Project to enhance the efficiency of concentrated solar power technology

September 17 2015, by Emil Venere

Vice President Joe Biden is announcing Wednesday (Sept. 16) that Purdue University has received an advanced U.S. Department of Energy research award to improve concentrating solar power (CSP) technology. Funded by the DOE SunShot Initiative, a research team from Purdue aims to test the material limitations of critical components often found in large-scale solar power plants.

The "power tower" system, a prominent type of CSP plant, uses an array of solar mirrors to transfer heat at the top of a tower to a high-temperature liquid. This liquid then carries the heat to a heat exchanger that transfers the heat to a fluid that drives a turbine to generate electricity.

Purdue, working with the Georgia Institute of Technology and University of Wisconsin, is developing a manufacturing method to produce a critical component of the power tower system: the heat exchanger. The heat exchanger must be capable of handling high-temperature fluids under high pressure at 800 degrees Celsius, or nearly 1,500 degrees Fahrenheit, said Kenneth Sandhage, the Reilly Professor of Materials Engineering in Purdue's School of Materials Engineering.

The research, funded with a $4.8 million three-year, university-matched award from DOE's SunShot initiative, also will involve Georgia Tech's Devesh Ranjan, an associate professor of mechanical engineering; Georgia Tech's Asegun Henry, an assistant professor of mechanical engineering; and Wisconsin's Mark Anderson, a research professor and director of the university's Thermal Hydraulics Laboratory.

Researchers from the three universities will work to complete six tasks in three main areas: processing, properties, and performance of the advanced heat exchangers.

"This is a highly-collaborative multidisciplinary effort," Sandhage said. "The heat exchanger is one of the critical choke points in the concentrated solar power system that needs to be enhanced to make this technology cost effective."

The power-tower system is designed to melt salt-based compounds such as sodium chloride-based salts, producing a high-temperature liquid that would then be transferred down the tower and either stored in tanks for use later or circulated through a heat exchanger. Inside the heat exchanger, heat would be transferred to another circulating fluid, "supercritical carbon dioxide," which would then power turbines to run generators.

The heat exchanger is made of many thin-walled, thermally-conductive plates containing channels for the circulating fluids. Supercritical carbon dioxide is a fluid under high pressure and temperature - above the "critical point" - that exhibits properties of both a liquid and a gas.

"It's like a very dense gas, which makes it an effective fluid for pushing turbine blades and generating electricity," Sandhage said. "At the same time, if you want to run a turbine engine more efficiently, you prefer to provide heat to the engine at a higher temperature."

The goal is to generate electricity at a cost of 6 cents per kilowatt hour, which would be competitive with fossil fuels. Current heat exchangers for the power tower design are limited to operating at around 600 degrees C. Increasing the operational temperature of the heat exchanger to 800 degrees C would result in an appreciable enhancement of the system efficiency, which would be an important step toward the 6-cent goal. However, conventional metal alloys now in use cannot withstand such high temperatures while circulating high-pressure supercritical carbon dioxide.

The researchers are developing a manufacturing process to economically produce a high-temperature, stiff ceramic-rich composite that has been shown to withstand much higher temperature conditions at elevated pressures.

"So 800 C is a modest temperature for these materials," Sandhage said.

The new manufacturing method involves a chemical-reaction process to generate dense, shaped, ceramic-rich composites with complex geometries, such as those required for the heat exchangers. The manufacturing process will be tailored to generate ceramic-rich composites that are mechanically, thermally and chemically robust.

The researchers will strive to demonstrate the scalability of the new manufacturing method and the material's suitability for the heat exchangers.

"Our job in this DOE SunShot project is to remove risk. By proving that these materials are sufficiently rigid, thermally conductive, and corrosion resistant, we can help make them cost effective. Successful completion of this project in three years would then allow us to move forward to the next level, involving larger scale components for a scaled-up prototype demonstration, on the pathway towards commercialization of such technology," Sandhage said.

Provided by Purdue University