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A Review on Thermodynamic Analysis of a Cascade Refrigeration System Based On Carbon Dioxide and Ammonia

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Abstract- Refrigeration and air conditioning (RAC) play a very important role in modern human life for cooling and heating requirements. This area covers a wide range of applications starting from food preservation to improving the thermal and hence living standards of people. The utilization of these equipment's in homes, buildings, vehicles and industries provides for thermal comfort in living/working environment and hence plays a very important in increased industrial production of any country. In present study a review has been done on the thermodynamic analysis of cascade refrigeration system.

Keywords- Refrigeration and air conditioning, refrigeration system, COP, cascade system.

I. INTRODUCTION

As energy conservation is becoming an increasingly important aspect/parameter, there is a need to optimize the thermodynamic processes for the minimum consumption of energy. Many parameters affect the performance of a refrigeration cycle. In order to optimize their design, a thorough study based on the second law of thermodynamics (exergy analysis) analysis is required.

Although, first law of thermodynamic analysis method is most commonly used, however, this is concerned only with the conservation of energy and therefore it cannot show how or where irreversibility in the system and or a process occurs. On the other hand, second law based exergy analysis is another well-known method being used to analyze these cycles. Unlike, the first law, second law analysis determine the magnitude of irreversible processes in a system and thereby, provides an indication to point out the directions in which the engineers should concentrate more to improve the performance of thermal system.

In view of shortage of energy and a quest to conserve it in all possible ways energy conservation is becoming a slogan of the present decade and new methods to save energy which is otherwise wasted are being explored.

Energy recovery from waste heat and/or to utilize it for useful applications to improve the system efficiency is growing concern in scientific community and hence, is in use for industrial installations now-days. Ever present energy crises have forced the scientists and engineers all over the world to take into account the energy conservation measures in various industries.

Reduction of electric power and thermal energy consumption are desirable but unavoidable in view of the fast and competitive industrial growth throughout the world. Refrigeration and air conditioning systems form a vital component for the industrial growth and affect both the food and energy problem of a country at large. RAC systems are also a major contributor to the energy consumption. Therefore it is desirable to provide a base for energy conservation and waste heat energy recovery from RAC & HP systems.

A cascade refrigeration system consists of two independently operated single-stage refrigeration systems. A lower system that maintains a lower evaporating temperature and produces a refrigeration effect and a higher system that operates at a higher evaporating temperature. For some industrial applications that require moderately low temperatures with a considerably large temperature and pressure difference then the single stage vapor-compression refrigeration cycles become impractical. One of the solutions for such cases is to perform the refrigeration in two or more stages which operate in series. These refrigeration cycles are called cascade refrigeration cycles. Therefore, cascade systems are employed to obtain high-temperature differentials between the heat source and heat sink and are applied for temperatures ranging from −70°C to -100°C.

Application of a three-stage vapor compression system for evaporating temperature below −70°C is limited, because of difficulties with refrigerants reaching their freezing temperatures. The Montreal protocol and Kyoto underlined the need of substitution of CFC's and HCFC's regarding their bad impact on atmospheric ozone layer which protects earth from U.Vrays.

II. LITERATURE REVIEW

In Cimsit (2018) study, the absorption part has been designed to improve the performance of absorption – vapour compression cascade cycle as serial flow double effect. The detailed thermodynamic analysis has been made of double effect absorption –vapour compression cascade refrigeration cycle.

For the novel cycle working fluid used R-134a for vapour compression section & LiBr-H2O for absorption section. This cycle has been compared with single effect absorption – vapour compression cascade cycle & one stage vapour compression refrigeration cycle. The results indicate that the electrical energy consumption in the novel cycle is 73% lower than the one stage vapour compression refrigeration cycle.

Botia (2018) document presents a combined refrigeration system consisting of two vapour compression refrigeration cycles linked by a heat exchanger that not only reduces the work of the compressor but also increases the amount of heat absorbed by the refrigerated space as a result of the cascade stages & improves the COP of a refrigeration system. Zhou et al (2018) find out that waste heat can be utilized in absorption refrigeration systems. In this article, the performance of an auto-cascade absorption refrigeration system using R23/R134a/DMF solutions as the working substance was analyzed.

Optimization analysis results showed that to some extent, the COP could be increased when the low pressure of the system decreased.

Mishra (2017) deals with thermodynamic analysis of three stages cascade vapour compression refrigeration systems using eco-friendly refrigerants used for low temperature applications. The effect of thermal performance parameters on the first law thermal performances COP system and also in terms of second law efficiency of the cascade system and System exergy destruction ratio have been optimized thermodynamically using entropy generation principle.

Rajmane (2017) study is presented a cascade refrigeration system using as refrigerant (R23) in low temperature circuit and R404a in high temperature circuit. The operating parameters considered in this paper include superheating, condensing, evaporating and sub cooling temperatures in the refrigerant (R404a) high temperature circuit and in the refrigerant (R23) low temperature circuit.

Dixit et al (2016) study helps to find out the best refrigerants and appropriate operation parameters. It is found in the study that cascade condenser, compressor and refrigerant throttle valve are the major source of exergy destruction. The analysis has been realized by means of mathematical model of the refrigeration system.

III. CONCLUSION

A small concern with cascade refrigeration system is the initial installation cost which is about 10% higher than the traditional direct expansion systems. But this cost can be negated with less refrigerant charge requirements and environmental advantage of the cascade system due to less direct emissions as compared to single stage system.

An improvement, which can also be observed in cascade system, is the reduced amount of superheat in the discharge temperature of the high temperature circuit that results in a reduced capacity of the high temperature condenser and an increased refrigeration effect.

In low temperature applications, including rapid freezing and the storage of frozen food, the required evaporating temperature of the refrigeration system ranges from -40°C to -55°C, so a single stage vapor-compression refrigeration system is insufficient.

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