A REVIEW STUDY ON EXPERIMENTAL ANALYSIS OF CASCADE REFRIGERATION SYSTEM

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Abstract : To the study of cascade refrigeration System the low temperature is obtained generally by vapour compression cycle. Cascade refrigeration system is a type of freezing system that is used by a two type of refrigerant having different boiling point. In this system temperature required -40^{0}c to -80^{0}c Cascade refrigeration system is made up of two single stage vapour compression system together condenser side of low temperature cycle and evaporator side of high temperature cycle. Cascade absorbs heat from the condenser for better effect of refrigeration. This system is designed to gain temperature up to -100^{0}c for the application like food storage, cold storage in malls and blood banks.

Keywords: Refrigeration system, Condenser, Compressor, Heating oil, cooling coil etc.

Introduction

In this study, Cascade refrigeration system working on two cycle first one is low temperature cycle and second one is high temperature cycle link by heat exchanger this setup also called the series combinations. In Cascade refrigeration system we generally used very low temperature range about (-40^{0}c to -120^{0}c) both refrigeration systems have compressor, condenser, expansion valve, evaporator and heat exchanger. In case we use low temperature and high temperature refrigerant. Cascade Refrigeration System we generally use the two type of Compressor First one is the LTC and second one is the HTC. This total arrangement done on the basis of refrigerant for example we choose the two refrigerant with different boiling point and freezing point first one is CO_2 (freezing point -56^{0}c) and second one is NH_3 (freezing point -77^{0}c) Cascade refrigeration system works on the two vapour compression cycle. This total setup called the series arrangement. In case when we fill up the refrigerant in the low temperature circuit evaporator in case refrigerant are compress than temperature are increased due to cooling in the evaporator after that heat rejected by the condenser in case high temperature circuit evaporator work same as the condenser in case rejected heat absorb high temperature circuit evaporator. So we use the natural refrigerant CO_2 (boiling point -78.5^{0}C) and NH_3 (boiling point -33.34^{0}C).

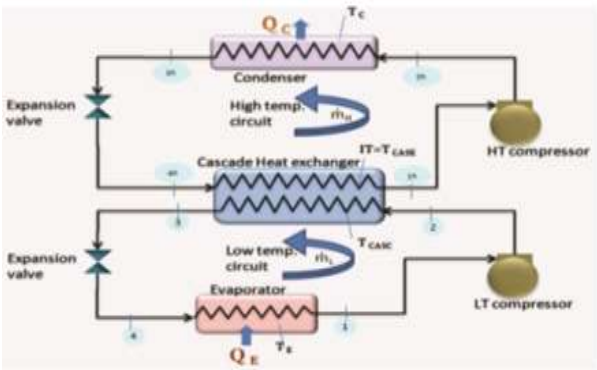

Fig-1: Line diagram of cascade refrigeration system

2. DESCRIPTION OF CASCADE REFRIGERATION SYSTEM

Cascade refrigeration system is the freezing system that can be used two types refrigerant having different boiling point and which run independent freezing cycle and are connected by heat exchanger. The schematic view and p-h diagram of cascade refrigeration system are shown in fig[a] this system is produce temperature of -40^{0}C to -100^{0}C the low temperature characteristics of refrigerant to consider poor level and making the system significantly inefficient. The efficiency increase of the system by combination of two different refrigerants.
This system has been following advantages to compare to a two-stage compression system.

a. In this system energy is saved because the system allows to use of refrigerants have suitable temperature of the higher-temperature side and lower-temperature side
b. This system allows fixed ultra-low temperature operation.

c. The running cost is low.
d. Repair is easily
In cascade refrigeration system higher-temperature side we generally used refrigerant (R404A, ammonia, etc.) and the lower-temperature side used R23.

3. LITERATURE REVIEW

A D Parekh et al. [1] designed the condenser for cascade refrigeration system operate eco-friendly refrigerant set R(404)A-R(508)A this refrigerant set have zero ozone consumption likely and minimum global warming. In this model study done on the basis of two condensers, first one is used as shell and coil type and second one is used as tube and tube type, refrigerant proceed inside the tube and water above the tube. The main objective of this model to find out heat transfer coefficients of both condensers. It initiate the heat transfers are both condenser reduce temperature difference of cascade condenser and are large expand.

