Reinforcing options for compounders

PHOTO: OWENS CORNING

Main image: Owens Corning says almost all of its chopped strand products are now boron-free Advantex glass, which offers environmental gains over standard E-glass

Glass reinforcement makers are improving products and enhancing their supply positions to cater for increasingly global customers. Peter Mapleston finds out more

Glass fibre reinforcements are a pretty mature product. While there may be opportunity to further improve performance in thermoplastics applications, judging from some of the most recent announcements and conversations with fibre manufacturers it seems we may be nearing the limits. Even so, potential surprises remain, as one major has recently demonstrated and we will discuss later.

For the most part, however, industry focus has turned to ensuring compounders can count on continuity and consistency of supply wherever they are in the world. Outside the world of glass, meanwhile, interesting work is going on to provide reinforcement with alternative materials – and in one case at least not using fibres at all.

Japan's **Nippon Electric Glass** (NEG) is certainly on a growth path in glass fibre. Last year, it acquired PPG's manufacturing facilities, R&D and administrative operations in the US, adding them to the European PPG glass fibre operations it acquired in 2016. The move means it now has production locations in the three main market regions. PPG also divested its ownership interests in two Asian glass joint ventures co-owned with Nan Ya Plastics in 2016 as well.

NEG has a 42-year history in production of glass fibres and has been building up its presence in the sector for several years. Its operation in Malaysia is the largest chopped strand production site in the world and its global glass fibre capacity is over one million tonnes.

Co den Besten, Marketing and R&D Director EMEA at NEG, says that the company has invested more than €100m in the European and US locations to support the growth of the business. In Lexington in North Carolina in the US, for example, a furnace has been switched from production of yarns to chopped strands as of July this year. And at its Wigan location in the UK, a furnace has been rebuilt to give the company the chance to introduce improved technology that den Besten says will result in improved efficiency and increased capacity. In Hoogezand in the Netherlands, a large investment is underway in a new furnace that is projected to start up early next year. In addition, an

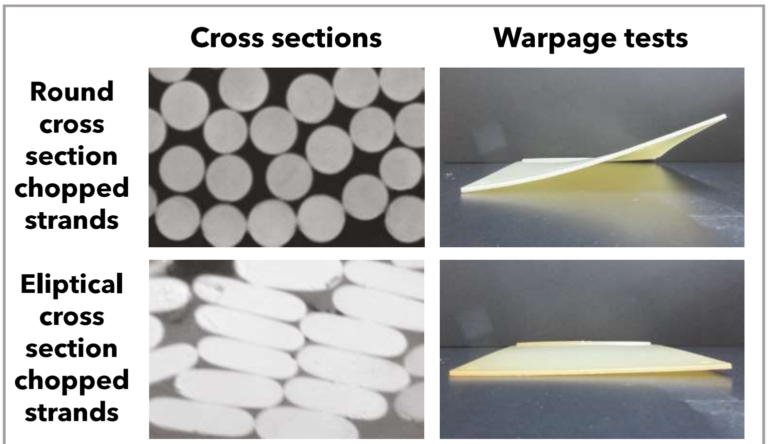

Figure 1: Images showing warpage in two edge-gated square test plaques (approx 170mm by 170mm by 2.2mm), moulded in PA66 30% reinforced with round and flat fibres respectively. Test bars (80 mm by 25 mm) were cut from the centres of the plaques in the flow and transverse directions and tested for flexural strength. Flexural strength in round fibre-reinforced test bars cut in the flow direction was 1.7 times higher than in bars cut in the transverse direction, while the ratio in test bars moulded with flat fibres was much lower, at 1.2.
Source: Nippon Electric Glass

