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Glass Bubbles Reduce Weight of TPO Parts

Resin compounder Noble Polymers of Grand Rapids, Michigan, a subsidiary of Cascade Engineering, has developed a low-density polyolefin resin formulation that reduces the weight of TPO plastic parts by up to twenty percent. This masterbatch bulk resin additive incorporates hollow glass bubbles from 3M Company to displace resin and reduce part density in injection molded, thermoformed and extruded thermoplastic parts.

"Mandated standards for Corporate Average Fuel Economy (CAFE), and the drive to reduce industrial emissions and achieve more sustainable production methods have led to a growing demand for enhanced TPO production methods," said Tim Patterson, Noble Polymers Business Unit Manager. "Glass bubble additives in our masterbatch material displace hydrocarbon-based resin content and lighten parts to help cut transport fuel consumption."

Noble Polymers markets both off-the-shelf and custom formulated TPO resins for automotive, office furniture and building and construction applications. The company also provides material selection, integrated design analysis and empirical testing services.

"Use of density-reducing agents for filled TPO raw material is not a new concept," Patterson notes. "While various filler materials have been used to reduce TPO part density, glass bubbles have significant process and resin displacement advantages over alternate fillers. We've found that the addition of glass bubbles yields secondary benefits to TPO components as well, including improved part stiffness, greater dimensional stability and reduced shrinkage."

According to Patterson, traditional resin displacement mineral fillers such as cenospheres, asbestos particulate, chopped glass fiber and calcium carbonate ($CaCO_3$) have considerably less volume per unit weight than glass bubbles. For example, 1kg of typical glass bubble material has a volume of 1666.7cc, while the equivalent weight of $CaCO_3$ occupies (displaces) only 370.4cc. Thus its resin displacement potential per unit of weight is only a fraction of that of glass bubbles.

Glass Microspheres

Hollow glass bubble technology was developed by 3M in the 1960s, and today this material is used in aerospace and military systems, paints and coatings, marine hulls, oil and gas exploration and production and other industrial uses. 3M Senior Product Development Specialist, Steve Amos, of the Energy and Advanced Materials Division laboratory explains that 3M™ Glass Bubbles are made from a chemically stable soda-lime borosilicate glass, and produced in a range of properties, including nominal diameters from 9-microns to 70-microns, densities from 0.15 to 0.60 g/cc, and compressive strength ratings from 250 psi to 30,000 psi.

Noble Polymers Materials Engineer Bo Wang explains that 3M and Noble have collaborated on resin masterbatch developments for a number of months, with the glass bubble supplier contributing to feed screw design and porting refinements, and recommending process variables to help ensure bubble survivability during formulation and TPO production. 3M also assisted Noble with information about loading levels, and conducted quality tests to measure and confirm bubble survival in molding and extrusion processes.

Glass Bubble Selection

Wang notes that the class of 3M glass bubbles selected for a masterbatch depends on the end-use of the TPO component. For example, the pressures involved in TPO injection molding require use of glass bubbles with elevated crush strength, such as 3M's iM30K product, which is rated at 30,000 psi. Lower crush strength bubbles such as the K46 product (at 6,000 psi) can be used for less demanding thermoforming, compression molding and extrusion processes. Glass bubble strength is generally proportional to density, and thus lower strength bubbles are less dense, and have greater potential for TPO weight reduction than thicker-walled, higher strength bubbles.

According to Wang, bubble size impacts TPO surface finish. Bubble size also affects stress transmission through the composite, with smaller bubbles contributing to more favorable impact and tensile properties.

"In general, lower strength (lower density) glass bubbles are best suited to items such as extruded and thermoformed tool boxes, rocker panels, plastic wood planks," said Wang, "while higher strength bubbles are required for injected molded interior and exterior automotive components, and other industrial components."

Noble Polymers development work shows that the degree of mold shrinkage in a TPO part is inversely proportional to the volume percentage of glass bubbles in the mix. The modulus (stiffness) of a part also increases in proportion to the ratio of glass bubbles to resin. The positive attributes of increased stiffness and heat distortion temperature (HDT) as well as decreasing coefficient of linear thermal expansion (CLTE), shrink, warp and sink marks continue to improve as the percentage of glass bubbles in the resin mix rises. Tensile strength, elongation, and impact strength tend to decrease as well. Complementary additives in the masterbatch can modify these values to some degree.

Product ID	HDPE 2	40% 6800MB 60% HDPE 2
	Technical Data Sheet	Injection Molded Specimen
MFI, g/10min	5	2.6
Flexual Modulus, psi	103,000	138,000
Ash Content, 3M Method, %	NA	13.426
Specific Gravity	0.948	0.863
Tensile at Yield, psi	3380	2450
Elongation at Yield, %	NA	10.6
Elongation at Break, %	70	452
Gardner Impact, in-lbs	NA	20

Figure 2: Characteristics of a representative high density polyethylene part, with and without a resin displacement additive.

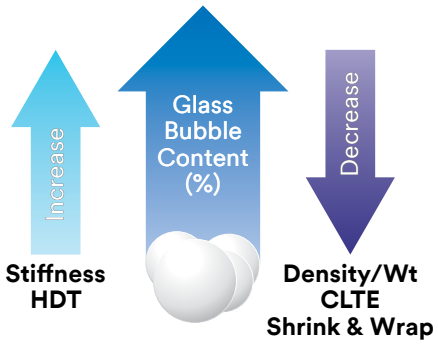

Figure 1: TPO part properties vary in accordance with glass bubble size and proportional content in the masterbatch.

"In general, plastics are flexible and experience ductile failure under stress, while glass adds stiffness but is more prone to brittle breakage," said Wang. "It is possible to improve TPO impact strength by adding an impact modifier to the masterbatch that reduces potential for brittle failure while maintaining the stiffness advantage." According to Wang, the concentration of glass bubbles in a masterbatch additive mix varies, and can be as much as 50 percent by weight, depending on customer requirements. Finished parts made using this masterbatch glass bubble concentration will be 20 percent lighter, or more, than resin-only parts as illustrated in Figure 1.

"Process tests show that a Noble masterbatch formulation with glass bubbles can cut TPO injection molding production time as much as 20 percent," said Wang. "This benefit is apparently related to changes in thermal properties that result from displacing resin with hollow glass (reduced mass), and the resulting time savings are concentrated primarily during the cooling period."

Noble Polymers works with individual customers to determine precise TPO part specifications, and multiple interests are weighted in a staged/gate process to achieve optimum density reduction while meeting necessary physical specifications. The resulting formulas are confidential and proprietary to customers. Noble Polymers Business Manager Tim Patterson estimates that nearly half of the company's TPO masterbatch customer applications call for some degree of formula customization, while the balance can be met using the company's standard masterbatch material.

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