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Fuzzy Based Evaporator Model in Waste Heat Recovery System

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Extended Abstract

Waste heat recovery (WHR) from internal combustion engines using an Organic Rankine Cycle (ORC) has been a growing research area in recent years for reducing the fuel consumption and enhancing the efficiency of the engine. The ORC is a thermodynamic cycle which converts heat into work. The operation of the ORC WHR system at supercritical pressure can improve the thermal efficiency of the cycle by 20% –50% more than a traditional subcritical condition [1]. In ORC WHR system, evaporator is considered to be the most critical component as the effective heat transfer of this device influences the efficiency of the system. Heat transfer in the evaporator under supercritical condition becomes unpredictable as the thermo-physical properties are strongly variable with temperature and the Finite Volume (FV) method is generally used to model the evaporator at this condition [2,3]. Although the FV model can successfully capture those changes in the evaporator, the computation time for this method is high as it consists of many iterative loops. Therefore, the model has a limitation in real time control applications. To reduce the time consumption, a new evaporator model using fuzzy inference technique is developed in this research.

The fuzzy evaporator model in this research is built using the fuzzy technique introduced by Mamdani and Assilian [4] and consists of fuzzy logic, membership functions, fuzzy sets, and fuzzy rules representing the nonlinear system of the evaporator by mapping its input variables to the output variables. This model has three inputs (mass flow rate of refrigerant, heat source flow rate and temperature) and two outputs (evaporator power and outlet temperature). The input and output ranges of the evaporator model are divided into different linguistic levels; each of these levels is called a membership function. The collection of membership functions is termed as a fuzzy set. The fuzzy rules of the evaporator are created using fuzzy If-Then statements and are determined and adjusted from intuition and knowledge of characteristics of the evaporator.

The simulation of heat transfer at the evaporator using the fuzzy based model was conducted at a supercritical pressure of 6 MPa. The generic heat source with variable mass flow rate and temperature, and a random flow rate of R134a refrigerant were used in the simulation. The outputs of the fuzzy model were compared with that of the FV model. The RMSE and congruency of the fit obtained for the evaporator power was 0.95 and 93.68%; while for the outlet temperature it was 1.48 and 89.16%, respectively. The fuzzy model outputs in the simulation were obtained almost instantly; whereas the simulation time for the FV model was 13,870s. The proposed fuzzy evaporator model can reduce the computation time significantly and therefore it can be used to develop a real time control system for the WHR process.

References

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