ABSTRACT

The practical use of Ocean Thermal Energy Conversion (OTEC) is refocused because it is possible to supply stable electric power and a variety of integrated applications. The aim of this study is to improve the system performance with Double Stage-Rankine cycle. The irreversible loss in heat exchanger can be decreased at this cycle. As a result, the thermal efficiencies of the cycle at the maximum power output are almost same. The working fluid flow rates at the maximum power output of the combination of working fluids are different. The pressures of the working fluids are not exceeding 1.5MPa.

KEY WORDS: Double stage-Rankine cycle; ocean thermal energy conversion (OTEC); Working fluid.

INTRODUCTION

Environmental problems such as global warming and air pollution are caused by an increase of consumption of fossil fuels. Fossil fuel is exhaustible, and energy demand increases. The OTEC is refocused as available option for securing a sustainable and environment friendly source of energy. The OTEC power plant is the system for generating electric power using temperature difference between warm surface seawater and cold deep seawater. The seawater temperature is stable and insusceptible to climate, so OTEC can generate electric power more constantly than the other natural resources such as the wind and the ocean waves. In addition, the seawater used for electronic generation can be used in many fields for living, such as seawater desalination, agriculture, and more. Ocean thermal energy has a huge energy; however, energy density and temperature difference are small. OTEC system is smaller than that in the conventional thermal or nuclear power systems, and subsequently. The system cycle thermal efficiency is theoretically small. Therefore it is necessary to enhance the thermal efficiency of the OTEC system in order to use a practical plant.

The evaluation method for optimization of power generation system using unutilized heat source including heat transfer performance of heat exchanger was proposed (Ikegami et al., 1998; 2008; 2010a). Ibrahim and Klein (1995) analyzed the multi-stage Rankine cycle aiming at optimizing the power output from low-temperature heat sources such as geothermal of waste heat. Irreversible loss in heat exchange process can be reduced by multi-stage power cycle system and give superior system performance (Ikegami et al., 2012). The multi-stage power cycle system in which each has an independent equipment is not examined enough to select working fluids for double stage-Rankine cycle application because operating temperature ranges differ each other.

This paper attempts to clarify the influence of different characteristics of working fluids on double stage-Rankine cycle system for the purpose of selection of working fluids. The combination of working fluids used for independent equipment respectively in two Rankine cycles is decided, and optimal selection method focusing on the influence on power output and evaporation pressure is investigated.

Double Stage-Rankine Cycle

Conceptual Temperature-entropy (T-s) diagram using pure substance as working fluid is shown in Fig. 1. Thermal efficiency of the cycle using pure substance as working fluid that converts thermal energy of the ocean to work increases with a decrease of irreversible losses in the cycle or an increase of the effective temperature difference, the working fluid temperature difference between evaporating and condensing temperature. For that reason, it is necessary to decrease energy losses in the heat exchangers, namely to decrease temperature difference between seawater and working fluid. This is done by increasing of the heat transfer area or the overall heat transfer coefficient.

Conceptual T-s diagram using non-azeotropic mixture as working fluid is shown in Fig. 2. Using non-azeotropic mixtures such like ammonia/water as working fluid in OTEC cycle was proposed by Kalina (1987). Reducing irreversible losses in heat exchangers by using non-azeotropic mixture as working fluid leads to improvement in the thermal efficiency of the cycle. Several theoretical studies have reported that thermal efficiency of Kalina cycle using ammonia/water mixture as working fluid is higher than that of Rankine cycle using pure ammonia (Uehara, et al, 1994; 1998). On the other hand, other studies have reported that the effective temperature difference and heat transfer coefficient decrease by the boundary layer concentration change during the evaporation and condensation processes (Panchal, et al, 1981;