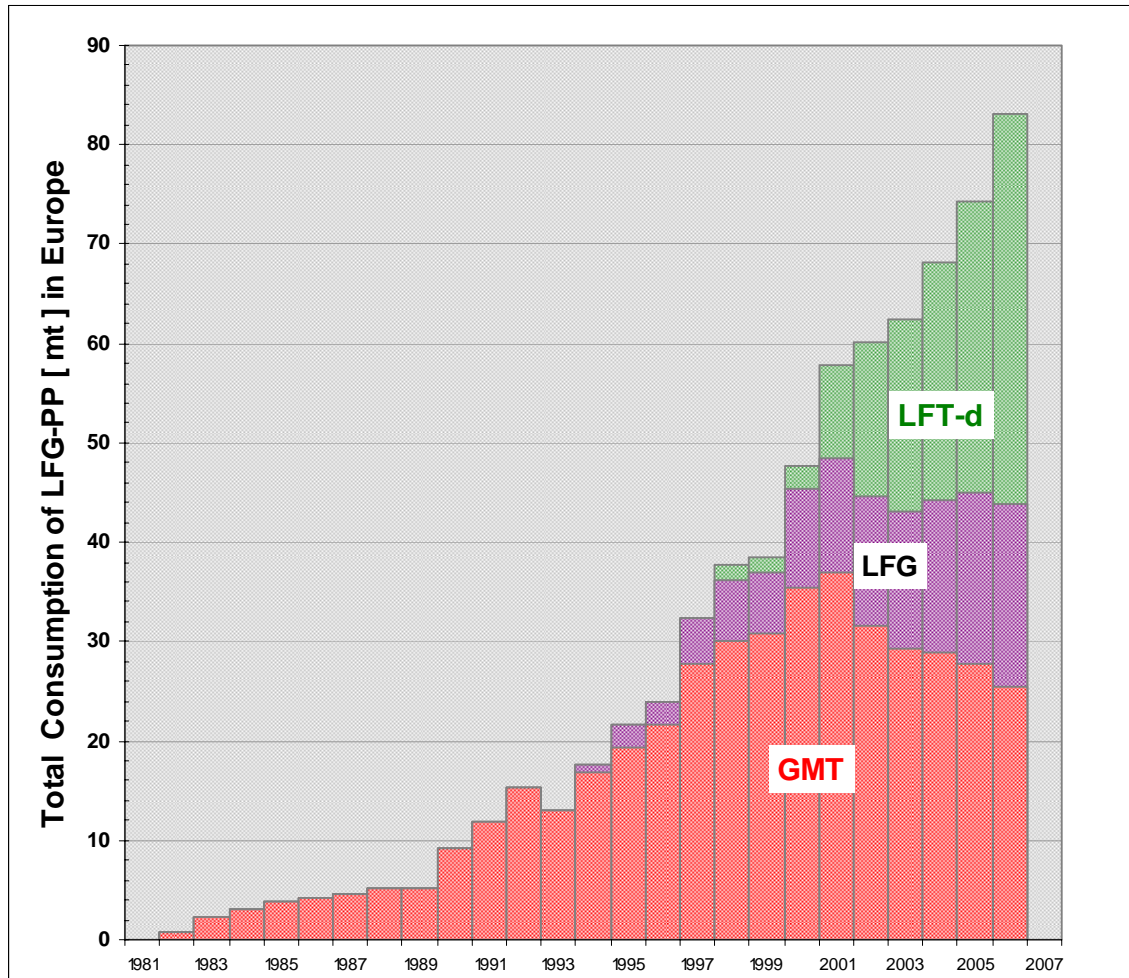


Figure 1: Total consumption of LGF PP (MT) in Europe

Dow Automotive's LGF PP pellets are produced with the pultrusion process where a glass roving is pulled through a melt of polypropylene which contains other functional ingredients. The strands coming out of the pultrusion process are then cut into ½ inch length pellets. Those pellets could be supplied fully finished or in the form of concentrates for dilution with neat Polypropylene to the desired glass level by the customer.