Tzong-Shing Lee et al. [2] have conducted a practical study of cascade refrigeration system which is uses carbon dioxide and ammonia as refrigerants. This model generally designed to determine the condensing temperature of cascade condenser given different design parameter. These refrigerant having different boiling point and different critical pressure in case to maximize COP and minimize exergy of the system. Cascade refrigeration system control at low temperature, in the practical study condensing temperature are 35^0 C, 40^0C ,45^0C and evaporating temperature -45^0C -50^0C -55^0C and temperature difference find out in cascade condenser are 3^0 C ,4^0 C, 5^0C.

H.M Getu et al. [3] have designed cascade refrigeration system to modify the design and control all parameter of the system. In this model design and control parameter considered e.g. condensing sub cooling evaporating and superheating temperature in ammonia R(717)A high temperature cycle. temperature difference of cascade heat exchanger and evaporating, superheating, condensing and sub cooling in carbon dioxide R(744)A low temperature cycle. This model operate -50^0C (evaporating) and 40^0C (condensing) temperature. it was show COP_{max} was for ethanol followed by R(717)A and low for R(404)A for same conditions

R.KARAALI et al. [4] has designed of a model for cooling by used of waste heat energy in food production. This model operates on the principal of first law of thermodynamics. This model calculates the thermodynamic properties e.g. pressure, temperature, entropy and mass flow rate. When we expand the generator inlet heat in case temperature expands. Generator inlet heat absorber outlet heat and condenser2 outlet heat energy are expand due to the pump pressure also expand the pump pressure in case cop reduce. The reason of expand generator temperature in case expand the condenser outlet temperature than reduce the ECOP. It is decide that expand generator temperature and pump pressure expand than total exergy of the system is destructed.

Ashutosh Mate et al. [5] this paper assigned to study of cascade refrigeration system. Cascade refrigeration system is the combination of two refrigeration cycle. This system is thermally combined with evaporator of HTC and condenser of LTC. This system generally designed to gain temperature up to -20^0C for the enquiry like cold storage and other freezing system. In this model working fluids are used e.g. R22 (LTC) and R134 (HTC). These refrigerant use for to find the boiling for the desire outcome from the system. Analysis of this system carried out using steady flow energy equation and mass balance equation.

M.Raja et al. [6] has investigation on cascade refrigeration system. This model designed to use concept of with and without phase change material. In cascade refrigeration system low temperature obtain by vapour compression refrigeration system. The idea of cooling obtains in evaporator which is used to cool the condenser and obtain low temperature for cold storage applications. The low temperature side cooling is particular to a phase change material and cooling store in PCM. This process done up to 20 hours approximately without any operation we maintain the low temperature without continuously power supply. In this system ethylene glycol used as a phase change material PCM can store cooling for long time and remove the heat from refrigerated area.

Gulshan Sachdeva et al. [7] has designed a model cascade refrigeration system on the basis of two single vapour compression cycles. These are thermally combined to the evaporator and condenser of cascades in case we used different refrigerant in everyone cycle depends on the properties of refrigerant. This model produces COP and other parameter e.g. compressor work, temperature, pressure, enthalpy and entropy. In vapour compression cycle efficiency of reciprocating compressor and success of heat exchanger do not constant due to variation of refrigeration capacity. In this study we used working fluid in LTC in CO_2(R744), ammonia(R717), propane(R290), propylene(R1270), R(404)A and HTC in we used the R12 refrigerant. After that we compare the performance of curve ammonia, propane, propylene and R404A with R12 and we find out ammonia is the best in comparing to the R12.

. **Nasruddin et al. [8]** in this study cascade refrigeration system used a mixture of refrigerant namely carbon dioxide and hydrocarbons (propane ethane or ethylene)as the refrigerant of low temperature cycle. This model determine the optimal composition of these refrigerant in the range of operating parameter The composition of two refrigerant in low temperature cycle manage at maximizing COP, produce that the carbon dioxide did not undertake crystallization value of burning(flammability) of hydrocarbons were decrease. To solve the effective limit of carbon dioxide, connected to its triple point CO_2 was mixed with hydrocarbons the recommend value of carbon dioxide is 37% and ethylene 63% the calculated value of the system reached approximately 0.65

J.S.Jadhav et al. [9] review on cascade refrigeration system with different refrigerant pairs and thermodynamic parameter R744 is used in low temperature cycle e.g. R134A, R290, R717 are used in HTC. The performance of this model has investigated by changing only parameter keep relax of parameter are constant. In this system low temperature cycle evaporator temperature diverse from -80^0C to -55^0C and high temperature cycle condensing temperature diverse from 30^0C to 40^0C from the relative of different cascade refrigeration pairs the R744-R717 pair has the maximum COP. The COP of the R744-R717 system enlarges from 1.236 to 2.08 at LTC evaporator temperature diverse from -55^{0}C to -30^{0}C and other parameter are constant.

