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FEATURE

Driving growth in carbon fiber

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BMW's i3 and i8 may mark a 'flashpoint' in demand for carbon fiber in the automotive sector, and possibly for the industry as a whole. But, as Future Materials Group (FMG)'s Adrian Williams explains to Steve Calder, all carbon fiber is not created equal: adopting a 'homogeneous' view may prove an expensive error for investors currently eyeing up the market.

For many years, demand for carbon fiber was restricted to low volume, big budget projects. Formula One racing cars, for example, and military fighter jets. But that all changed a little over a decade ago when Boeing began developing the 787 Dreamliner. With its 50% carbon fiber reinforced plastic airframe, the Dreamliner employs more composite materials than any of Boeing's previous commercial airplanes – resulting in weight savings of around 20% when compared to conventional aluminum designs.

The 787 Dreamliner, with its 50% carbon fiber reinforced plastic airframe, being manufactured at Boeing's factory in Everett, Washington. (Picture © Boeing.)

At time of writing, approximately 250 Dreamliners have been delivered, hundreds more are on order, and other airlines are following Boeing's lead. In particular, the Airbus A350 XWB is currently in assembly and undergoing preparations for flight testing. Similar to the 787, around 50% of the A350 is constructed of carbon fiber composite (including its wings).

And inevitably greater use of composites will be made in existing 'legacy' aircraft too – such as Boeing's 777, which is to employ more carbon fiber than its predecessors, most notably in its wings.

Around 50% of the new Airbus A350 XWB is constructed of carbon fiber composite, including its aerodynamic wings. (Picture © Airbus S.A.S. 2014 – photo by master films/A. Doumenjou.)

Given all this, it will come as no surprise that aerospace currently dominates the carbon fiber market. But not, it seems, for long – likely, as it is, to be dwarfed by demand for carbon fiber from the automotive industry. Indeed, many industry commentators, including FMG, believe that automotive has significant potential to be as large as aerospace for carbon fiber, if not larger.

BMW in particular is committed to developing carbon fiber cars for the mass market – its i3 and i8 electric cars marking, in the

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opinion of many commentators, a 'flashpoint' in the industry similar to that created by the Dreamliner in aerospace. With that commitment firmly in mind, the company is a partner in SGL Automotive Carbon Fibers, which expects to triple the capacity of its Washington-based plant with the help of a US$300 million investment.

Shedding weight

The increasing use of carbon fiber in automotive is driven by the need for 'light weighting' – helping manufacturers to meet emissions standards. And although Ford may beg to differ, focused as the company is on utilizing aluminum and lightweight steel to trim mass, it is something of a lone voice (although even they are exploring carbon fiber light weighting options with DowAksa). Most leading marques, in particular manufacturers of mid- to full-size luxury cars, sports cars and SUVs such as VW, Toyota and Mercedes, have been quick to grasp the carbon fiber nettle.

Of course the wider adoption of carbon in mid-to-high volume models is not going to happen overnight. The mass auto market demands robust, high-speed processes that, like 'traditional' metal stamping, enable cycle times measured in minutes. So there are processing issues to address. And pricing clearly remains a limiting factor.

BMW is committed to developing carbon fiber cars for the mass market – its i3 and i8 electric cars marking, in the opinion of many commentators, a 'flashpoint' in the industry similar to that created by the Dreamliner in aerospace. (Picture © iStock.com/kontrast-fotodesign.)

But despite the current high price of carbon fiber, and prevailing processing concerns, there is clearly potential for explosive growth in the use of composites in the sector – with many analysts predicting a tripling in capacity over the next 10 years. The question therefore has to be: where is all this carbon fiber going to come from? And, equally importantly, what type of carbon fiber is going to be needed? Because, as FMG's Adrian Williams points out: all carbon fiber is not created equal.

He says: ''There are, in reality, many different grades of carbon fiber, which may be divided – very simplistically – into two clusters. One is the established 'aerospace' cluster; the other, the nascent 'automotive' cluster. And the economics of the two are very different.''

''The commercial aerospace market is – and will likely remain – the most critical, and highest profile, application of *intermediate-modulus* carbon fiber. But in automotive, the price point – and quality requirements – are very different. To date, the economics of carbon fiber have been driven by aerospace. But we are looking at a very different business model for automotive.''

''Whilst the volumes in aerospace are not actually that huge – at about 20% of the market – the value of the sector is extremely high, representing perhaps 45% of the market in dollar terms. By 2020, it is predicted that auto will use more fiber than aerospace, but at a much lower cost per kg, due in large part to the use of cheaper fibers, resins, and processing methods, and more low-cost chopped fiber.''

