ABSTRACT

Title: Studies on the low-temperature driven and low-temperature generating absorption chillers using H_2O/LiBr solution as working fluid

Doctor Course in – Doctor of Engineering

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[Abstract]

The Paris agreement (COP21), a legally binding framework that aims to prevent global warming, describes all countries' work to make greenhouse gas emissions essentially zero in the second half of this century. In such a situation, absorption refrigerating cycles are essential to reducing fossil fuel and electricity consumption since they use thermal energy nearby the surrounding temperature.

This thesis focuses mainly on hot-water-driven absorption chillers among various applications of the absorption cycle. These chillers can reduce the cooling load of electrical vapour-compression cooling cycles and direct fuel-fired absorption machines by producing cold heat from reused low-temperature waste heat. The author discussed three research and development themes in this thesis. In the following, the author described significant findings in Part 1 ~ 3 and mentioned the future outlook of the absorption cycles in Part 4.

1. Development and implementation of an absorption chiller with 1 to 3°C output

In part one, the author studied an absorption chiller with a "dilute solution cycle," which reduced the freezing temperature of water refrigerant in the evaporator by mixing a small amount of absorbent. Thus, the absorption chiller can generate a lower output temperature of 1 to 3°C.

(1) Output temperature reduction by using a dilute solution

In chapter one, the author reviewed previous research and developments concerning the "dilute solution cycle." The relation between the dilute solution's concentration, freezing point, and heat transfer degradation in the evaporator was already quantified. However, these developments adopted a "two-stage cycle," which reduced the chiller's COP (coefficient of performance) by almost half. This disadvantage of the dilute solution cycle was problematic.

(2) Cycle simulation considering dilute solution in the evaporator

To overcome the above COP decrease, the author developed a new absorption chiller that applied a dilute solution cycle for a normal absorption cooling cycle without the "two-stage cycle."

In chapter two, the author modeled and simulated the dilute solution cycle as the first step of development. As a result, the author predicted that the dilute solution cycle could deliver 1 to 3 °C chilled water from 90 °C heat source hot water and 28 °C cooling water.

(3) Experimental verification of the cycle behavior by production prototype

The author manufactured a production prototype in chapter three based on the above discussion. This prototype had almost the same structure as present hot-water-driven single-effect absorption chillers. This prototype performed desired cooling capacity and COP of 0.71~0.73, which is enough comparable value to a general single-effect machine whose COP was 0.75.

2. Study of a low-temperature-driven absorption chiller using vapour-exchange double-lift cycle

In part two, the author studied the double-lift cycle as a critical method to reduce absorption chillers' driving heat source temperature. Formerly this cycle was pointed out to be suitable for utilizing low-temperature waste heat, so this study manufactured a proof-of-concept prototype of this cycle.

(4) Experimental proof of 7 °C chilled water output driven by 60 °C hot water with a prototype

In chapter four, the author demonstrated that 7 °C chilled water was obtained from 60 °C hot water and 30 °C cooling water from the experimental result of a double-lift cycle prototype. The reliability of this result was confirmed by the heat balance of the whole system. Cooling output and COP decreased from their rated value, and the cause of this degradation was explained clearly by internal heat loss.

(5) Hot water temperature characteristics and validation of the cycle simulation

In chapter five, the author studied the hot water characteristics of the prototype by the measured data and cycle simulation. The accuracy of the simulation was estimated by comparing it with the experiment for further application study. As a result, the author revealed the basic characteristics and showed the simulator had enough accuracy, i.e., ± 5% for the cooling capacity and ± 0.01 for the COP.

3. Development and implementation of single-effect double-lift absorption chiller

In part three, the author developed a "single-effect double-lift (SEDL) absorption chiller," combining a double-lift cycle and a conventional single-effect cycle. This chiller is driven by hot water with wide temperature differences and has appropriate COP for given temperature conditions. These SEDL absorption chillers were installed in some cases in Europe.

(6) Development of a primary prototype of a single-effect double-lift absorption chiller

In chapter six, the author manufactured a primary prototype of a SEDL absorption chiller to study its behavior and function, based on simulation results concerning cycle configurations. This prototype delivered 7 °C chilled water and recovered heat from 88.7 °C to 53.0 °C of hot water; thus approximately 35 °C difference between inlet and outlet was demonstrated.

(7) Operation verification of a production prototype and commercialization

In chapter seven, the author manufactured a production prototype based on the experimental results of the primary prototype of SEDL, premised on practical use, and verified its operation. As a result, the production prototype was operated with a 97 °C inlet, and the outlet hot water temperature was less than 57 °C. Thus over a 40 °C temperature difference was observed. The author predicted the COP considering body heat loss as 0.71 in the case of regular insulation of actual products.

(8) Social implementation of the single-effect double-lift absorption chillers

Based on the above studies, in chapter eight, the author introduced the first product of the SEDL absorption chiller to an office building with a co-generation system. According to its test run data, the chilled water outlet temperature was almost stable at approximately 6 °C of its set value. In another condition of approximately 30% cooling load, 60 °C hot water was available as the heat source for space cooling use. This result reproduced the experimental result of the proof-of-concept prototype studied in chapter four and was one of the most important results of this thesis.

4. Future outlook of absorption cooling cycles

In conclusion, the author is willing to study further lowering output temperature using a novel heat exchanger, commercialization of simple double-lift cycle, and applying a dilute solution cycle to the SEDL absorption chillers as the future outlook.

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