In addition, Dow is involved with supplying polypropylene systems for LGF direct compression as well as for LGF direct injection molding processes (INSPIRE* LGF 7000 and LGF 8000 series) . For those applications, Dow supplies a LGF PP system consisting of a LGF PP base polymer (produced in the reactor) in combination with a master batch containing the additional functional ingredients designed for the targeted application.

MECHANICAL PROPERTIES LGF PP

In general unfilled polypropylene has rather low impact and stiffness properties. Therefore polypropylene resins are often modified to improve their mechanical properties.

In order to improve the impact properties, polypropylene resins are often elastomer filled which could be added in the reactor (copolymers) or could be added through an additional compounding step. Adding elastomer has an adverse effect on the stiffness of the polymer. To improve the stiffness of polypropylene, the polypropylene is compounded with chopped glass resulting in a short glass reinforced polypropylene (SGF PP).

Long glass fiber reinforced polypropylene improves both impact and stiffness properties of the polypropylene base resin. Figure 2 illustrates the differences in properties for modified polypropylene resins:

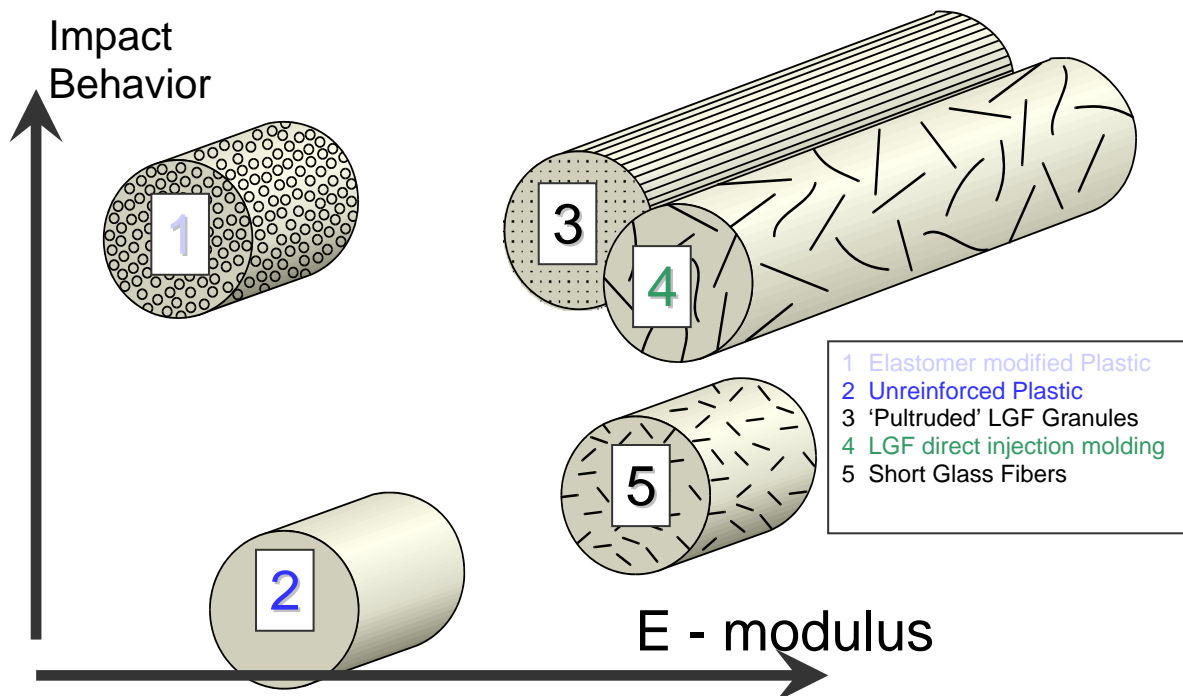


Figure 2: Effect on mechanical properties of modified polypropylene resins.