Twin challenges

Automotive is not the only sector for which price – and, right now, supply – are limiting factors. Wind energy is another. And despite the sector being dominated by just a handful of 'key players,' those firms consume huge amounts of carbon fiber each year.

In 2012, GE Energy alone consumed 3000 metric tons of carbon fiber for use in its turbine blades, driven in large part by the need to reduce weight, whilst maintaining strength and stiffness.

But with carbon fiber costing 15-20 times more than glass fiber, the twin challenges of price and supply may, the company's lead engineer Nirav Patel asserted, ultimately become ''show stoppers'' that ''unless overcome, will preclude further application of carbon fiber in GE Energy blades.''

The fact is, that although low blade weight is important, it's not critical. So carbon fiber is not considered by the likes of GE to be an essential manufacturing material.

And manufacturing costs simply have to be kept in check if wind is to remain competitive. A carbon fiber spar cap may weigh 80% less than one reinforced with glass fiber, but it costs five times more.

And, to borrow from the company's Manufacturing Engineering Manager Steve Johnson, though GE may ''love carbon fiber . . . they hate the cost associated with it.''

Nonetheless, estimates suggest that the wind energy sector is on track to consume more than 35,000 metric tonnes of the stuff by 2020. This forecast, if realized, will make it the largest carbon fiber consumer in the world.

Construction sector

Other consumers of carbon fiber include the not insignificant sports and leisure market, which spans for example golf club shafts, bicycles, fishing rods, tennis racquets, skis, snowboards and wind surfing equipment.

The use of carbon fiber is also growing fast in the construction section – being employed extensively in new builds, bridgework and concrete reinforcements. In one such example, AltusGroup now uses epoxy-coated carbon fiber composite grids to replace traditional welded steel-wire mesh for concrete reinforcement. The group's use of CarbonCast precast concrete solutions has grown steadily over the past 10 years, replacing heavier and thicker steel grid-reinforced precast elements.

To date, CarbonCast has been used in more than 125 parking garage structures and – being up to 65% lighter than the materials used in traditional façades – it's also increasingly being used in architectural cladding. In this case, cost is not so much of an issue; the price of carbon is insignificant compared to the crane costs incurred in the installation of façade panels during skyscraper construction. But in other nascent markets, such as oil and gas exploration, natural gas pressure vessels and of course automotive, it most assuredly is.

That said, as Williams explains, driving down prices 'across the board' is not a realistic solution.

''Clearly, reducing prices will facilitate the wider adoption of carbon fiber. But all carbon fiber is not created equal. The aerospace sector will continue to demand a very high quality material. So a carbon fiber plant that is producing material for aerospace is never going to make material for automotive or wind energy, for example. Consequently, there is a very real disconnect in the industry right now.''

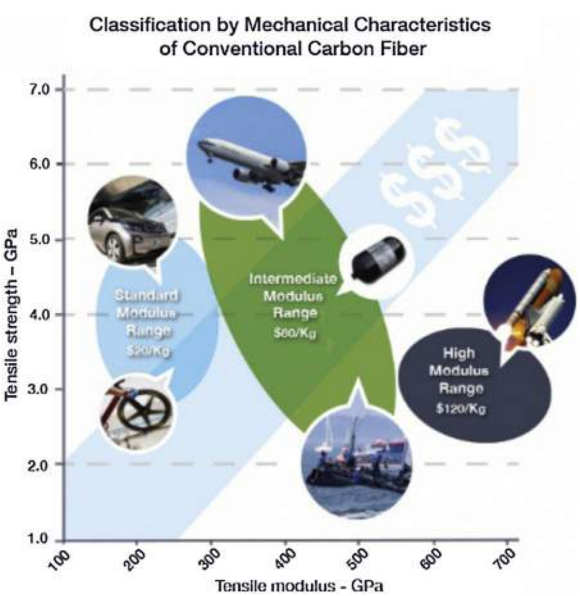
''You have for instance Hexcel [one of the leading suppliers of carbon fiber to the aerospace industry], saying 'This is really expensive stuff and delivers lots of value, and we need to charge you more for it.' Then you have BMW partners SGL on the automotive side, acknowledging the need to reduce costs, to enable high volume manufacturing. And of course both are right because, where carbon fiber is concerned, one size does not fit all.''

Trade off

Understanding the economics of the market demands a broad understanding of the production process, and of the differing grades of carbon fiber that can result. And like all good recipes, that process begins with a PAN – or more specifically in this case PolyAcryloNitrile fiber (from which almost all carbon fiber is currently made).

PAN is used to make carbon fiber in a 'pyrolising' process, meaning it is heated to ultra-high temperatures to remove all the elements except the carbon. Most carbon fiber is sold at this point, with a tensile modulus (that is: a measurement of stiffness) of 33 million pounds per square inch (MSI).

