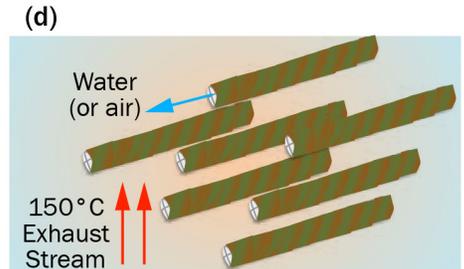
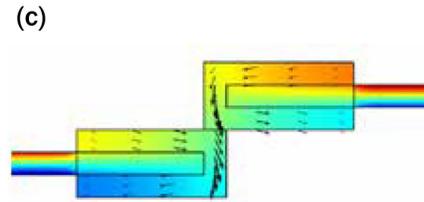
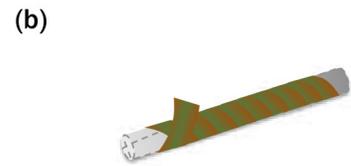
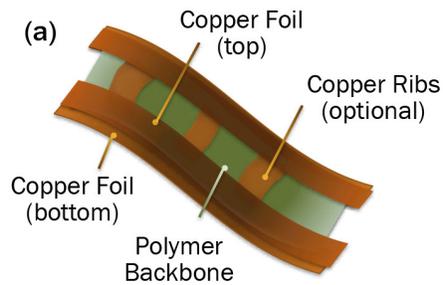


Roll-to-Roll Manufactured Hybrid Metal-Polymer Heat Exchanger

Low temperature exhaust gas streams represent a large untapped waste energy source at industrial facilities. Recovering waste heat from these sources is challenging because of the relatively small temperature difference available for heat exchange, which significantly increases the size and cost of the needed heat exchanger. In addition, when the temperature of the exhaust gas stream falls below 150°C, condensable corrosives in a typical exhaust stream drastically reduce the lifetime of heat exchanger components. Because of these challenges, most heat exchanger technologies currently in the market for low-grade waste heat recovery do not provide attractive system economics.

This project seeks to overcome these long-standing challenges in low temperature waste heat recovery through four primary heat exchanger innovations: 1) simple modular design that utilizes a hybrid metal-polymer material to achieve higher thermal conductivity than all-plastic heat exchangers; 2) innovative roll-to-roll manufacturing technique for the metal-polymer tape used in the heat exchanger; 3) novel anti-fouling coatings to reduce corrosion and fouling; and 4) continuous system health monitoring based on integrated sensors and machine learning.



The proposed concept is a simple and modular heat exchanger formed from an array of tubes. (a) The tape that is used to construct the heat exchanger consists of a polymer backbone and copper-clad edges. (b) The heat exchanger tubes are manufactured by winding the metal-polymer tape and bonding the edges. (c) The overlapping copper edges enhance heat transfer. (d) Tubes are placed in the flue gas stack. *Photo credit University of Illinois.*

The key concept is to replace significant volume of metal in a typical heat exchanger with polymers. This reduces material and fabrication costs and improves resistance to fouling from sulphuric and carbonic acids present in typical low temperature flue gas streams. To ensure effective heat recovery, strategic metal pathways are created for heat conduction between the hot and cold sides of the heat exchanger. The project goal is for the developed heat exchanger to provide 30% or greater improvement in performance when compared to competing composite plastic heat exchangers.

Benefits for Our Industry and Our Nation

If successfully developed, the hybrid metal-polymer heat exchanger would enable industrial facilities to utilize low temperature waste heat that is typically uneconomic to capture. According to a 2008 analysis conducted for DOE, in U.S. industry approximately 900 trillion Btu of low temperature (below 230°C) waste heat goes unrecovered annually. If 20% of this low temperature waste heat could be captured through technologies such as the hybrid metal-polymer heat

exchanger being developed, it would amount to total energy savings of 180 trillion Btu annually.

The modular design and self-monitoring capabilities provide additional benefits for industrial end users, such as predictive maintenance, reduced maintenance cost, and extended system life.