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The actual property difference of short glass reinforced polypropylene resins vs long glass reinforced polypropylene resins as well as the effect of the glass level and polypropylene type on the mechanical properties is demonstrated in Figure 3. Clearly the impact properties are improved greatly with the long glass fibers while maintaining other physical properties. One can see that the type of polypropylene (A,B) does also affect the performance although to a lesser extent.

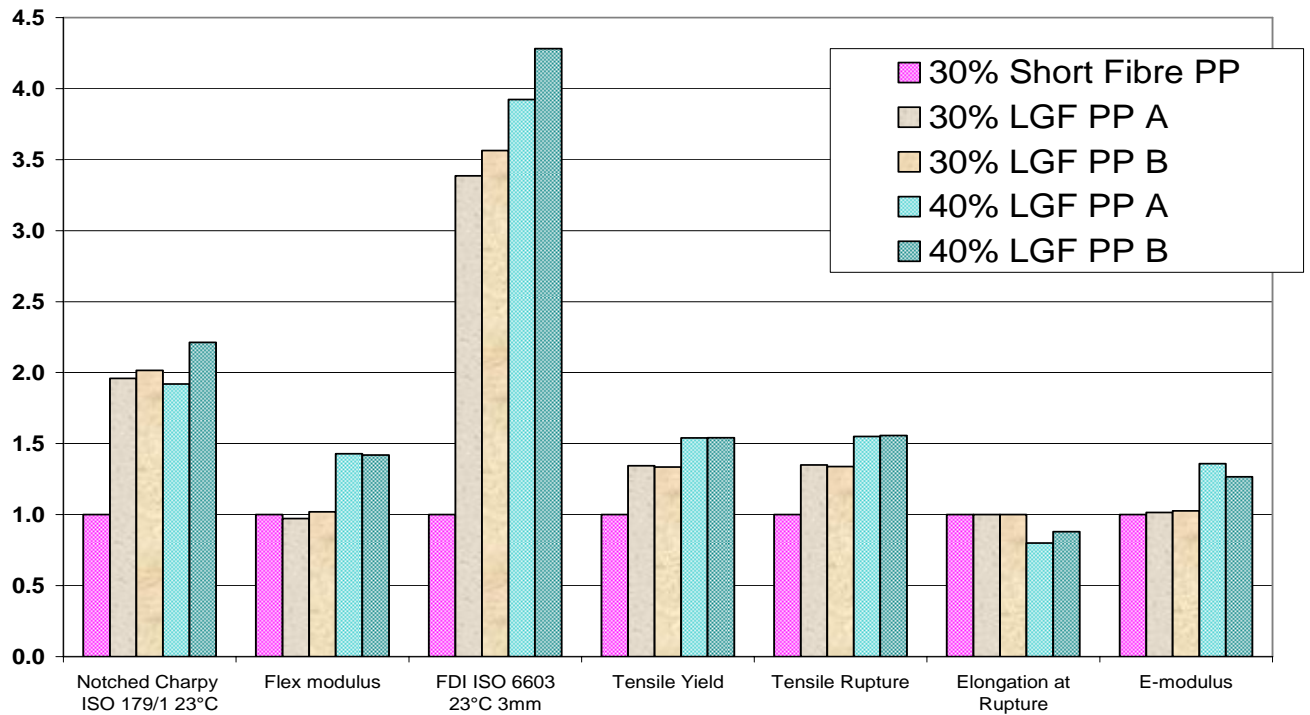


Figure 3: Mechanical properties comparison

When comparing a short glass reinforced PP with a long glass reinforced resin on falling dart impact, the failure mechanism illustrates clearly why we find higher impact values for the long glass. The long glass is still forming a network which is much more difficult to destroy than short glass when a dart is impacting this disk. The broken pieces are still held together by this network, see figure 4.

