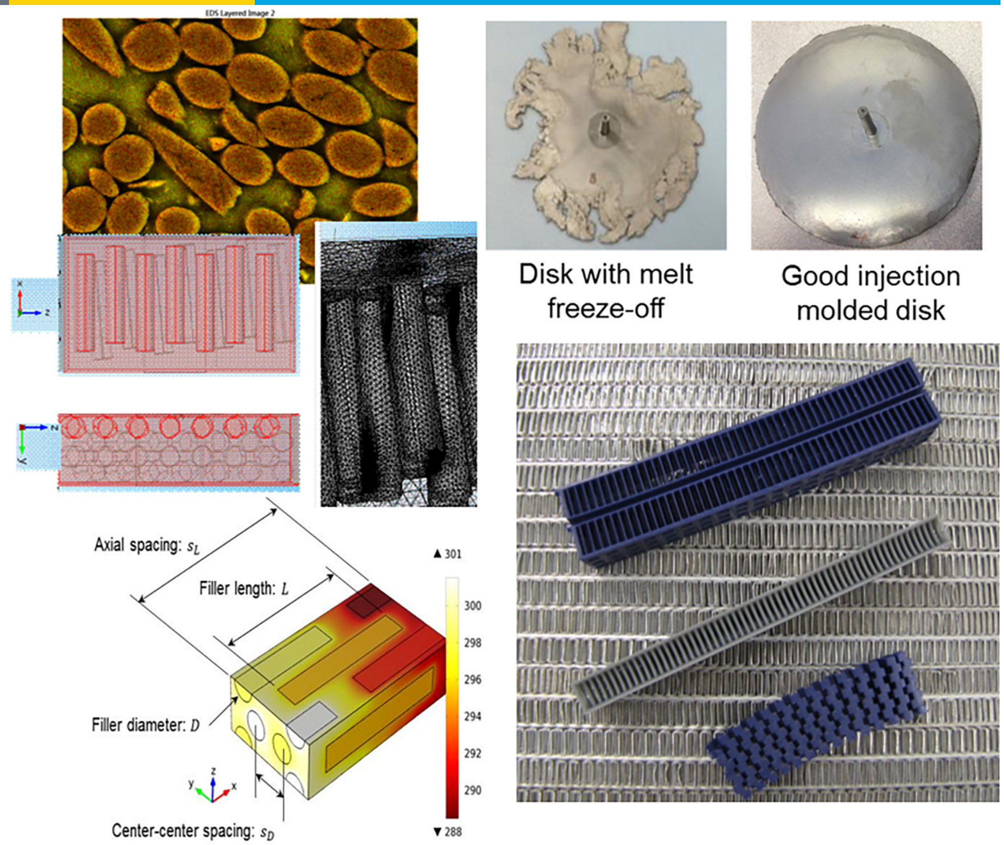
High Thermal Conductivity Polymer Composites for Heat Recovery Technologies

Evaluating low-cost options for non-metallic heat exchangers



The project explored the design and fabrication of composite heat exchangers through material characterization and modeling.
Image courtesy of United Technologies Research Center.

A heat exchanger is a device used to transfer heat from one area to another. Heat exchangers are critical components of thermal systems widely used in industrial and commercial applications, such as car radiators, heat pumps, refrigeration, and ambient cooling systems.

Most heat exchangers are constructed from metals such as copper and aluminum that are subject to corrosion and corrosion-related failure during use. Metallic systems can also pose manufacturing constraints, including costly assembly processes. For example, designs such as the shell-tube and fan coil require significant manual labor during assembly.

Heat exchangers constructed of polymer-based materials could offer an alternative to metallic heat exchangers. The use of high thermal conductivity polymer composites in place of copper and aluminum could reduce materials costs and overall manufacturing costs, and provide energy savings during manufacturing and end use. Polymer materials could also reduce component weight, mitigate corrosion risks, and enable new innovative design options.

This project identified and evaluated commercially available and state-of-the-art polymer-based material options for manufacturing industrial and commercial non-metallic heat exchangers.