Applications in Our Nation's Industry

While the end-use applications for low temperature heat recovery are more limited than for higher temperature waste heat streams, there are several suitable uses for the recovered energy. Potential end uses for low temperature heat recovery include domestic water heating, space heating, and low temperature process heating. Heat pumps can be used to “upgrade” the waste heat, and low temperature power generation technologies, such as organic Rankine cycle systems, can be used to generate electricity.

Project Description

The project seeks to develop an inexpensive, modular, and corrosion-resistant heat exchanger that can be used for waste heat recovery from low-temperature flue gas streams. The material used in the heat exchanger is a hybrid metal-polymer, which enables the system to achieve much higher thermal conductivity than all-plastic heat exchangers. The hybrid metal-polymer material will be manufactured as a tape, which will then be wound into tubes.

Because corrosion and fouling are major concerns with low temperature heat exchangers, novel anti-corrosion coatings will be utilized in the system design. To improve the performance of the heat exchanger and to prolong its life, a sophisticated monitoring and control system will be incorporated into the heat exchanger.

The project goal is for the heat exchanger to provide 30% or greater improvement in performance when compared to competing composite plastic heat exchangers and to achieve a payback period of less than three years.

Barriers

- Development of anti-fouling coatings that are able to withstand the manufacturing process and be durable in use
- Incorporating ultrasonic welding into the roll-to-roll manufacturing process
- Reduced thermal conductance at welded joints of heat exchanger tubes
- Integration of thin film sensors into the heat exchanger design and manufacturing process

Pathways

This project seeks to develop a new heat exchanger technology by pursuing innovation in four different areas.

The key innovation in this project is to design a simple and modular heat exchanger where a significant volume of metal is replaced with polymers while maintaining good thermal conductivity.

The heat exchanger consists of a bank of tubes made of a hybrid metal-polymer material placed in the flue gas stack in cross-flow geometry. Such simple design allows fouled tubes to be individually replaced.

The second major innovation pathway entails the development of a roll-to-roll manufacturing technique to fabricate the metal-polymer material used in the heat exchanger. The hybrid metal-polymer material will be manufactured as a tape where a metallic foil is wrapped around the edges of a polymer backbone.

The third innovation pathway relates to reducing the impacts of corrosion and fouling on the heat exchanger. To achieve this, omniphobic and durable anti-corrosive coatings that can withstand acid condensates and reduce internal fouling will be developed for use in the heat exchanger.

The fourth innovation pathway seeks to make improvements to the operation and maintenance of the heat exchanger. Taking advantage of the modular system design and ability to individually replace fouled tubes, a learning-based health monitoring system will be incorporated into the heat exchanger design. Such a monitoring system will also enable more precise system control to optimize the performance of the heat exchanger in real time.

Milestones

This two-year project began in April 2018.

- Thermal and thermomechanical design of the heat exchanger material (2018)
- Heat exchanger design (2018)
- Development and optimization of the roll-to-roll manufacturing process to produce the hybrid metal-polymer tape (2019)
- Development and optimization of the manufacturing methods for the tape laying and bonding process to produce the heat exchanger tubes (2019)

- Heat exchanger prototype manufacture and testing (2019)

Technology Transition

The technology being developed is a significant departure from the typical heat exchangers that are based on brazed, drilled, and machined sheet metal. The new technology concepts being incorporated into the system design are still in the R&D phase. If successfully developed, the projected payback period, long system life, and predictive maintenance make it likely that the technology could find success in the low temperature heat recovery market where there are few other cost-effective options. Eventual market entry would likely happen through project partner Modine Manufacturing Company, which is a major manufacturer of heat exchangers.

Project Partners

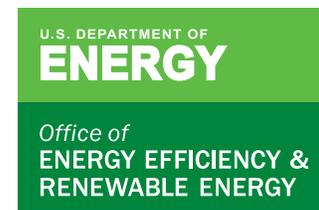
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