A review of waste heat driven absorption-vapour compression cascade refrigeration system

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***Abstract*— Different types of waste heat recovery technologies available among this all technologies this paper study provides the advantages of absorption –vapour compression cascade refrigeration system. From different sources like turbine exhaust, boiler exhaust, I.C.engine exhaust waste heat is recovered with the help of this cascade system and it also gives less electricity consumption as compare to conventional system.Normally in absorption system the working pair of refrigerant used is ammonia-water and lithium bromide-water.**

***IndexTerms*— absorption, compression, cascade**

I. INTRODUCTION

Vapour compression refrigeration system are commonly used in commercial and industrial area due to its high cooling capacity at low temperature, but to run this system high grade energy is required. High grade energy or electrical energy is one of the major input for economic development of any country. For human activities in all section like industrial, agriculture transportation etc. electricity is the basic need. Therefore for the sustainable development , high grade energy should be conserved and utilization of renewable sources should be encouraged. By cascading the vapour compression system with absorption system the consumption of electricity can be reduced. Renewable energy sources such as solar, geothermal can be used for supply low grade energy to cascade system [7]

II. DESCRIPTION OF THE CASCADE SYSTEM

Figure 1 shows the schematic view of absorption-vapour compression cascade system. In this cascade system the high temperature system is absorption system and low temperature system is vapour compression system. The component where heat of condensation of lower stage refrigerant is supplied for vaporization of next level refrigerant is called as *cascade condenser*.

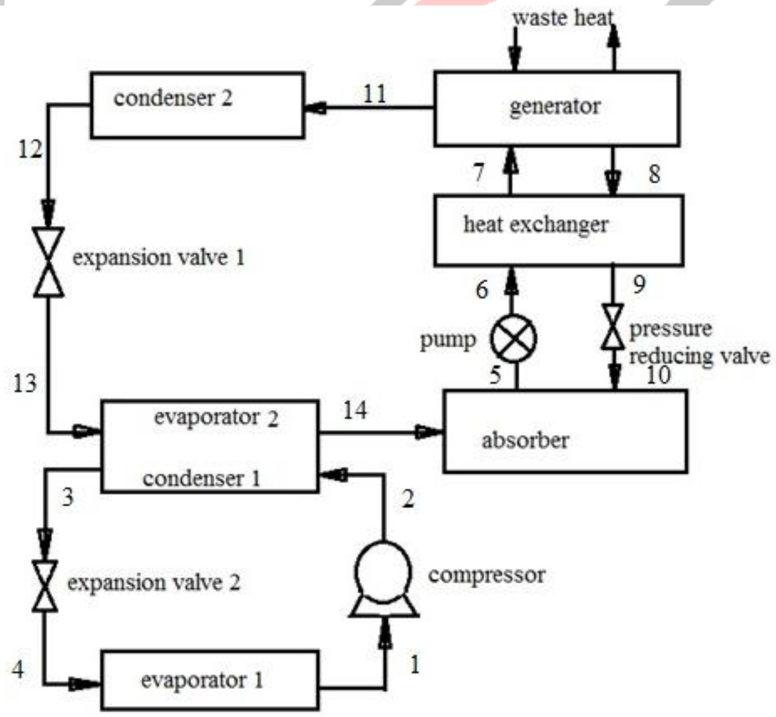

Figure 1: schematic diagram of absorption- vapour compression cascade system

For vapour compression system

Process 1-2: Isentropic compression of saturated vapour in compressor
Process 2-3: Isobaric heat rejection in condenser
Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
Process 4-1: Isobaric heat extraction in the evaporator

For absorption system
Process 5-6: Pump work
Process 6-7: heat supplied to heat exchanger
Process 13-14: Heat absorbed in evaporator
Process 11-12: Heat rejected in condenser
Process 14-5: Heat rejected in the absorber
Process 11-7,:Heat rejected in the generator from the source

In absorption system, the absorber weak solution of the working fluid is forced passed to the heat exchanger and from heat exchanger it draws to the generator.in the generator the weak solution absorbed the heat and strong solution is goes to the condenser.

Strong solution of working fluid leaves the generator and passed through the condenser. After condensation in the condenser the refrigerant is flow inside the expansion valve where pressure drop is happened and low pressurized refrigerant floe inside the evaporator coil and produced cooling effect. Refrigerant vapour is absorbed by absorber. In absorption system this process is repeated.

In compression system the refrigerant pressure and temperature is increased. Pressurized refrigerant is flow inside the condenser. Condensed refrigerant is passed through expansion valve where pressure is dropped. Then it is passed through evaporator where required cooling effect is produced.

III. LITERATURE RIVIEW

Ventas et al. [1] studied single-effect absorption refrigeration hybridized with mechanical vapor compression system. The ammonia-lithium nitrate solution is used as the working pair and it allows for working at lower driving temperatures, with low electricity consumption. The COP was higher than ammonia vapor compression cycle for same working conditions.

Rodgers et al. [2] conducted study on LNG gas with sea water utilization. Lithium bromide/water absorption system driven by waste heat of gas turbine was used. They evaluated different three absorption chiller configuration namely single effect, double effect and cascade chiller. They considered two alternative methods for precooling condenser.

Cimsit et al. [3] presented the thermo-economic optimization. Using non-linear simplex direct search method thermo-economic analysis and thermo-economic optimization is carried out. Optimum generator temperature, condenser temperature and effectiveness of heat exchanger were revealed in thermo-economical optimization. Carefully heat exchanger design suggested based on exergo economic factor value.