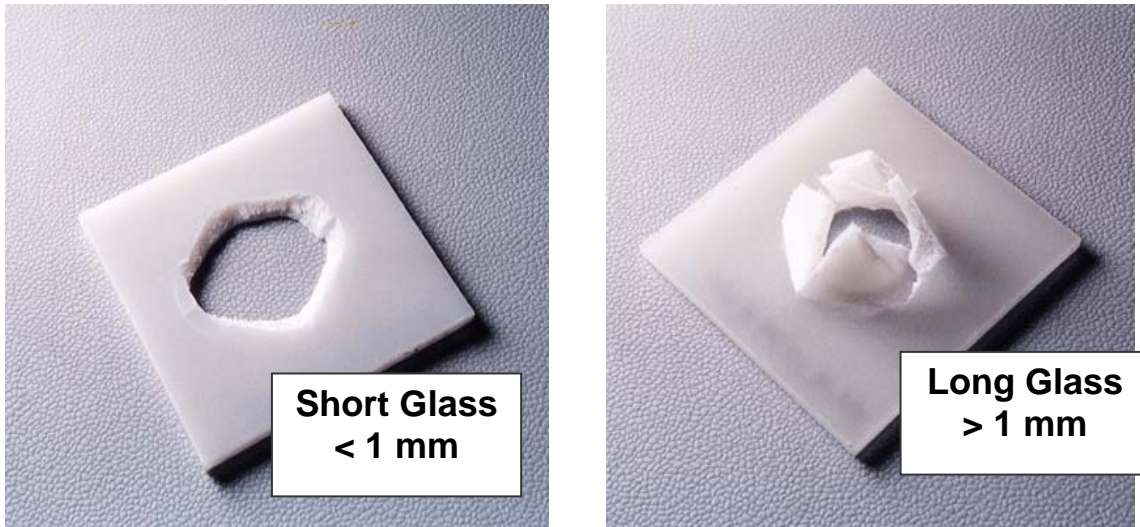


Figure 4: Falling dart impact comparison

INFLUENCE OF LGF PP FORMULATIONS ON MECHANICAL PROPERTIES AND PROPERTIES AFTER AGEING

It is our mission to constantly improve our products by mastering material science and technology. In order to improve and optimize LGF PP products it is critical to understand the fundamentals of additives and PP on physical properties. A Box Behnken Design of experiments was used to look at the influence of PP type, additives and glass loading on the mechanical properties before and after aging, the additives being coupling agents, anti-oxidant packages, processing agents, demoulding agents. The different formulations were produced with the pultrusion process. Based on this design of experiments, we have developed models for formulating LGF PP products. These models are helping us to formulate products that meet our customer needs and the OEM requirements.

The data in figure 5 demonstrates the effect of our formulations on the Tensile modulus at Room temperature. The model explains 98.4% of the variation in our Design of experiment (R Square). The standard deviation of the model is +/- 172 MPa (Root mean Square). Clearly and as expected, the flexural modulus is mainly an effect of the glass fiber content. Our Additive A, additive B and the type of PP have a limited effect on flexural modulus. All other components in our LGF PP formulations showed insignificant effect on the flexural modulus. No interrelations were found to be significant.

