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Experimental Study of an Isobaric Expansion Heat Engine with Hydraulic Power Output for Conversion of Low-Grade-Heat to Electricity

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Abstract : Isobaric expansion (IE) process is an alternative to conventional gas/vapor expansion accompanied by a pressure decrease typical of all state-of-the-art heat engines. The elimination of the expansion stage accompanied by useful work means that the most critical and expensive parts of ORC systems (turbine, screw expander, etc.) are also eliminated. In many cases, IE heat engines can be more efficient than conventional expansion machines. In addition, IE machines have a very simple, reliable, and inexpensive design. They can also perform all the known operations of existing heat engines and provide usable energy in a very convenient hydraulic or pneumatic form. This paper reports measurement made with the engine operating as a heat-to-shaft-power or electricity converter and a comparison of the experimental results to a thermodynamic model. Experiments were carried out at heat source temperature in the range 30–85 °C and heat sink temperature around 20 °C; refrigerant R134a was used as the engine working fluid. The pressure difference generated by the engine varied from 2.5 bar at the heat source temperature 40 °C to 23 bar at the heat source temperature 85 °C. Using a differential piston, the generated pressure was quadrupled to pump hydraulic oil through a hydraulic motor that generates shaft power and is connected to an alternator. At the frequency of about 0.5 Hz, the engine operates with useful powers up to 1 kW and an oil pumping flowrate of 7 L/min. Depending on the temperature of the heat source, the obtained efficiency was 3.5 – 6 %. This efficiency looks very high, considering such a low temperature difference (10 – 65 °C) and low power (< 1 kW). The engine's observed performance is in good agreement with the predictions of the model. The results are very promising, showing that the engine is a simple and low-cost alternative to ORC plants and other known energy conversion systems, especially at low temperatures (< 100 °C) and low power range (< 500 kW) where other known technologies are not economic. Thus low-grade solar, geothermal energy, biomass combustion, and waste heat with a temperature above 30 °C can be involved into various energy conversion processes.

Keywords : isobaric expansion, low-grade heat, heat engine, renewable energy, waste heat recovery
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