Selbaş, R., et al. [10] this model has been designed to energy and exergy of cascade refrigeration system carried out. In this system refrigeration load assumed 1kw. The condenser temperature has been used 50^{0}C to 60^{0}C and evaporator temperature was changed -30^{0}C to -40^{0}C. In cascade refrigeration system refrigerant pairs are used e.g. R134a-R404A, R134a-R407C and R404A-R410A. These refrigerant pairs are new generation refrigerant pairs. These all pairs are nondestructive to environment and to ozone layer. In this study the COP of the cascade refrigeration system expand when the evaporator temperature expand for all refrigerant pairs. But, the irreversibility of the system reduces.

Carlos Sanz-Kock et al. [11] has been done experimental analysis of cascade refrigeration plant by using R134a/CO_2 and designed this model for low temperature evaporation in commercial refrigeration application. This model working on two single-stage vapour compression cycle and compressor thermally combine by heat exchanger. In experimental analysis evaporating temperature varies from range about -40^{0}C to -30^{0}C and condensing temperature varies from range 30^{0}C to 50^{0}C. These values find and maintain by secondary fluid loop system before the testing and fixing degree of superheat is R134a cascade condenser and CO_2 evaporator at 10^{0}C. Gas cooler always consuming a constant value of 75W.

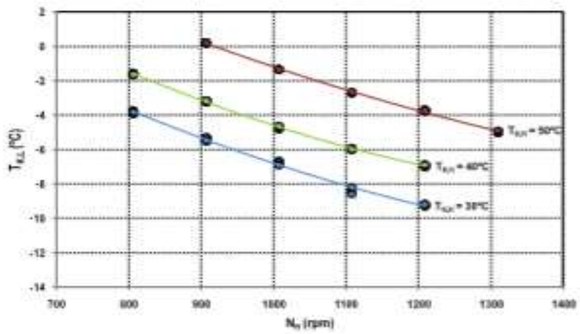

Fig-2: LT condensing temperature vs. HT compressor speed

Umesh C. Rajmane et al. [12] discussed on a cascade refrigeration system using refrigerant R23 in low temperature cycle and R404a using in high temperature cycle and analysis of this model in proper position where its level is horizontal and it is effectively ventilated and this model must have two meters clearances from all side. This system runs for 15-20 minutes to conduct the temperature after expansion range -10^{0}C to -15^{0}C. In case cascade temperature remains constant.

J. Alberto Dopazo et al. [13] In this study a cascade refrigeration system we used CO_2 and NH_3 as a working fluids in the low temperature cycle and high temperature cycle, respectively has been analyzed. To find out the COP and exegetic efficiency versus operating system and design parameter have been secure. The environmental problems related to global warming and depletion of the ozone layer is case of used synthetic refrigerant (CFC'S, HCF'S and HFC'S) this system has been designed to find out COP of the system. In this system we find out the COP expand 70%, when temperature of carbon dioxide in evaporators change from -55^{0}C to -30^{0}C in case COP is always expand. The COP expands 45% and temperature of ammonia in condenser change from 25^{0}C to 50^{0}C.

Hansaem Park et al.[14] has been defined the optimal in-between temperature of cascade refrigeration by using R134a and R410A this model generally designed for water heating purpose the suggested model totally based on thermodynamic laws and properties of refrigerants and operate its maximum efficiency in this model major parameter we have to find R134a use as a condensing temperature and R410A use as evaporating temperature. When R134a condensing temperatures are expanding the optimal in-between temperature is also overhead and in case maximum COP is reduce.

Q. N Khatib et al.[15] has experimental analysis of simulation study of R134a-R404a in cascade refrigeration system in this system to be obtain is performance by changing evaporating temperature with heater load further investigation of this system is done and system is reproduce and approve with experimental result. Parametric study done at different temperature by changing UA value of heat exchanger it is notice that performance of cascade condenser by shall and coil type. The performance of this system assess at different heat transfer areas of cascade condenser. It is noticed this system convey better performance by use of plate heat exchanger.

