Applied Thermal Engineering 48 (2012) 176–185

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Ammonia–water cogeneration cycle for utilizing waste heat from the GT-MHR plant

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HIGHLIGHTS

- Utilization of waste heat from GT-MHR through an ammonia–water cogeneration cycle is investigated.
- First and second law efficiencies for the combined cycle are 9–15% and 4–10% higher than that for GT-MHR.
- The helium mass flow rate in the combined cycle is significantly lower than that in the GT-MHR.
- A cooling temperature of lower than 0 °C is achieved at the AWM turbine exhaust.
- Superheating the ammonia vapor at the turbine entrance has negative effect on the combined cycle performance.

ARTICLE INFO

Article history:
Received 8 October 2011
Accepted 8 May 2012
Available online 14 May 2012

Keywords:
GT-MHR
Ammonia–water mixture
Power/cooling cogeneration
Combined cycle
Exergy

ABSTRACT

A combined cycle is proposed in which the waste heat from a gas turbine-modular helium reactor (GT-MHR) is utilized by an ammonia–water mixture (AWM) cycle to produce cooling and additional power. The AWM cycle is a combination of the Kalina and an absorption refrigeration cycles and has been referred to as the Goswami cycle in the literature. A detailed thermodynamic analysis is carried out for the proposed combined cycle and the effects of some important parameters such as; the compressor pressure ratio, the turbine inlet temperature, the pump pressure ratio and the boiler temperature on the combined cycle performance are investigated. The cycle performance is also optimized based on the first and second laws of thermodynamics. It is found that, at nearly optimum conditions, the energy utilization and second law efficiencies of the combined cycle are about 9–15% and 4–10% higher than those of the GT-MHR cycle, respectively. It is also concluded that superheating the ammonia vapor at the turbine entry results in a decrease of the combined cycle efficiency and output cooling.

1. Introduction

In recent years, gas-cooled reactors have attracted the interest of many researchers and industrial organizations. The modular helium reactors (MHR) are among those which meet the safety, proliferation resistance, sustainability and low operation and maintenance cost requirements [1]. A lot of attention is paid to the Gas turbine-modular helium reactor (GT-MHR) and pellet bed modular reactor (PBMR) because of their promising thermodynamic and economic features for power production. An interesting aspect of these systems is their potential of being coupled to some other cycles for better efficiency as a huge amount of low grade energy is rejected to the atmosphere via their intercooler and pre-cooler [2–4]. Some efforts have been made and reported in the literature in utilizing this low grade energy for seawater desalination. It is shown that, for water desalination purposes, using the waste heat from nuclear power plant appears more profitable than using the fossil fuel [5–8].

Waste heat utilization from the GT-MHR, to produce power by means of organic Rankine cycles, has been previously reported by the authors [9–11]. Yari and Mahmoudi [9] proposed a system in which the waste heat from pre-cooler and intercooler of the GT-MHR cycle are utilized in two separate simple organic Rankine cycles (ORCs). They reported that both the first and second-law efficiencies of the GT-MHR cycle are enhanced by 3%-points when it was combined with the ORCs. In another work they investigated the utilization of this waste heat using different arrangements of ORCs [11]. The results prove that the simple ORC is the best, to be combined with the GT-MHR, from the viewpoint of both the thermodynamics and economics.

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doi:10.1016/j.applthermaleng.2012.05.009