BY AMANDA M. KLEMP

Conceptualizing More Power For The U.S. Navy

Concepts NREC developing heat recovery system using CO_2 and Brayton cycle

The U.S. Navy, along with the U.S. Department of Energy, has set forth an initiative to improve fuel economy in naval ships. To prompt development of new, fuel-efficient technology, they extended Small Business Innovative Research (SBIR) grants. The Navy did not specify what type of technology should be developed, only that it improves output of the prime mover by 20%.

As the Navy moves to gas turbines for prime movers, it is looking for ways to extend the turbines' efficiency. Frank DiBella, program manager, large product development at Concepts NREC said, "Gas turbines can be very efficient, but only when they're running at their designed point conditions. That means that they're running at full speed." However, in naval propulsion, there is significant operating time at partial load.

"The Navy's looking for ways of improving the fuel efficiency of these devices in the operating modes that they need to operate in," said DiBella.

Concepts NREC, one of the SBIR grant recipients, is working to develop a gas turbine waste heat recovery system. Different than a typical Rankine cycle waste heat recovery system, Concepts is making use of the Brayton cycle with CO_2 as the working fluid and thermoelectric generators inside the heat exchanger, along with the possibility of using an auxiliary combustion system to provide thermal stability. The company is in the analytical phase of the project, and with the go-ahead from the Navy, phase two will see a small-scale system for testing.

While a traditional Rankine cycle system heats the working fluid to gas and then condenses it back to fluid to start the cycle over, the Brayton cycle compresses a gas, in this case CO_2, to create super-critical state point, then heats the liquid and expands it in a turbine and then cools it to begin the cycle again.

Concepts NREC's waste heat recovery system begins in the exhaust path of the gas turbine. The CO_2, chosen for its chemical stability, goes through a "super heater" heat exchanger. The tubes inside the heat exchanger are fitted with the thermoelectric generators inside the walls — a patented design. The solid-state thermoelectric generators take advantage of the temperature difference between the cooler inner tube and the hot outer wall to make electricity, which can be used for virtually any function on the vessel requiring power.

As the CO_2 passes through the heat exchanger, it is heated to about 288°C and compressed to about 207 bar, the fluid then expands to operate the turbine, which drives a generator to produce power for ship propulsion or auxiliary functions. Once through the turbine, the CO_2 is cooled and returns to the compressor to begin the cycle again.

DiBella said the working fluids can affect the turbine design, explaining that CO_2 has different pressures, temperatures and densities than steam, which can make a difference in the size and speed of a turbine. He's predicting a smaller and slower turbine for CO_2 operation.

The feasibility analysis that Concepts NREC completed for the proposal indicated a power improvement over the gas turbine engine from 20% — with only the baseline, simple CO_2 waste heat recovery system — to as high as 27% when as many as four TEG systems are included in various places within the CO_2 cycle.

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