DEVELOPMENT OF MATHEMATICAL MODEL AND SIMULATION FOR THE HIGH CAPACITY PRODUCTION OF CARBON FIBER

Srikanth Allu (ORNL) , Srdjan Simunovic (ORNL), Tae-Seok Lee (Harper International)

HPC 4 MANUFACTURING

Scaling Up of Carbon Fiber Furnaces

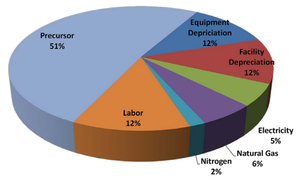
Increasing the production capacity and process efficiency of carbon fiber plants requires larger, faster and more energy efficient furnaces.
The main technical challenges are:

- Understanding the process of off-gas mixing with the nitrogen cover gas into purge gas which critically affects the fiber properties.
- Maintaining uniform temperature and atmosphere conditions across the width of the furnace in order to ensure uniformity of the resulting properties of carbon fiber.

Carbon Fiber Market

Demand for low cost CFRP is increasing, especially in automotive industry.

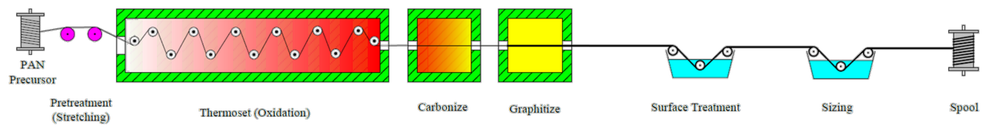
The passenger frame of BMW's i3 is fashioned from lightweight carbon fiber Courtesy Auto Motorsind Sport, Germany



Cost of Manufacturing 1500 ton/year 12k tow

Carbon Fiber Furnaces

The carbonization process converts stabilized precursor PAN fiber into carbon fiber inside LT furnaces. Detailed decomposition mechanism and gas evolution with consideration of temperature, time, and tension is not fully understood.



Project Approach

Develop parametric computational models for carbonization and gas flows inside the carbon fiber furnace. The developed model will be used to investigate various design strategies for scaling up carbon fiber furnaces.

The models will integrate the kinetic thermochemical model of the fiber carbonization process and the three-dimensional computational fluid dynamic model of mixing of off-gases from carbonization and purge gas.

Carbonization inside LT furnace

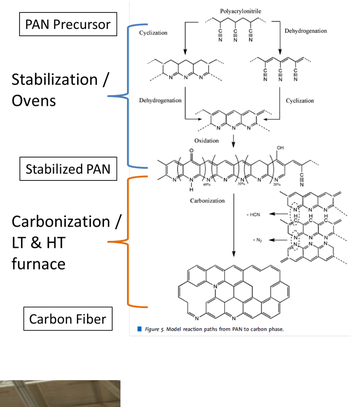
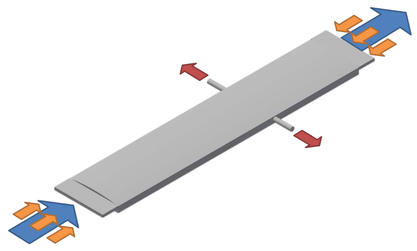


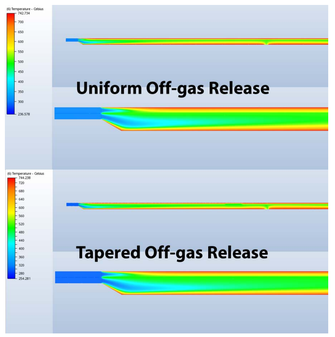
Figure 3. Model reaction paths from PAN to carbon phase.



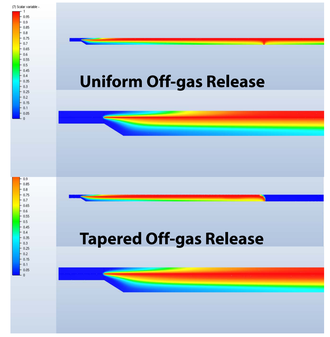
Schematic of the computational domain

Preliminary Results

Initial scoping studies indicated significant impact of the fluid dynamics on the distribution and flow of the nitrogen cover gas and process off-gas mixture.



Contours of temperature



Contours of off-gas release

The proposed work will use commercial CFD software Converge and adapt it to modeling of carbon fiber production. The simulations will be validated at the pilot scale equipment available at ORNL followed by iteration and refinement and tested in a commercial production facility.

Expected Benefits from the Project

- Evaluation of various approaches for increasing the size, capacity and efficiency of carbon fiber furnaces.
- Improved understanding of the underlying physical, chemical and thermal processes in the carbon fiber furnaces.
- Enabling material cost reduction necessary for increased use of CFRP in automotive industry.
- Increased ability to control the process conditions in the furnace.
- Current ‘state of the art’ 1500TPY carbon fiber line uses 30kW of energy to produce 1 kg of fiber
- A scaled up line capable of making 10,000 TPY from a current 1500 TPY will result in more than 50% of energy savings.

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