Abstract

Around 17% of the global generated energy is consumed for residential, commercial, and transportation refrigeration. The current cooling technologies utilize refrigerants with high Ozone Depletion and Global Warming Potentials. Furthermore, the current technologies are expensive alongside with toxicity and flammability hazards. On the other side, energy produced by combustion of fossil fuels result in substantial amounts of waste heat. So, it is necessary to develop new refrigeration technologies that utilize waste heat as a source of energy with eco-friendly refrigerants with zero ozone depletion potential and zero global warming potential. Also, the Thermal Mechanical Refrigeration (TMR) technology improves the energy efficiency of the source waste heat system and minimizes the emissions of the carbon dioxide (CO2). In this study, a novel thermo-mechanical refrigeration system is proposed. It operates with low-grade energy sources (such as waste heat) at temperature range of 60 °C to 100 °C. Furthermore, it has the advantage of working with low-frequency driver-compressor unit, which eliminates noise and increases its lifetime. Moreover, the TMR system is adaptable to commercial, transportation, and residential refrigeration applications.

Introduction

- Refrigeration and air-conditioning systems consume about 30% of the generated electrical energy in Qatar [1,7].
- Exiting thermal refrigeration systems usually require heat source temperature much higher than 100°C [2].
- It is necessary to develop cooling system that has very low effect on the environment, simple design, low cost, flexible performance, and could be powered by various sources of renewable energy and waste heat.
- A novel isobaric thermal mechanical refrigeration (TMR) system has been introduced [3]. It is powered by an isobaric engine developed by Encontech B.V. company [4].

Description

- The system consists of a vapor-compression cycle integrated with vapor power cycle (See Figure 2).
- The compression process is performed by an isobaric expansion engine (See Figure 3).
- The power stroke is performed by the high-pressure vapor generated in the heater.
- The hydraulic accumulator permits using arbitrary vapor pressure.
- The backstroke is performed by the pressure of the evaporator.
- It can be operated as subcritical mode or supercritical mode (See Figure 5).
- The regenerator can be used to improve the efficiency and to minimize the condenser size.

Benefits of the study

- At heat source temperature from 70 °C to 100 °C, the subcritical mode is more advantageous than supercritical mode. In this range, using R717 as power loop with R32 in cooling loop provides maximum power efficiency of 7.8%. (See Figure 6).
- At heat source temperatures higher than 100 °C, the supercritical mode is more advantageous than subcritical mode. In this range, using R32 in power and cooling loops provides power efficiency of 10.8% (with regenerative) and 9.6% (without regenerator).
- The size of the expander-compressor unit depends on four factors: pressure difference between the higher and lower pressures of the power cycle, the evaporator temperature, the condenser temperature and the cooling capacity of the cooling cycle.
- Systematic steps are performed to select the proper fluids for subcritical mode (See Figure 4) and supercritical mode (See Figure 5).
- Over the design range, the expander diameter range varies from 45 mm to 65 mm and the compressor diameter range varies from 72 mm to 80 mm for a cooling capacity of 2 kW to 6 kW (See Figure 7).

Comparison

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Conclusions

- A novel thermo-mechanical refrigeration system is introduced.
- The proposed system able to operate with low-grade energy with temperature range of 60 °C to 100 °C.
- It can work with low-frequency which eliminate noise and increase the service time.
- Thermodynamic investigation of the system performance under subcritical and supercritical mode is applied and published.
- It is important to improve the control mechanism of the valves of the proposed system. It may be applied mechanically as shown in Figure 8.

Acknowledgement

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References