4. CONCLUSION:

After study and analysis of above research we find out the two refrigerants having different boiling point as carbon dioxide and ammonia suitable for to produce temperature range about -40^{0}C to -80^{0}C. Carbon dioxide is low temperature refrigerant and ammonia is the high temperature refrigerant. Cascade refrigeration system is very useful for industrial purpose.

REFERENCES

[1].Tzong-Shing Lee, Cheng-Hao Liu, Tung-Wei Chen "Thermodynamic analysis of optimal condensing temperature of cascade-condenser in CO2/NH3 cascade refrigeration systems" Elsevier. International Journal of Refrigeration 29 (2006) 1100-1108.

[2].H.M. Getu, P.K. Bansal "Thermodynamic analysis of an R744–R717 cascade refrigeration system" Elsevier. International journal of refrigeration 31 (2008) 45–54.

[3]. Ashutosh Mate, Prayag Panhale, Vandana shinde, Pritesh Mane "System Design and Development of Cascade Refrigeration" volume: 04 Issue: 06 June -2017 International Research Journal of Engineering and Technology (IRJET).

[4]. J.S.Jadhav, A.D.Apte “Review on cascade refrigeration system with different refrigerant pairs” International journal of innovations in engineering research and technology [IJIERT] ISSN: 2394-3696 VOLUME 2, ISSUE 6, june-2015R.
[5]. R. Karaali “Thermodynamic Analysis of a Cascade Refrigeration System” Vol. 130 (2016) Paper presented at 2nd International Conference on Computational and Experimental Science and Engineering (ICCESEN 2015).
[6]. A. D. Parekh, P. R. Tailor, H.R Jivanramajiwala “Optimization of R507A-R23 Cascade Refrigeration System using Genetic Algorithm” International Journal of Mechanical and Mechatronics Engineering Vol:4, No:10, 2010.
[7]. Nasruddin, Arnas, Ahmad Faqih, and Niccolo Giannetti “Thermoeconomic Optimization of Cascade Refrigeration System Using Mixed Carbon Dioxide and Hydrocarbons at Low Temperature Circuit” Makara J. Technol. 20/3 (2016), 132-138 doi: 10.7454/mst.v20i3.3068.
[8]. Gulshan Sachdeva, Vaibhav Jain, S. S. Kachhwaha “Performance Study of Cascade Refrigeration System Using Alternative Refrigerants” International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:3, 2014.
[9]. M.Raja , G. Maruthi Prasad Yadav “Experimental Investigation on Cascade Refrigeration System with And without Phase Change Material” International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 4, Issue 2, February 2015.
[10]. Selbaş, R., “An Application for Refrigerant Selecting In the Cascade Refrigeration Systems” International (Journal of YEKARUM) Yıl 2015/Cilt 3/ Sayı 1 E - ISNN: 1309-9388.
[11]. J. Alberto Dopazo, José Fernández-Seara , Jaime Sieres, Francisco J. Uhía “Theoretical analysis of a CO2–NH3 cascade refrigeration system for cooling applications at low temperatures” Elsevier Applied Thermal Engineering 29 (2009) 1577–1583.
[12]. Carlos Sanz-Kock, Rodrigo Llopis, Daniel S anchez a “Experimental evaluation of a R134a/CO2 cascade refrigeration plant” Elsevier Applied Thermal Engineering 73 (2014) 39e48.
[13]. Umesh C. Rajmane designed “Cascade Refrigeration System by using R404a-R23 Refrigerant” Asian Journal of Electrical Sciences ISSN: 2249 - 6297 Vol. 6 No. 1, 2017, pp.18-22.
[14]. Hansaem Park, Dong Ho Kim, Min Soo Kim has done “Thermodynamic analysis of cascade refrigeration system for optimal intermediate temperatures in R134aeR410A” Applied Thermal Engineering 54 (2013) 319-327.
[15]. Q. N. Khatib, C. D. Sagat, and M. S. Joshi “Experimental and Simulation Studies of R134aR404a Cascade Refrigeration System” International Journal of Engineering Innovation & Research Volume 1, Issue 3, and ISSN: 2277 – 5668.