Low Cost Carbon Fiber Production

Carbon Fiber Manufacturing Cost Modeling

Background

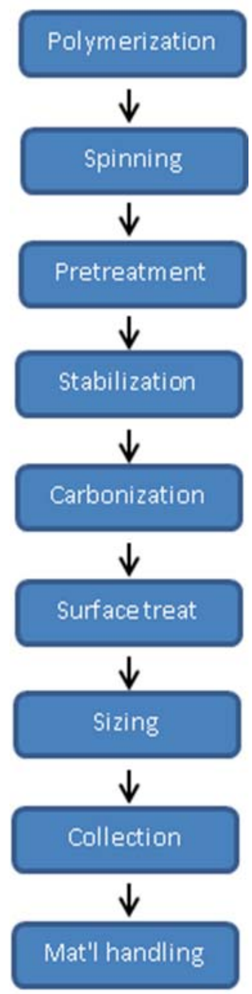
The automotive industry has long been identified by carbon fiber manufacturers as a market with substantial growth potential. When manufactured with carbon fiber as opposed to traditional materials such as steel, automotive parts are able to achieve requisite levels of strength and stiffness with significantly less overall vehicle weight. These potential large reductions in vehicle weight, in turn, afford the opportunity for substantial improvements in fuel economy and greenhouse gas emissions.

Despite their significant performance advantages, carbon fiber reinforced composites have enjoyed limited acceptance in the automotive industry due to high costs associated with both the manufacture of carbon fibers themselves as well as their composites. Traditional carbon fiber manufacturing uses polyacrylonitirile (PAN) as a precursor. This precursor requires a lengthy and energy intensive oxidative stabilization step so that the fibers can endure the high temperatures of the subsequent carbonization step without decomposing. At the conclusion of the carbonization step, approximately one half of the original PAN precursor mass has been lost as volatile effluent. This effluent contains toxic species requiring abatement before reintroduction into the environment. Following the carbonization step, carbon fibers undergo a surface treatment and sizing step which improves their ability to bond with composite matrix material. It is important that a carbon fiber manufacturing cost model be developed in order to evaluate the cost-effectiveness of alternative manufacturing pathways being considered by the industry today.

Approach

ORNL is investigating various alternative precursors and advanced manufacturing technologies with the potential to substantially reduce carbon fiber costs. Vehicle Technology Program goals include the development of industrial grade carbon fibers which are performance and cost competitive with traditional automotive materials. Specific targets are carbon fibers having strength of at least 250 Ksi, modulus of at least 25 Msi, and a selling price of $5-7 per pound.

Alternative precursors being examined include textile grade PAN, lignin, polyolefins, and PAN-lignin blends. Precursor costs represent approximately 50% of the total cost



Benefits

- Highly customizable carbon fiber cost estimation using conventional or advanced precursors and processing technologies
- Road mapping and identification of alternative precursors and processing techniques with high potential for significant cost reduction
- Rapid carbon fiber cost estimation capability for new precursors and processing technologies using the model

