Carbon fiber production: a step-by-step design and market analysis

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Abstract

Research into recycling carbon fibres for sustainable manufacturing has led to lighter high strength recycled components for the aerospace industry and novel heated materials for garments and food bags. Carbon fibre is energy intensive to manufacture and most waste goes to landfill. Recycling has been pioneered at Nottingham to produce short individual filaments in a fluffy formwhich are both cost-saving in manufacturing and environmentally friendly. The team isre also developing materials with appropriate quality control methods so that designers and manufacturers will have confidence in using recycled materials in future.

Early work used injection molding to produce fibre reinforced thermoplastic composite materials for the aerospace industry. This success has led to the Boeing Corporation funding further carbon fibre recycling research and product development in 2011 with a new three year £1.89 milliion programme.

After recovering from the largest decline in the history of the carbon fiber industry in 2009, the market is poised for strong double-digit growth annually for the next five years. In terms of dollar shipment, the global carbon fiber market is expected to reach $3.3 billion by 2019 from $1.8 billion in 2013. Both industrial and aerospace markets are expected to witness annual double-digit growth. The sporting goods market is likely to witness the lowest growth over 2014-2018 in terms of dollar shipment.

This research indicates that the future growth of global carbon fiber industry will likely be driven by emerging applications such as wind blades; nuclear centrifuge rotor tubes; laptop cases; mobile phones; and risers, tethers and umbilical in the oil and gas industry. In addition, civil and bridge applications; CNG tanks, fuel cells, and automotive applications in high-end cars; defense aircraft; commercial aerospace applications such as B787, A380, B747-8, A350; and next-generation narrow body aircraft are leading applications for carbon fiber use.

The industrial market is expected to see the highest growth among the other major sectors such as aerospace and sporting goods. The industrial market is forecast to grow at the highest rate annually over the next five years in terms of million dollars in shipments. More new carbon fiber suppliers from India, China, Russia, the Middle East, and other developing regions are likely to emerge. Although there is likely be a rise in pricing of final products annually over the next five years, this will be compensated because of high manufacturing efficiency. Additionally, competition from offshore suppliers, such as China and India, is expected to drive down the cost of end products.

Carbon fibers are used for light and strong materials in e.g. aerospace, defense, recreation and general industrial markets. Carbon fibers are currently produced in relatively limited quantities due to the high costs of the material, but are expected to see a rapidly growing market if the prices can be lowered, e.g. for use in lightweight and fuel efficient cars (carbon fiber composites have the potential to reduce vehicle weight by 50-60%). Most conventional production of carbon fibers today is based on fossil derived polyacrylonitrile (PAN). Lignin has gained a lot of attention as an alternative precursor as it has the potential of providing a less expensive material. The estimated annual growth for the carbon fiber composite industry for the period 2009-2015 is approximately 5- 25% depending on applications, with high growth in e.g. aerospace and windmill industry.

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Possibilities to offer a less expensive precursor

Knowledge exists on how to produce general performance grade carbon fibers from Kraft lignin, using similar processes as developed for the manufacturing of PAN-derived carbon fibers. Key questions to address are related to implement-ation of lab scale methodologies into full scale industrial processes while still achieving the desired properties of the carbon fiber.

Cost reductions can be achieved by scaling up plant and production capacity with the current technology to reach a high volume production. With the high volume production scenario, the share of the precursor cost during manufactu-ring is increasing, making lignin even more interesting as it is expected to be less expensive as a precursor compared to PAN. A microwave assisted plasma conversion process (MAP) has also been developed that has the potential to further reduce production costs as well as processing time.

Great potential if robust production is achieved

The market price for today's production of carbon fibers from PAN for the automotive sector (using large tow fibers) is about $17-26/kg. It is estimated that lignin-derived carbon fibers would be attractive to the automotive industry when they can be produced and offered to the market at a price in the order of $6.5-11/kg. Currently, the estimated price for lignin derived carbon fibers produced with the MAP technique is in the range of $8.40-9.30/kg and expected to be lowered further by increased production speed (that also increases production capacity). As soon as the production techniques of carbon fibers from lignin are robust enough, this may well quickly take over a large share of the market.

Carbon fiber sales will increase to 80,000 or 90,000 metric tonnes (176.4 million to 198.4 million lb) by 2015, with major growth in the industrial sector; yet, because 2.2 lb of precursor is required to make 1 lb of carbon fiber, nearly 300,000 metric tonnes (661.4 million lb) would be required in 2015, almost double the output of 2011. Although global acrylonitrile production per year is 6 million metric tonnes (13.227 billion lb), the chemical is a necessary feedstock for many products. Further, its cost is steep, currently between $1,500 and $3,000 per metric tonne, which directly affects precursor cost. He estimates that it will take about $30 million to build a plant capable of 1,000 metric tonnes (2.2 million lb) of PAN precursor annually, and he's unaware of any near-term plans for big new facilities or plant expansions. Given these precursor, realities, Service estimates that the per-pound cost is now $10.90, up 32 percent compared to 2001.

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