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Experimental study of the effect of brazed compact metal-foam evaporator in an organic Rankine cycle performance: Toward a compact ORC

Omid Nematollahi[a], Gholamreza Bamorovat Abadi[a,b], Dae Yeon Kim[a], Kyung Chun Kim[a,*]

[a] School of Mechanical Engineering, Pusan National University, Jangjeon-dong, Geumjeong-gu, Busan 609-735, Republic of Korea
[b] Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 335 Gwahag-ro, Yuseong-gu, Daejeon 305-701, Republic of Korea

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ABSTRACT

Compact-sized organic Rankine cycle (ORC) power generators require small-scale heat exchangers to achieve high power density. The objective of this study is to investigate the effect of a Brazed Metal-foam Plate Heat Exchanger (BMPHE) in an Organic Rankine Cycle (ORC) performance parameters. This evaporator is one of the first industrial full BMPHE which is composed by Nickle-foam with 25 PPI (pore per inch). In addition, a series of the experiments have been done using conventional Brazed Plate Heat Exchanger (BPHE) to make a comprehensive comparison for both cycles. Two parameters of power density and pressure gradient are introduced to make a clear comparison in addition to ORC performance parameters. Experimental data are presented for a 1-kW scroll expander and heat source temperatures between 80 and 120 °C. The results show that although the compact evaporator (BMPHE) increases the pressure drop by factors of 1.4–2.6, the overall performance of the ORC is not adversely affected, and the power density is increased by a factor of 2.5 in maximum.

1. Introduction

Global warming and climate change are the most worrying problems of the new millennium. Overpopulation and overusing fossil fuels are among the causes. Renewable energies are one of the viable substitutes for fossil fuels to reduce greenhouse gases and solve the global warming problem. The main problems with using renewable energies are (a) they are not yet commercially viable, and often, fossil fuels are cheaper to produce and distribute; and (b) they are not mature enough, have low efficiency. The former will be solved if the market shifts toward renewable energies and if solar, wind, or waste heat power plants are mass produced, but the latter requires technological advances.

The organic Rankine cycle (ORC) has proven to be commercially viable, have acceptable efficiency, and produce a large amount of power output [1]. Today's ORC systems have the thermal efficiency of around 10%, which might not seem high but is made from waste heat that would otherwise be dumped in the atmosphere. Larjola [2] estimated that there were more than 30 commercial ORC plants built in the world before 1984. They also discuss the commercial viability and special conditions for using ORCs. Refrigerants such as R11, R113, and R114 were common at that time. Hung et al. [3] compared the performance of an ORC system with different dry, isentropic, and wet refrigerants as the working fluid. They concluded that the best option for ORC systems is isentropic fluids, but the global warming effect of such refrigerants was not an issue at the time. After the 2000 s, the global warming effect of such refrigerants and the eventual phasing out of CFCs forced researchers to look for alternatives. This is shown in most of the publications after 2000, such as in the working fluid selection guidelines with different approaches such as [4–7].

One of the first applications of the ORC system was in geothermal plants. For example, in 1993, Paloso and Mohanty [8] discussed the concept of coupling the absorption cycle to the organic Rankine cycle in a low-temperature geothermal heat source. Solar ORCs are also a viable option, although the added price of the solar panels is discouraging [9–11].

ORC research has been going in many directions. Some research focuses on the expander and optimizing its design. Scroll and screw expanders are two of the most used design architectures [12–14]. Furthermore, many of studies investigate new configuration of ORCs including new heat sources, hybridization with other cycles and etc., in both of energy and exergy approach [15–17]. Besides, new working fluids with very low global warming potential and zero ozone depletion potentials, such as R1234ze(Z) and R1233zd(E), have been proposed to replace the old ones, but they are still too expensive for adoption [18,19].

In addition, a number of studies have been focusing on design and optimization of ORC heat exchangers in both sub- and supercritical conditions [20–22]. The modern ORC power plants are still bulky and

* Corresponding author.
E-mail address: kckim@pusan.ac.kr (K.C. Kim).

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