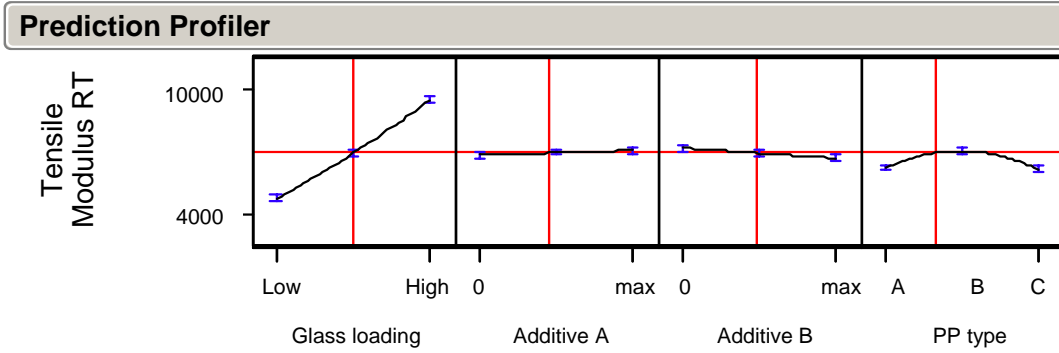


Figure 5: Prediction profiler Tensile modulus RT (MPa)

The two graphs in figure 6 demonstrate the effect of our formulations on the Charpy edgewise unnotched impact at room temperature and their interrelations. The model explains 74.6% of the variation in our design of experiment (R Square). The standard deviation of the model is +/- 5.6 (Root mean Square). The above model shows us that the Charpy is affected by "Additive A". In addition, an interaction exists between "Additive A" and the glass concentration. The pigment concentration has a slight negative effect on the Charpy impact.

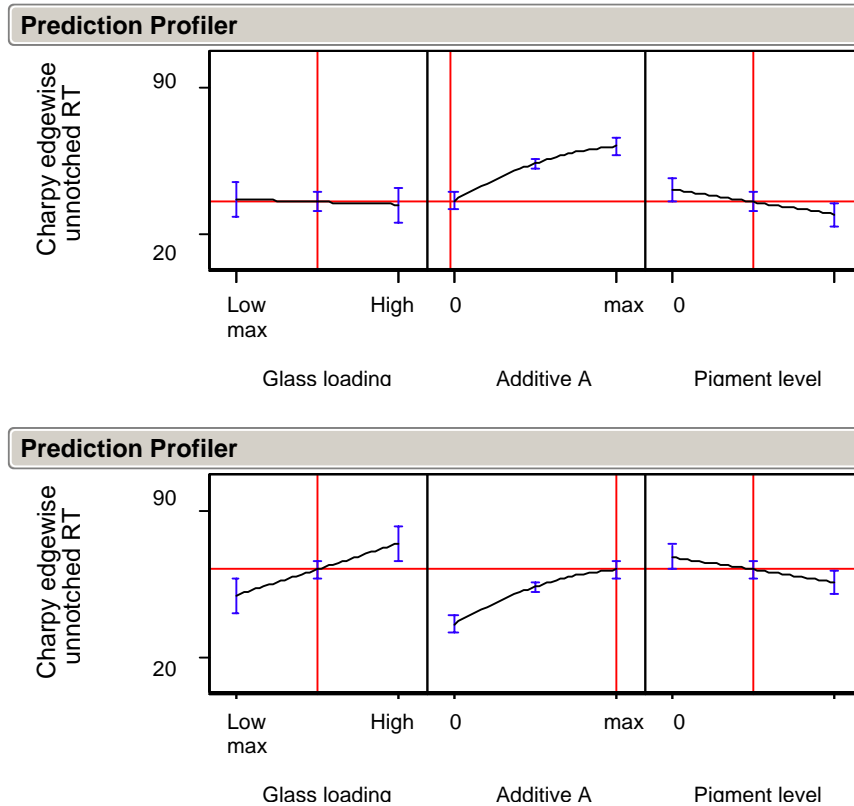


Figure 6: Charpy edge unnotched at Room temp. with & w/o additive A (kJ/M2).

As part of the development of these models, property retention after aging was examined. Figure 7 demonstrates the property retention of the Charpy impact after 1000 hours at 150 C. This model explains 93.1% of the variation in our Design of experiment (R Square). The standard deviation of the model is +/- 7% (Root mean Square). The above model shows us that the % retention of Charpy after 1000 hours at 150 C is mainly dependent on the level of "Additive B". All other components were found to be insignificant.