Colorado and Rivera [4] reported a comparison of first low and second low of thermodynamic of conventional vapour compression system, compression absorption single stage-CASS and compression absorption double stage-CADS with CO2 and R-134a refrigerant in compression system and lithium bromide-water in absorption system. Under the same operating condition electrical energy consumption was 46 % lower than conventional VCR system with CO2 and R-134a as a refrigerant. COP of R-134a was higher than same of CO2. COP of CADS was found 50 % higher than CASS.

Han et al. [5] proposed a new hybrid absorption–compression refrigerator powered by mid temperature waste heat. In this system ammonia–water binary mixture was used as working fluid. Waste heat from turbine is used for absorption system which was coupled with compression refrigeration system. To compress ammonia vapour from evaporator to condenser mid temperature waste heat was used. This system produced efficient cooling effect with waste heat input.

Kim et al. [6] developed a hybride systema in which ammonia-water is used as refrigerant. Experimentally observation was carried out with different operating characteristic of the compression-absorption hybride system. Combination of vapour compression system and absorber system was used for hybride heat pump system. Two stage compressor, absorbers and a desorber were main components of this system. By changing the composition of the mixture different benefits like large temperature glid, flexible opeating range and capacity control were achieved.

Jain et al. [7] developed a thermodynamic model for cascaded vapor compression- absorption system (CVCAS) which consists of a vapor compression refrigeration system (VCRS) coupled with single effect vapor absorption refrigeration system (VARS). Design capacity for performance analysis is carried out 66.67 kW and it was found that the electricity consumption is reduced 61 % in CVCAS.

Shu et al. [8] discussed different types of waste heat recovery technologies available onboard ships from the perspective of technical principle and application feasibility.

Shu et al. [8] studied of basic principle, novel methods, existing designs, theoretical and experimental analyses, economics and feasibility were discussed. The primary focus was to provide a better understanding of the options available for waste heat recovery and using in various applications onboard ocean-going ships to improve fuel economy and environmental compliance.

Little and Garimella [9] assessed for waste heat recovery applications based on vapor compression/expansion. Waste heat at 60 ℃ and 120 ℃ is taken for two case small scale- lower temperature and higher scale-higher temperature respectively. Also case study is done for waste heat recovery data from vehicles, process plants to utilize primary source input.

Aprile et al. [10] developed the prototype of an air-cooled double-lift $NH_3 - H_2O$ absorption chiller driven by hot water at low temperature. To study internal thermodynamic cycle they developed mathematical model of the cycle. They performed experiment

with inlet temperature of chilled water 12 ℃ and outlet temperature 7 ℃. For the capacity of 2.5 kW at air temperature 30 ℃ thermal COP was found 0.3 and electrical COP was found about 10.
Goktun [11] described an end reversible heat engine refrigeration cycle based on the combination of an absorption cycle with vapor and ejector compression cycles. This attachment provided higher performance as compared to conventional system.
Cimsit and Ozturk [12] have presented work proposed that to achieved -30 ℃ and lower than that temperature the single stage vapour compression system can be combined with single stage vapour absorption system using water-ammonia pair as refrigerant with less electricity consumption. For the absorption refrigeration system waste heat from industrial processes, solar and geothermal energy is utilized.
Kairouani and Nehdi [13] developed a novel combined refrigeration system, and discussed the thermodynamic analysis. In this study geothermal energy was utilized at 335 K to generator. R717, R22 and R134a were used as compression system refrigerant and ammonia-water pair as absorption system refrigerant
Seara et al. [14] determined optimum temperature for vapour compression refrigeration system and this performance is done only energy bases.
Wang et al. [15] developed the solar-assisted cascade refrigeration system. Vapour compression system was run by electricity and vapour absorption system was run by solar energy. Without sunlight how the system is run was also designed. Solar cascade system COP is higher than the conventional vapour compression system.
Garimella et al. [16] conceptualized and analyzed a novel cascaded absorption/vapor-compression refrigeration system. They developed thermodynamic model of the system. To achieve -40 ℃ for high heat flux application lithium bromide absorption and CO2 compression system coupled together. This cascade system saved 31% electricity as compared to conventionalvapour compression system
Seyfouri and Ameri [17] analyzed various setup for refrigeration system consists of a compression chiller and an absorption chiller that powered by a micro turbine. Waste heat from micro gas turbine was used to run the system. Different configuration invested for chiller and among that all the best configuration found was two stage compression chiller with an intercooler.
Jain et al. [18] analyzed exergy analysis for vapour compression absorption refrigeration system and compared this analysis with modified method using Gouy-Stodola equation.
Colorado and Velzquez et al. [19] simulated a compression–absorption cascade system with different working fluids. Lithium bromide-water pair was used in the absorption cycle and ammonium, R134a and carbon dioxide are used as refrigerant in the compression cycle. COP of the system was higher than conventional vapour compression system.

IV. CONCLUSION

From this study it was found that by using this cascade system the electricity consumption should be reduced up to 61% by using low grade energy. Highest coefficient of performance could be obtained in Lithium Bromide-Water fluid pair as compare to Ammonia-Water fluid pair in absorption refrigeration system. This type of cascade system is also operate with solar and geothermal types low grade energy sources.

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