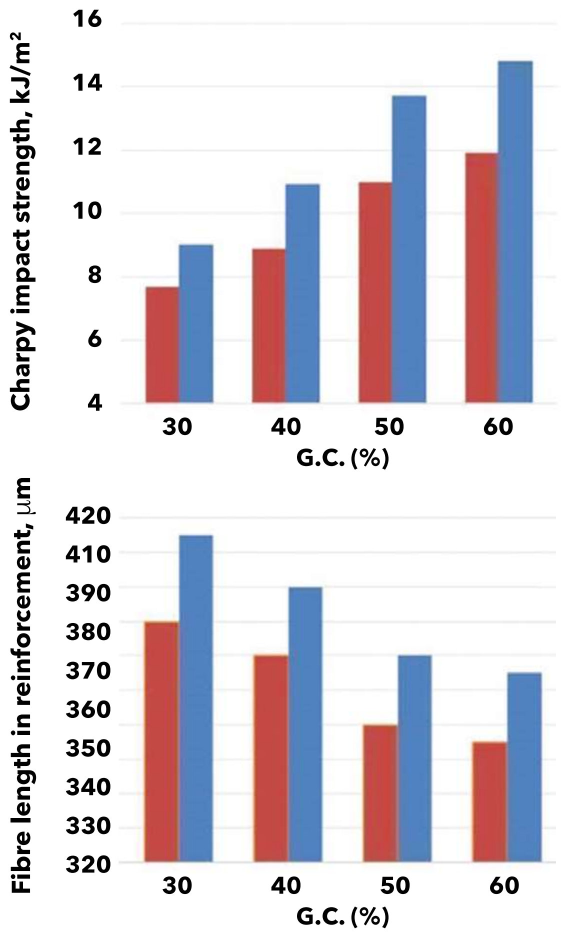

Figure 2: Comparison of impact strength and fibre length retention of PA66 reinforced with conventional round glass fibres (red) and flat glass fibres (blue)
Source: Nippon Electric Glass

incremental capacity increase is planned for the Malaysia location.

Flat innovation

NEG has also strengthened its global research operations with a new R&D building opened early this year at Notogawa in Japan. One of the most recent results of its research activities is the development of a "flat" glass fibre for thermoplastics. The products, which are more elliptical than flat, are currently produced on a pilot line in Notogawa, but den Besten says NEG it will scale up soon to a larger capacity. Products are available for various polymers, including PA, PP, PBT, and PPS.

"The main advantages for flat glass fibre are reduced warp, higher flow and better surface quality of moulded products, but it also shows very promising mechanical properties at higher glass contents," den Besten says (see Figures 1 and 2).

In the US, NEG has launched an improved roving for long fibre-reinforced PP. TufRov 4520 is said to show improved processing with very low fuzz, while mechanical properties are claimed to be better than existing LFT rovings for this segment. The company is now considering marketing it in Europe. Also for the LFT segment, it has introduced a roving for food compliant polyamides. TufRov 4515 is said to show good processing performance while meeting all requirements for latest European Food compliance standards.

In the chopped strand segment, NEG says demand for higher performance in a number of thermoplastic polymers can be met with products based on a modified glass composition. It now offers several chopped strands based on its Innofiber XM technology, which was originally developed for the wind energy segment but is now offered for PA and PBT with a grade for PP in the offing.

Other chopped strand products launched in Europe for the thermoplastics segment include ChopVantage HP 3720, designed for PBT and PET compounds requiring food contact compliance, and ChopVantage HP 3293 and HP 3290 (13 and 10μm diameter respectively), developed for improved performance in products coming into contact with hot detergents. Further products are set for introduction next year.

Den Besten says NEG has also decided to support global customers by producing traditional Asian "T" products in Europe and the US as well. "We are also transferring HP products to Malaysia," he says. "NEG will continue to invest in capacity in all regions in the world and we will continue to develop new products to meet new requirements from our customers." ›

PHOTO: OWENS CORNING

Above: Owens Corning has invested $50m at its glass reinforcements facility at Chambéry in France, expanding capacity for chopped strand products

Supporting demand

NEG is not the only company investing in the sector. **Owens Corning** (OC) recently spent some $50m to rebuild a glass melter and expand production capacity by approximately 25% at its composites manufacturing facility at Chambéry in France. It says the investment, which came on stream in the summer, will support growing demand for reinforced thermoplastics in Europe.

