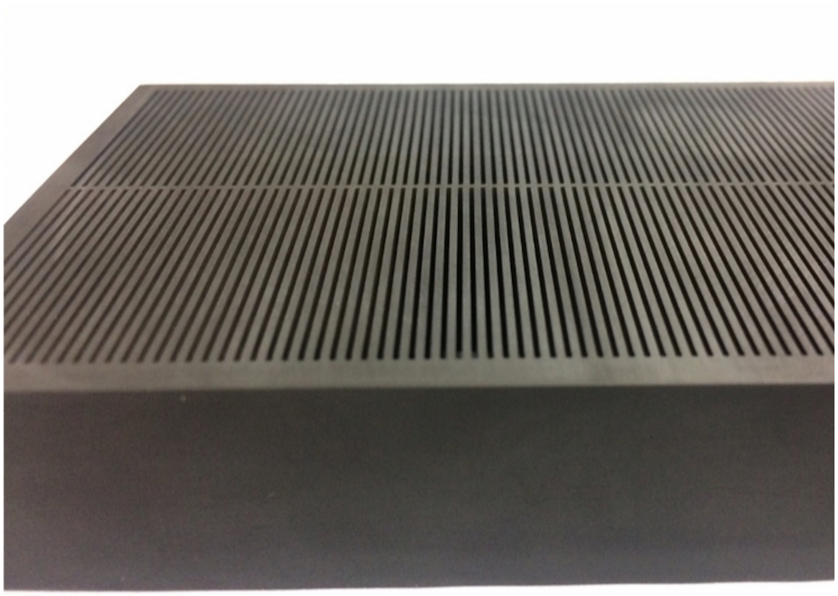

National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Power Generation and Storage

High-Performance, Lightweight, Easy-to-Fabricate Heat Exchanger

A key enabling technology for next-generation thermoelectric generators and other energy recovery systems

Researchers at NASA's Jet Propulsion Laboratory (JPL) have developed an advanced heat exchanger that addresses problems typically associated with metal-based systems. Unlike typical metal heat exchangers, which suffer from high thermal expansion and high density, JPL's innovation offers several improved properties. Its lightweight, high heat flux design offers a low coefficient of thermal expansion (CTE)—and therefore low expansion characteristics—and reduces the pressure drop during heat transfer. The design can handle high-temperature gases (up to 650 °C). This technology has undergone successful preliminary testing. Developed for an aircraft exhaust energy recovery application, the system meets the requirements of high-temperature, high-specific-power thermoelectric generators and other energy recovery systems for industrial, automotive, military, and space applications.

BENEFITS

- High performance: This technology offers high-efficiency thermal energy recovery with a low drop in exhaust flow pressure.
- Lightweight, yet high power: The innovative design results in its leveraging a high ratio of thermal conductivity to density.
- Easy to manufacture: The graphite material used in JPL's heat exchanger is widely available and reasonably easy to use in and compatible with standard machining and fabrication processes.
- Robust: As a graphite-based heat exchanger, JPL's technology has a low coefficient of thermal expansion and good structural strength.
- Flexible: The current prototype of JPL's innovation is easy to reconfigure into other designs using similar materials.

THE TECHNOLOGY

Researchers at JPL have developed, built, and tested an innovative heat exchanger that offers reduced thermal expansion, increased structural strength, low pressure drop, and improved thermal performance while lowering the weight associated with typical heat exchangers. This innovation would benefit the commercial thermoelectric generator, aircraft, and industrial processing (i.e., glass, steel, petrochemical, cement, aluminum) industries by improving energy management/efficiency, reducing carbon dioxide emissions, and increasing system durability due to the reduced stress from thermal expansion.

The Problem
Thermoelectric generator systems require high-performance hot-side and cold-side heat exchangers to provide the temperature differential needed to transfer thermal energy while withstanding temperatures up to 650 °C. Because the hot-side heat exchangers must have a high heat flux, they are often made of metals such as stainless steel or Inconel® alloys. Although these materials can operate at high temperatures, resist corrosion, and are chemically stable, they also have several drawbacks: (1) Their lower thermal conductivity negatively affects their thermal performance. (2) Their higher thermal expansion leads to stresses that compromise system structural integrity. (3) Their high mass/volume reduces the power density of generator systems into which they are integrated. As a result, they are difficult to integrate into viable energy recovery systems. They also make the systems unreliable, non-durable, and susceptible to failures caused by thermal-structural expansion.

The Solution
JPL researchers chose to replace the metal in traditional heat exchangers with graphite, which offers an improved conductivity-to-density ratio in thermal applications as well as a low coefficient of thermal expansion. In addition, they used a mini-channel design to further increase thermal performance. Combining more advanced materials with the innovative thermal design has yielded significant improvements in performance. For example, a 200-cm^3, 128-g version of JPL's exchanger successfully transported 1,100 W from exhaust at nearly 550 °C with approximately 20 W/cm^2 thermal flux and a pressure drop of only 0.066 psi.

JPL's technology combines lightweight, high-strength graphite material with a mini-channel design that offers high thermal performance. Further development and testing are underway.

Inconel is a registered trademark of Special Materials Corporation.

APPLICATIONS

The technology has several potential applications:

- Thermoelectric generators
- Thermal energy recovery in industrial processes (e.g., oil/gas, steel, glass, aluminum, cement, paper)
- Exhaust energy recovery systems for automobiles, aircraft, etc.
- Hypersonic engine and aircraft cooling
- Potentially extreme chemical and thermal environments on Venus

PUBLICATIONS

Patent Pending

Hendricks TJ, et al. Design and testing of high-performance mini-channel graphite heat exchangers in thermoelectric energy recovery systems. Proceedings of the American Society of Mechanical Engineers (ASME) 2017 International Mechanical Engineering Congress and Exposition. Nov. 3-9, 2017. Tampa, FL. Paper #IMECE2017-72411.

More Information

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