Further processing, however, results in even smoother, rounder fibers with a narrower diameter, which can be packed into a smaller space (resulting in even higher stiffness). The resulting 42 MSI fiber, known as intermediate modulus (or IM) fiber, allows the use of less material to achieve the same stiffness (and thus a lighter structure).



Classification of conventional carbon fiber.

And further processing still yields even stiffer fibers, which are again smaller and denser. These latter are known as high modulus fibers – in the range of 55 MSI and higher. And, inevitably, they are far more expensive to produce.

Cheaper precursor

In an effort to reduce costs, BMW partner SGL is working with Oak Ridge National Laboratory in the US. Its aim is to develop a less-expensive alternative to the polyacrylonitrile precursor (which is what makes carbon fiber so expensive).

Williams says: ''Logically, if you find a lower cost precursor, cheaper carbon fiber will result. But it is highly debatable whether a non-PAN material can provide the 'chemistry' that makes carbon fiber such an effective material – in particular, the intermediate-modulus carbon fiber, which is used in high-performance applications such as airplane manufacture.''

''And therein lies the problem: non-PAN materials may have a future as a precursor, but most likely only in commercial grade *standard*-modulus fiber – where it is feasible to sacrifice a degree of performance in the interests of cost reduction. This is an acceptable trade-off for car makers, as they have less stringent performance requirements. But it's not an option for the aerospace market. Applying the alternative precursors to applications that require high-modulus fiber is simply not an option.''

''This means the carbon fiber manufacturing industry has to 'segregate' itself based on specific markets based on cost and performance requirements. The development of a non-PAN precursor would become more closely associated with non-aerospace market applications. Consequently, I think there is a more intelligent debate to be had within the industry that recognizes the different applications, and the widely varying economics.''

''Clearly, considerable investment will be required for essential growth to happen and supply issues to be overcome. The question therefore should be: what level of investment is needed, not simply to boost capacity of carbon fiber, but to create capacity of *the right grade* of carbon fiber in line with the potential of each market.''

''So on one side you have the aerospace camp, which is very expensive capacity; it's going to be high priced. Then on the other side, you've got an as yet unproven expectation of far higher demand from the low cost camp. So, looking at the industry from the point of view of an investor, you have to ask: which horse should we back? The high volume, lower price and relatively fast production needed for the automotive industry differs greatly from that of aerospace. From a financial investment point of view, this 'disconnect' isn't conducive to attracting capital: it creates a rather skewed view of the market.''

''Although capital has been piling in to carbon fiber, particularly in the Asian markets, there remains a big mismatch between expectations. Right now there are a lot of consultancies out there making quite extraordinary claims about what the likely market growth is going to be *as a whole*. But I think a more measured and nuanced understanding of the market – and of the sectors within it – would facilitate the attraction of capital.''

Imports

Only a few regions currently produce carbon fiber in bulk, most notably Japan and the United States. Whilst some production exists in Europe, the region as a whole is reliant on imports – using 35% of global supply, while only producing 12%.

And there are currently fewer than 10 principal manufacturers in the market. That situation is, however, set to change. A host of new carbon fiber manufacturers are now entering the market, including Hyosung (of Seoul, South Korea), DowAksa (a joint venture between Dow Chemical, USA, and Turkey's AKSA), Russian firm HCC with their Alabuga Fiber, and over 20 Chinese firms.

For the most part, these organizations are committed to producing *industrial-grade* fiber, suitable for markets other than aerospace. Is that the right call? Market leader Toray seem to think so. Acknowledging that applications of industrial-grade fiber are growing at a far faster rate than those for aerospace-grade product, the company acquired Zoltek back in 2013 for a princely US$584 million.

The synergies between the two firms are clear. Whilst Toray provides carbon fiber for high-performance aerospace applications (including Boeing's 787 Dreamliner), Zoltek is a pioneer in the production of PAN-based carbon fiber for use in, amongst others, wind energy and automotive structural components. With Toray effectively covering all the bases, the company is set to remain the largest carbon fiber supplier, with a cluster of other producers now vying for second place.

Accordingly, all eyes are, for the moment, fixed on BMW, whose new breed electric vehicles represent not just a paradigm shift for composites use in production vehicles; they may prove a bellwether for the carbon fiber industry as a whole.

Further information

A graduate in Aeronautical Engineering, FMG's managing director Adrian Williams advises extensively on growth strategy and implementation across a broad range of companies, from start-ups to large multi-nationals, across Europe, Asia and North America. Specialized in the advanced materials and high value manufacturing sectors, his company helps businesses at all stages of their development, from start-up to maturity, to create and increase value through accelerating and managing growth.

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