Announcing the expansion, Umberto Rigamonti, OC's Vice President and Managing Director of Glass Reinforcements Europe and Global Thermoplastic Products, said: "This investment will support our customers' growth in the thermoplastic chopped strand market by ensuring that we continue providing consistent, high-quality products. It also strengthens our value proposition to thermoplastic customers, supporting our respective growth agendas."

With the rebuild now completed, all thermoplastic chopped strand products from the Chambéry facility are based on boron-free Advantex glass. In fact, according to Chris Skinner, Vice President of Strategic Marketing, Composites, virtually all of the company's production of chopped strand fibre is now boron-free. He says Advantex glass contributes to decreased emissions and reduces the environmental impact of manufacturing fiberglass compared to standard E-glass. Advantex also provides superior performance in composites used in corrosive environments compared to E-glass, he adds.

Discussing other changes in product line-ups, Skinner says that, as reinforced thermoplastics take on more roles in structural and semi-structural parts in areas such as automotive, reinforcement levels are creeping up. He says 15 years ago the average glass fibre level in polyamides was around 18%. Today it is more like 30% and some compounds have much higher levels. To facilitate these higher fill rates, OC and other fibre makers are now enhancing the dispersibility of the fibres, improving consistency, and offering thinner fibres – 10 micron diameter rather than 13 micron, for example.

Beyond product development, which Skinner admits is moving at a slower pace now than in the past (something he says applies to the glass fibre industry in general, not just to OC), the company is putting strong emphasis on being able to respond to developments in demand all around the world.

Global customers

Globalisation of the customer base, especially in the automotive sector, is pushing globalisation of reinforcement supply – something which favours majors such as OC and NEG over smaller, more regional companies, Skinner says. Beyond its major bases in Europe and North America, OC is also expanding its presence in Asia. The company has, for example, invested around $110m over the last two years to expand capacity at its composites operations in India, installing an 80,000 tonne/yr glass melter at its facility in Taloja, which started up earlier this year.

Further east, OC entered into technology licensing and manufacturing supply agreements in April this year with Taiwan Glass Ind Corp, based in Taipei in Taiwan. The agreements will leverage its Advantex glass fibre reinforcements and the manufacturing platform of Taiwan Glass to produce a mix of products for both thermoplastic and thermoset applications. The companies will continue to operate as separate commercial entities.

OC said the agreements with Taiwan Glass will

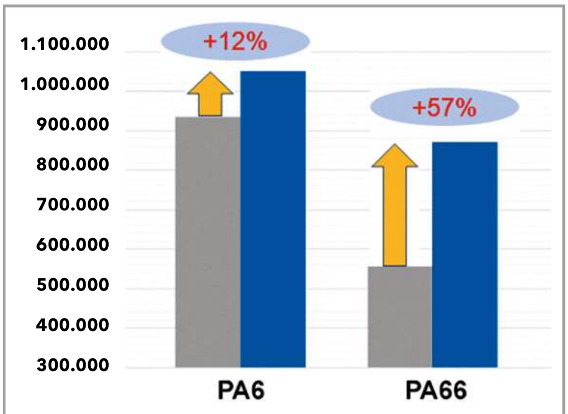

Figure 3: Chart showing the fatigue performance of test samples in PA 6 and 66 compounds reinforced with ThermoFlow 675 (blue) and a competing chopped strand product (grey). Samples were put under sinusoidal stress (50-5.0 %) with a frequency of 1 Hz and tested to fracture. The vertical axis indicates the number of cycles before fracture ***Source: Johns Manville***

support its growth in the Asia Pacific region beyond China, while also expanding capacity to supply its existing customers in Europe and North America.