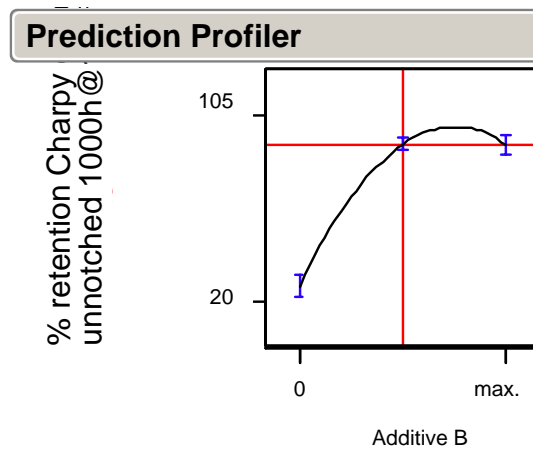


Figure 7: Property retention Charpy edgewise unnotched after 1000hrs @ 150C (in %)

Besides the above demonstrated models we have developed prediction profilers for most of the mechanical properties measured on LGF PP which are helping us to design the most optimized formulation for our customers applications in order to meet their OEM requirements.

LGF PP SYSTEMS COMPARISON

We have developed formulations that meet the industry needs whether for fully formulated pellets for injection molding or glass, master batch and polypropylene systems for in line processing on injection compression type of equipment. Recently, we've developed a 60% concentrate solution that allows one to get similar to better property performance while gaining an improved cost position versus a fully formulated pellet.

The data in Table 1 demonstrates this performance when compared with DLGF 9200.00

Table 1: Comparative Data in Parts Molded to 20% Glass Concentration between Fully Formulated Pellets and Concentrates

Property	Unit	Test method	DLGF 9200	60% Concentrate
		ISO		
Density	Kg/m3	1183	1030	1030
Falling Dart 3mm @ RT	Total Energy (J)	6603-2	10.7	8.2
Charpy edge unnotched RT	kJ/m2	179/1eU	30.3	44.8
Charpy flatwise unnotched RT	kJ/m2	179/1fU	30	36.3
Tensile strength at yield 50 mm/min	MPa	527-2	72.5	80.3
Tensile elongation at rupture 50 mm/min	%	527-2	1.9	2.2
Tensile modulus	MPa	527-2	4701	4905
Flexural Strength	MPa	178	100	125
Flexural modulus	MPa	178	4559	4712

Our goal has been to meet and exceed the requirements of the industry by providing solutions to match existing equipment and to assist in meeting the OEM requirements for performance. We've developed the material science to understand the optimum formulations for property performance optimized to the various equipment you own or are purchasing.

The LGF PP OFFERING

For the LGF PP direct compression as well as the LGF PP direct injection moulding we are offering a system which consists of an LGF PP base polymer in two versions, the 7000 and 8000 series and a combi masterbatch which is designed to meet the customers specific requirement, see figure 8.