The project team identified and evaluated optimal filler material, shapes, and orientation to enhance polymer thermal conductivity. Other relevant properties such as strength, fluid compatibility, permeability, and flammability were also evaluated. The results were presented in a database of relevant material properties and characteristics to provide guidance for future heat exchanger development.

Benefits for Our Industry and Our Nation

Increased use of non-metallic heat exchangers could reduce U.S. energy use and greenhouse gas emissions, and realize significant productivity benefits. For example, the manufacturing time for polymer composite heat exchangers is expected to be reduced by up to 90% compared to typical metallic heat exchangers. Total materials costs and overall manufacturing costs could be reduced by as much as 50%. These innovations will help keep the United States competitive in the global market.

Applications in Our Nation's Industry

Heat exchangers are widely used in U.S. industry, including at chemical plants, petrochemical plants, petroleum refineries, natural gas processing, sewage treatment, and power stations. Commercial applications include space heating, refrigeration, and air conditioning. The identification and evaluation of polymer-based heat recovery technologies with superior corrosion resistance will enable greater market adoption of affordable heat exchangers, saving money and energy throughout the United States.

Project Description

The objective of this project was to identify, evaluate, and characterize composite materials systems to enable the fabrication of non-metallic heat exchangers for industrial and commercial applications. The project team developed a heat exchanger concept and evaluated its performance with innovative heat transfer modeling tools.

Barriers

- Plastic durability, including fatigue and leakage, is a concern.
- Material costs could be higher than anticipated due to increased demand for plastics.
- Polymer-based materials with higher thermal conductivity tend to be more difficult to process and fabricate.

Pathways

The project team reviewed and compiled a list of relevant material properties for several polymer composite materials, both commercially available and in the development stage. The materials were evaluated for thermal conductivity, permeability, life cycle cost, flammability, stability, and manufacturability. The project team determined which materials have properties that meet the requirements for integration into a high-performance heat exchanger. The evaluation was based on published data. When not available, modeled or measured properties data were used. The project team also developed and validated modeling tools, and model validation was carried out at material coupon levels.

The project team worked closely with United Technologies Company's (UTC's) business units manufacturing building and aerospace applications to define requirements and estimate the impacts of a polymer-based heat exchanger in a range of applications. The project team conducted further research on material selection for the three most impacted applications. For one selected application and material system, a heat exchanger concept was developed and its performance evaluated with the heat transfer modeling tools. In addition, fabrication options were proposed and a manufacturing risk assessment was performed.

Milestones

The project began in 2014 and concluded in 2016.

- Review commercially-available and state-of-the-art composite materials and compile their relevant properties through literature-based searches and consultation with experts in the field
- Identify three potential applications to focus material selection on, based on market size and potential energy impact
- Develop and validate modeling tools to predict the thermal conductivity and mechanical properties of composite materials
- Test commercial samples to validate results and potential use in heat exchangers
- Develop a heat exchanger concept for one application and evaluate its performance based on existing heat transfer modeling tools

Accomplishments

The project team's analysis indicates that heat exchanger costs could be significantly reduced by using polymer-based materials. The cost of a traditional brazed plate metal heat exchanger manufactured in the United States is around \$600, or approximately \$200 if manufactured in China. The cost of an equivalent polypropylene-based heat exchanger made in the United States by injection molding is estimated to be between \$100 and \$150.

Commercialization

This project indicates that polymer-based heat exchangers could become a cost-effective solution for commercial and industrial applications. The next step in product development will be to demonstrate the manufacturability and durability of a full-sized heat exchanger.

United Technologies Research Center (UTRC) is the central research organization for United Technologies Corporation (UTC), the parent company to Carrier (air conditioning) and Pratt & Whitney (aircraft engines). UTRC has demonstrated experience in the development of technology and its commercialization, supporting the breadth of UTC's business units, as well as a substantial manufacturing footprint in the United States.

Project Partners

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Project final report available at
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