Polyamide focus

At **Johns Manville**, Karin Demez, Global Marketing and Portfolio Leader for Fibres, says the company's latest products for PA compounds provide "excellent performance in fatigue performance, which become more and more demanding when long-term testing and vibration tests are performed for demanding automotive applications." She says ThermoFlow 675 short-glass fibres have out-performed benchmarking fibres in PA6 and PA66 during fatigue testing by more than 10% and 50% respectively (Figure 3).

According to Demez, ThermoFlow 675 chopped strands yield excellent tensile strength in PA6 after aging for more than 2,000 hours at 190°C. "Those properties enable compounders to continue to develop new solutions for demanding under-the-hood applications in both petrol/diesel engines and new critical electrical components for e-cars," she says.

Alternative solutions

Development work is continuing on mineral-based reinforcements that may provide alternatives to glass or to other mineral fillers that have only minimal reinforcement effect. At basalt fibre producer **Mafic**, Head of Sales and Marketing Jeff Thompson says the company has been making good progress in its thermoplastics work. Basalt fibres have a similar structure to glass fibres. It offers chopped basalt fibres in various lengths, as well as rovings, and is pitching them as a lower-cost alternative to glass, claiming they still provide high stiffness and strength.

"We are also excited about our new basalt fibre production facility in North Carolina," Thompson says. Mafic is targeting furnace heat-up at the facility, which will be the first to produce basalt fibre in the US, for December this year. Mafic already produces at Kells in Northern Ireland, not far from the Giants Causeway, possibly the most famous basalt deposit in the world.

Independent technical consultant Chris DeArmitt, who has worked for numerous functional filler companies, points to the high pace of growth in such materials. Notable among

PHOTO: JOHNS MANVILLE

Right: The latest Thermoflow grades from Johns Manville target PA applications requiring high fatigue performance

recent developments, he says, is a new alternative to wollastonite, the dominant mineral filler in the marketplace at present. Supplier of the new product, called FiberFlex, is **Arctic Minerals**.

"This new amorphous mineral fibre product is just being introduced as an experimental product with samples available shortly," DeArmitt said earlier this year. "It has a higher aspect ratio than wollastonite to provide superior mechanical properties and unlike wollastonite, it contains no detectable crystalline silica. The main applications are as a reinforcement and to provide scratch resistance in PP automotive parts. Arctic Minerals have a waiting list for first samples."

Reacting to lignin

Another alternative for providing reinforcement that sits on the border between filler addition and polymer blending has emerged from the **Oak Ridge National Laboratory** in Oak Ridge in Tennessee in the US. "We are using reactive compounding method to produce new materials based on natural polymer-lignin," says Armit Naskar from its Carbon and Composites group. "Lignin is historically treated as filler. It is an organic material with branched chemical architecture and can be mixed at submicron scale in the polymer matrices to yield materials with outstanding properties."

Naskar recently co-authored a paper reporting on a new class of thermoplastic elastomers created by

PHOTO: MAFIC

Right: Basalt fibres from Mafic are among the potential alternatives to glass for polymer reinforcement applications

