別紙第１号様式　　　　　　　　　　　　　No.1

博　士　論　文　の　要　旨

専攻名　システム創成科学専攻
氏　名（本籍）Fontaine Kevin Davy - Erik

博士論文題名

Determination of Optimum Plate Heat Exchanger Geometry for OTEC Based on Net Power Maximization.

（海洋温度差発電の正味出力の最大化に基づく熱交換器の最適形状決定に関する研究)

要旨

Ocean Thermal Energy Conversion (OTEC) consists a heat engine that uses the thermal gradient within the sea to generate electricity. It is a steady renewable energy and can help reaching many sustainable developments goals. One of the most important and expensive components of OTEC are the heat exchangers – evaporator and condenser – which allow for the harvesting of the seawater thermal energy by transferring it to a low boiling point working fluid. Although many OTEC system optimizations can be found in the literature, none can provide insight on which heat exchanger geometry would lead to the highest net power output.

This thesis aims at investigating this matter through three main objectives. The first one is to provide a simplified yet accurate method for OTEC optimization that account for heat transfer coefficients and pressure drops of both fluids. The second one is to perform the optimization of heat exchangers geometry in order to maximize the net power output using the developed method. The third objective is to propose the use of Computational Fluid Dynamics (CFD) to derive accurate heat exchanger specific correlations to increase the accuracy and scope of the optimization of heat exchanger geometry.

A first chapter presents the background and operating principle of OTEC. Then, based on an analysis of the previous research on OTEC optimization methods and heat exchangers as well as CFD for boiling heat transfer coefficient, the motivation, purpose, and structure of this study are described.

In a second chapter, a simplified optimization method for heat exchanger selection that only depends on seawater heat transfer coefficient and pressure drop is developed for the Carnot and Rankine cycles and applied to three heat exchangers from the literature. The comparison between these three heat exchangers were made in terms of maximum net power output per unit of heat transfer area, with a value that significantly vary from one heat exchanger to another, and results were found to be consistent with data from the literature. Moreover, the most suitable heat exchanger was found to be the same for the Carnot and Rankine cycles, allowing the selection of heat exchanger to be based on the Carnot cycle for which computational time is less important

In a third chapter, the method’s accuracy is increased by including the working fluid heat transfer coefficient and pressure drop, and the heat exchanger geometry optimization was performed using global correlations after comparing results for two of the three heat exchanger investigated in the first chapter, for which the most suitable heat exchanger remained the same. The heat exchanger geometry optimization consisted in finding, for the evaporator and condenser, values of chevron angle, mean channel spacing, corrugation pitch and aspect ratio that would lead to the highest net power output per unit of heat transfer area. This led to a value of net power output per unit of heat transfer area 59 % higher than what was achieved with the previously found most suitable heat exchanger.

A fourth chapter proposes to use CFD to find the boiling heat transfer coefficient of the working fluid, ammonia, to use in the optimization method instead of a less accurate global correlation. A model was developed and compared with experimental data from the literature using water and was then applied to ammonia and operating conditions matching what can be found in OTEC. From these results, a heat transfer coefficient correlation was successfully derived, although the model requires further investigation in terms of stability. Nonetheless, this chapter propose a new way to analyze ammonia boiling heat transfer.

A final chapter summarizes the findings of this research and discusses the issues that need to be resolved in the future regarding the optimal design of the Ocean Thermal Energy Conversion system and optimum heat exchanger geometries.