Research Areas

Freight Flows

Passenger Flows

Supply Chain
Efficiency

Transportation:
Energy
Environment

Safety
Security

Vehicle
Technologies

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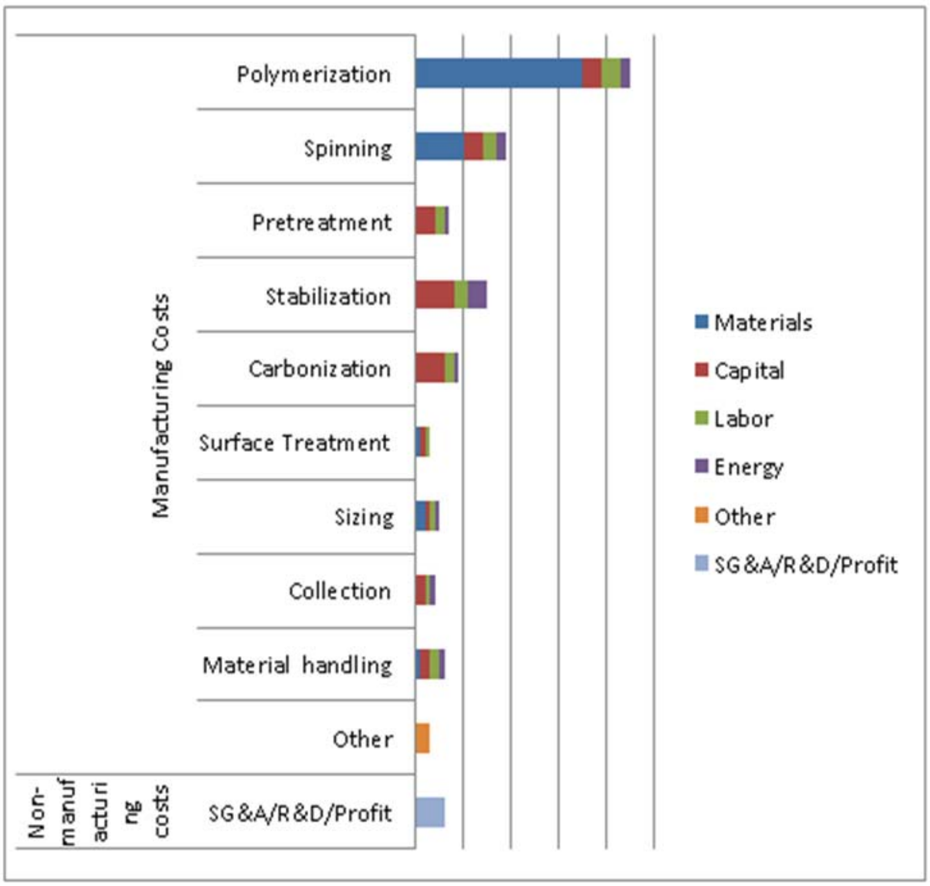
of conventionally manufactured carbon fibers due to the high cost of the main raw material (acrylonitirile), the low mass throughput of wet spinning, and the low mass conversion yield of precursor to carbon fiber. Alternative precursors have the potential to substantially reduce carbon fiber costs through lower raw material costs, higher mass throughput melt spinning as opposed to wet spinning, and higher mass conversion yields from precursor to carbon fiber.

Advanced processing technologies being investigated by ORNL include plasma oxidation, microwave assisted plasma carbonization, and advanced surface treatments and sizings. Plasma technologies have the potential to substantially reduce costs through lower energy requirements, smaller floor space requirements, and reduced processing times. For example, oxidation processing time has the potential to be reduced from 90-120 minutes for conventional processing to as little as 20 minutes for plasma oxidation. Microwave assisted plasma carbonization may reduce costs through reduced energy requirements, faster processing times, and greatly diminished or eliminated abatement and surface treatment needs. Advanced surface treatments are also being examined, and have the potential to generate significant cost savings by increasing the bond strength at the carbon fiber-matrix interface in composites. Increased bonding strength, in turn, translates into a reduction in the mass of carbon fiber required to achieve a desired performance for carbon fiber reinforced composite strength.

A manufacturing cost modeling tool is being developed to accurately gauge the cost reduction potential and adoption risk of alternative precursors and advanced processing technologies. By disaggregating costs into major processing steps and cost categories, the cost modeling tool will allow the estimation of changes in cost due to changes in precursor types, processing technologies, and processing parameters. Monte Carlo simulation and sensitivity analysis will be used to assess the cost impact of uncertain and stochastic inputs such as commodity raw material prices.

Processing steps being examined are the precursor steps of polymerization and spinning, as well as the carbon fiber production steps of pretreatment, stabilization, carbonization, surface treatment, sizing, collection, and material handling. For each processing step, costs will be disaggregated into the major categories of materials, capital, labor, and energy. A modular design will facilitate the rapid incorporation of new precursors and processing technologies into the cost model environment.



Example bar chart of costs disaggregated by processing steps and cost components

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