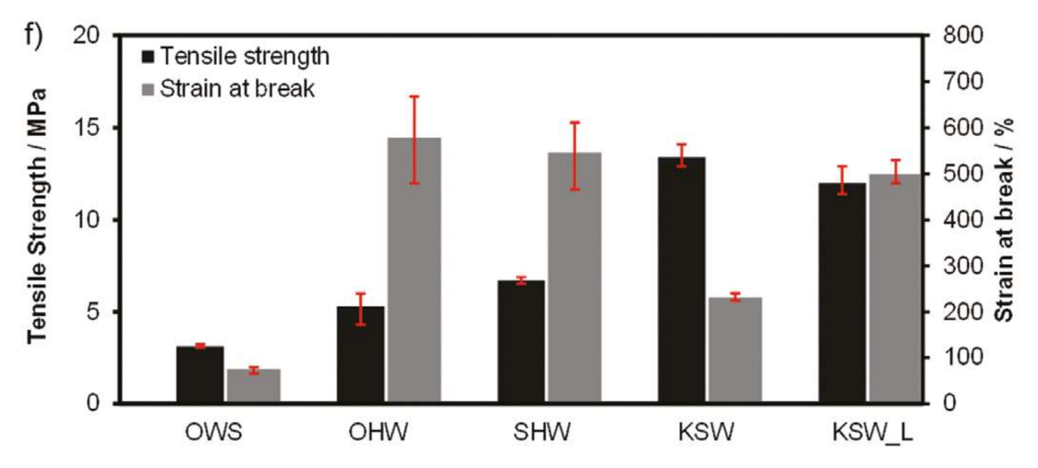

Figure 4: Tensile failure strength and elongation at break of mixtures of NBR-33 with different lignins at 50/50 ratio, including organosolv wheat straw (OWS), organosolv hardwood (OHW), sodium hydroxide extracted hardwood lignin (SHW), Kraft softwood (KSW), and methanol fractionated low-molecular-weight Kraft softwood lignin (KSW_L). ***Source: ORNL***

introducing nanoscale-dispersed biomass-derived lignin into nitrile rubber. The authors say the material is "a compositional analogue of ABS, where the styrene fraction is completely replaced with lignin." The researchers say the material offers significantly higher toughness than ABS (Figure 4).

"Temperature-induced controlled miscibility between the lignin and the rubber during high shear melt-phase synthesis allows tuning the material's morphology and performance," the researchers explain in a paper published in the journal Advanced Functional Materials. They say the product has "unprecedented" yield stress (15-45 MPa).

Stiff thermoplastic elastomers would find immediate use if they were based on low-cost renewables, the researchers argue. "The common bio-based thermoplastic elastomers have low softening points and most of these elastomers require expensive polyesters or polyamides that have poor hydrolytic stability, which limits their end uses. Hydrothermally stable, higher performance thermoplastic materials made of renewable polymer hard segments bridged with soft segments will offer a great solution for renewable thermoplastic elastomers."

Energy efficient

The team's energy-efficient method for synthesising and extruding high-performance thermoplastic elastomers based on lignin involves fractionating a rigid, thermally malleable lignin that can then be melt-mixed with appropriate soft commodity rubbers to form high-performance polymers with precisely controlled morphology.

Previous reports on incorporation of lignin into rubbers as a potential candidate for the replacement of the conventional reinforcement – carbon black – showed little effect on rubber reinforcing due to its large particle size and lack of interfacial interactions, they say. "Our method…eliminates the need for costly and energy-intensive chemical functionalisation of lignin and obviates the need for a separate unit operation of polymer synthesis in a reactor with solvents," the researcher team claims.

Morphology challenge

"Common styrenic thermoplastic elastomers typically contain homogeneous distribution of chemically bonded domains of polystyrene (50–200 nm in length) in a soft matrix. Our research strategy was to replace polystyrene segments with lignin in similar soft matrices. The 'grand challenge' in this approach is that of controlling the morphology of lignin domains in the soft rubbery matrix and retaining these domains during processing, testing, and end use."

The ORNL group used nitrile rubber with 41% and 51% acrylonitrile contents (NBR-41 and NBR-51, respectively) with methanol-extracted low-molecular-weight fractions of Kraft softwood lignin. In their conclusion, the researchers report: "Temperature-induced controlled miscibility between the lignin and the nitrile rubber during high shear melt-phase synthesis allowed us to tune the material's morphology and performance. Lignin–rubber interaction was further improved by using fractionated melt-stable lignin in the composition with nitrile rubber of optimal acrylonitrile content. The products from equal-mass mixtures of lignin and rubber exhibit unprecedented yield stress and strain harden at large deformation."

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