Energy Optimization of a Solar-Thermal Driven Ejector Refrigeration System

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Abstract

The performance of a solar thermal powered Ejector Refrigeration System (ERS) is highly dynamic and is greatly affected by the solar and weather conditions under the considered location. From previously conducted studies, it has been shown that the performance of the system is also highly dependent on the type of working fluid considered. However, investigations on suitable working fluid selection have shown that there is a significant gap in finding working fluids that deliver high Coefficient of Performance (COP) values whilst being environmentally friendly and non hazardous. Moreover, the dynamic performance of the ERS under South African solar and weather conditions is not well documented compared to other locations across the globe.

With the goal of studying the dynamic performance of the ejector refrigeration system, a steady state, real gas model of the ejector was developed in Engineering Equation Solver (EES). The steady state model was validated against published data for R134a, R245fa, R290, and R1234ze(Z). R1234ze(Z) was considered as the adequate working fluid as it gave high COP values and is an environmentally benign refrigerant. The developed model was then coupled with a transient system simulation software (TRNSYS) for observation and optimization under variable solar radiation and ambient conditions experienced in Johannesburg, Durban, Upington, Bloemfontein and Cape Town.

Findings from the study showed how optimal performance was also affected by the slope of the solar collectors, the size of the collector surface area, and the capacity of the hot water storage tank. Optimization was conducted by varying the size of the solar collectors, slope of the solar collectors, and the storage capacity of the hot water tank to achieve optimal performance. During the optimization process, the key performance indices are the system's Coefficient of Performance, Generator Temperature, and Critical Condenser Temperature. Location based analysis of the solar ERS showed that the system is best suited for locations with low ambient temperatures. From the cities considered, Johannesburg and Cape Town provided the highest Overall Coefficient of Performance values over the 24 hour period with respective daytime averages of 0.334 and 0.345. The ERS in Bloemfontein closely follows the performance of systems in Johannesburg and Cape Town (especially between 8:00 and 10:00), with a daytime average overall coefficient of performance value of 0.279 which is due to low ambient temperatures. Thereafter, the overall system coefficient of performance values degrade to become similar to those experienced in Durban (with daytime average values of 0.237) due to high ambient temperature values which require system operation at high generator temperature values. The Upington ERS attains the lowest overall system coefficient of

performance values (with a daytime average of 0.187) as a result of the extremely high ambient temperature values which demand system operation at high generator temperature values.

The general conclusion of the study is that the optimal performance of the solar-powered ejectors is achieved in areas with low ambient temperatures (Johannesburg and Capetown) as they allow for system operation at low TG values. Low-performance figures are achieved in Upington as a result of high ambient temperatures which require the system to operate at high generator temperature. To achieve high generator temperatures, the system is required to have large solar collectors (44 sq meters) which have to be coupled to a large hot storage tank (6 cubic meters) to achieve prolonged operation hours.