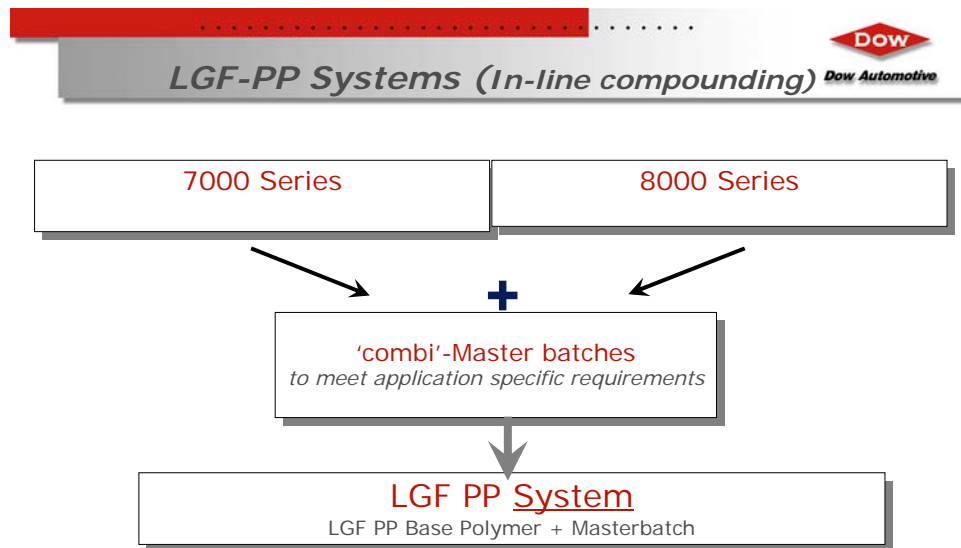


Figure 8: LGF PP system for direct compression or injection moulding

In our LGF PP pellets, we offer products with glass levels from 20 to 60 %. The 20 to 40% glass loaded products are fully finished products while the 60% LGF PP products are intended for dilution with the 7000 series or 8000 series base polymer resins.

Figure 9 gives an overview of our product portfolio with the typical applications.

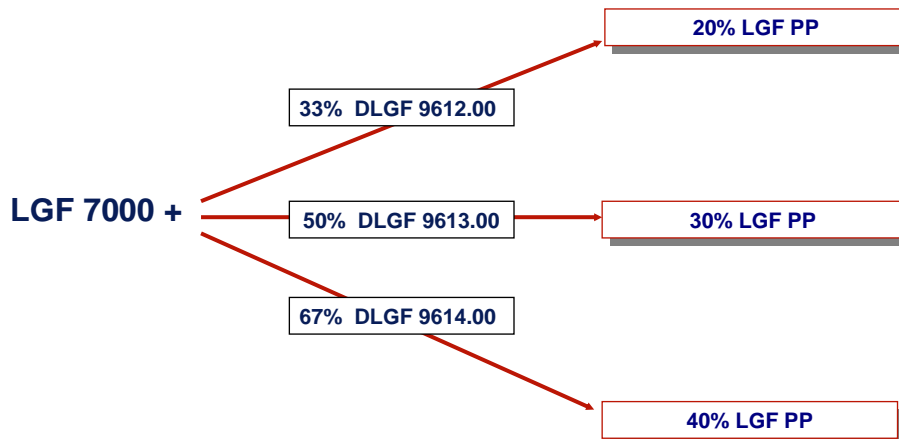
Figure 10 is giving an overview of the nomenclature of the LGF PP systems for dilution.

Material	Description:	Typical Application:
INSPIRE* LGF 9200 INSPIRE* LGF 9210	20% LGF-PP Low smell and emission	Instrument panel
INSPIRE* LGF 9300 INSPIRE* LGF 9310	30% LGF-PP Low smell and emission	Instrument panel, Front-end Carrier
INSPIRE* LGF 9400 INSPIRE* LGF 9410	40% LGF-PP Low smell and emission	Front-end Carrier, Concentrate to let down with feedstock
INSPIRE* LGF 960X INSPIRE* LGF 961X	60% LGF-PP Concentrate Low smell and emission	Concentrate to let down with feedstock

* Trade mark of The Dow Chemical Company

Remark: above mentioned products might not yet be available under above mentioned trade marks but still under development nomenclature

Figure 9: Product overview



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Figure 10: LGF PP systems for dilution

CONCLUSION

We have developed a basic understanding of the material science to influence mechanic properties of polypropylene long glass fiber pellets. These material solutions can be optimized for the different applications as specified by the OEM's. The process technologies utilized by the molders is varied and our product offering has been developed to match their respective capabilities. We have demonstrated continued material science understanding and innovation to ensure the PP LGF materials have the performance and cost competitiveness necessary to meet the market demands

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