LOW-COST CARBON FIBER FROM ASPHALTENES

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Background

Bitumen is produced in Alberta at a rate upwards of 1.5 million barrels per day in situ. Diverting the use of bitumen to non-combustion applications is a way that the province can contribute to its sustainability goals. One of the products that can be made using asphaltenes, a bitumen by-product, is carbon fiber. Asphaltenes have become an increasingly favored material by engineers and designers for manufacturing due to the favorable mechanical properties.

Purpose

The current limiting factor in carbon fiber production is the price of the feedstock. Up to 90% of the carbon fiber produced today uses polyacrylonitrile (PAN) as the precursor. PAN precursor accounts for close to 50% of the material cost. The carbon fiber produced from PAN is an expensive raw material, deterring industrial manufacturers.

Asphaltenes are a large component of bitumen. The heavy fraction of a barrel of bitumen can be sourced for less than $1 per kilogram. The significantly lower cost of the pitch precursor would allow for a reduction in the cost of carbon fiber produced. This initiative explores the process required to generate carbon fiber using asphaltene pitch.

Environmental and Safety

Benefits:

- Diversion of bitumen away from combustion.
- Carbon fiber replaces GHG intensive products created using PAN.
- Increase transportation fuel efficiency by introducing lighter weight composites to vehicle manufacturing

Drawbacks:

- Furnaces in the process still use a large amount of electricity.
- The most efficient disposal of volatized atoms within the process is incineration.

Safety Measures:

- Flammables and explosion risk in vessels are mitigated with process controls.
- Emergency Response Plan and protocols established for operating personnel.
- Aspiration risks from furnace operations are mitigated by incinerating hazardous gases.
- Molten sodium is produced onsite to reduce risk of spillage or contamination during transport.
- Ensuring ventilation is sufficient in all process buildings to avoid carbon fiber dust risk.

Process Overview

Diluent Separation

- Christina Dilbit Blend is received as a feedstock.
- The diluent is separated from the bitumen for reuse using a distillation column.

Sulfur Removal

- The heavy hydrocarbon enters a reactor accompanied by molten sodium.
- NaS is formed as a by-product and removed from the bitumen to reduce impurities.
- Trace amounts of heavy metals are removed.

Solvent De-Asphalting (SDA)

- Bitumen is combined with solvent in a gravity settler to separate out asphaltenes.
- De-asphalted oil is sold as a by-product.
- Solvent is flashed off and recycled in the SDA.

Melt Spinning

- Asphaltene powder is melted into a viscous liquid.
- The liquid is extruded through 200 µm capillaries to form fibers.

Stabilization + Carbonization

- A series of furnaces increases temperature gradually up to 1500°C.
- Tighter bonding within the fibers occurs and fibers are strengthened.

Treatment and Coating

- Strands are treated with microwave assisted plasma.
- A resin is applied to enhance the properties of the fibers.

Figure 1: Carbon Fiber Process Infographic

Market Viability

The global demand for carbon fiber across all markets in 2022 is 100, 000 tonnes per year. In 2020 the global market size was $2.23 billion USD and is forecasted to grow to $4.08 billion USD by 2028. The uses of carbon fiber are extremely versatile as seen in Figure 2. As carbon fiber cost decreases, it will see an increased uptake.

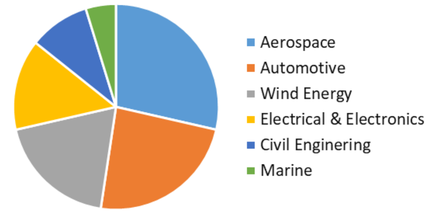

Figure 2: Carbon Fiber Market Demand by Share 2021

Economic Analysis

The process currently exhibits healthy financial metrics. The capital cost and operating costs are expected at $175 MM and $89 MM, respectively. In Table 1, the profitability metrics are summarized with respect to the OPEX and CAPEX.

Profitability Items	Profitability Metric
Net Present Value, NPV	$260M
Lifetime Projected Cash Flow	$1.4B
Return on Investment, ROI	33.5%/year
Payback Period	2.0 years

Table 1: Summary of Profitability Metrics

Conclusion

It is currently shown that the process using asphaltenes from bitumen feedstock is physically and economically viable to produce carbon fiber. The process of solvent de-asphalting has been simulated to show the feasible extraction of precursor material asphaltenes from a diluted bitumen feedstock. The goal of manufacturing carbon fiber can be achieved with substantial environmental benefits.

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