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Utility of thermodynamic (exergy-exergy) analysis in cryogenic systems for liquefaction of gases: A Review

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Abstract

The exergy efficiency depend upon mainly upon the inlet condition of the system because inlet condition best suit for a particular type of the system except to increase the whole system efficiency stresses are done on particular parts of system and research are done on that systems. It was observed that that every part of system has its own and equal importance because ones effect on another whether it is small or big create a lot of difference in proper thermodynamic analysis of system. Ignoring one small system due less effect can put gap in complete thermodynamic research analysis of system that why it quite important take all parts of system as one and finding out the every part impact on another to calculate right equation for high output. Due to Air separation unit and compressor, condenser and evaporator of cryo system are the center of research because most of exergy destruction takes place in these parts. Heat exchanger and expansion valve, expander and other addition parts should also properly analyze

The main objectives of present investigations are Exergy analysis of considered cryogenics systems and finding exergy destruction in each and there individuals components Suggestion for reducing exergy destruction losses in whole systems and there components

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Keywords: Cryogenics, Thermodynamic Analysis, Energy-Exergy Analysis, First and second law efficiencies

1. Introduction

Cryogenics has been an important area of refrigeration because of its application in industrial and commercial utilization, and many scientific and engineering researches are going on by using low temperature liquefied gases. Cryogenics isa branch of physics which deals with the achieving very low temperatures (below the 173 K.) and study their effects on matter .Cryogenic study presents broad goals for cryogenic support for various gas liquefaction systems. Due to industrial revolution, various issues like cost, efficiency and reliability are the challenges factors in employment of cryogenic support technology. In field of mechanical engineering we try to refine or improve the ability or quality of material to get in maximum use at maximum level at a reduce cost. In past many fantasticclaim have been made as to the degree of improve performance achieved by employing cryogenics technology. Cryogenic engineering is the application of low temperatures that cannot be observed on Earth or in the atmosphere around earth under natural conditions to practical problems .In refrigeration, the temperature from -100 0C to -2730C (Or absolute Zero) are treated as low temperatures and Cryogenics is the science connected with reaching and applying temperatures below 120K (-1530C) [1].

1.1 Cryogenics Fluids

Today for achieving cryostat we uses many fluid but in due course some fluid considered as the main fluid to achieve cryostat and the temperature range of cryostat mostly depend upon the fluid we uses in apparatus .The chief fluids to achieve very low temperature are methane, oxygen, nitrogen, neon, hydrogen and helium. The characteristics of the most widely used cryogenic liquids are collected in Table 1. Table 1 gives the normal (1 bar) boiling temperature TN, the critical temperature TC and pressure PC, the temperature T3 and pressure p3 at triple point and the volume ratio VV/VL describing the increase in the fluid volume due to the process of vaporization and heating to the atmospheric temperature.

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Table: 1 Properties of Cryogenics Liquids [2].

Cryogenics	TN	TC	Pc	T3	P3	VV/VL
Liquid	K	K	MPa	K	kPa	
Methane	111.6	190.7	4.63	88.7	10.1	590
Oxygen	90.2	154.6	5.04	54.4	0.15	797
Nitrogen	77.3	126.2	3.39	63.2	12.53	646
Neon	27.1	44.4	2.71	24.6	43.0	1341
Hydrogen	20.3	32.9	1.29	13.8	7.04	788
Helium	4.2	5.2	.227	-----	-----	701

As seen from the table helium can achieve a very low temperature of 4.2 K but initially when helium is evaporated from its liquid state under high vacuum , the temperature as low as 1.1 K (-271.90C) was obtained but now a days , the lowest temperature achieved is 0.001 K very close to absolute temperature) [1].

1.2 Applications of Cryogenics

- Cryogenic Technology is used for production of Gases for industrial and commercial applications. In this process liquefaction and purification of Helium, Nitrogen gases are done. Also using this technique production of inert gases is done.
- Cryogenics is very crucial for aerospace application. This technology is very critical for wind tunnel testing application. High performance wind tunnel required rapid movement of nitrogen gas around the aerodynamic circuit.
- Cryogenic is required for Frozen Food Industries for preservation of food item depending upon type of food item and whether they are cooked or not before freezing.
- Cryogenic has got lot of application in medical field. It is wildly used in MRI equipment for diagnosis of diseases.
- Cryogenic has got a great role in chilled water storage system.

2. Literature Review

Walther Nernst (1906) [1]: Implies the impossibility of attaining absolute zero and introduce third law thermodynamics but modern science has reached temperatures only one-millionth of a degree above absolute zero, but absolute zero itself cannot be attained

Ref No	Author	Journal	Year	Work Done	Future Scope
2	Thomas et al	Cryogenics	2011	Lowest temp. of high liquid system can be improved by increasing the pressure ratio, mass imbalance gets compensated by the specific heat imbalance, optimum expander flow is found to be 80% of the total flow through the cycle.	Optimization of every system can be done to analyze to improve efficiency
3	Thomas et al	International journal of refrigeration	2012	In He system when two Brayton stages are combined to make one modified Brayton stages, the performance deteriorates. When one Brayton stage is split into two modified Brayton stages without changine show improvement without changine HX area.	More alternate arrangement s of cycle can be explore to enhance efficiency
4	Thomas et al	Energy	2012	Done exergy analysis to system so the result can be applicable on large He liquefier to get right parameters for geometric design. . Compressor pressure, expander flow rates, heat exchanger surface area are some of the parameters optimized considering both presence and absence of pressure drop in the heat exchangers.	At Different pressure values the system is analysied and again to find best pressure ration for optimum number of stages for liquefaction system
5	Thomas et al	International journal of refrigeration	2013	It has been demonstrated that four refrigeration stages is the best option for large helium liquefiers when all expanders operate between the entire available pressure differences when some of the expanders are operated at intermediate pressure, a more number of stages gives a higher thermodynamic efficiency. The intermediate pressure that gives the maximum exergy efficiency for the plant increases	More analysis can be done adopting more intermediate expander to increase overall efficiency
6	Cammarata et al	Applied energy	2001	This paper presents an optimization methodology for liquefaction/refrigeration systems in the cryogenic field. An optimization methodology based on genetic algorithms has been defined on helium liquefaction system	More different methodology can be put to get better results like Applied mathematics dealing critical variables

7	Thomas et al	Cryogenics	2012	Time consuming simulation are demerit in computational technique. The simulation time of the flow-sheet with PR and MBWR EOS(s) is also found to be 45 times faster than the real time, while the flow sheet with MBWR is found to be only 39 times faster than the real time.	More advance technology and more good simulation tool like HYSYS can done simulation more better and use of them can
8	Berstad et al	International Journal of Hydrogen Energy	2009	A methodology for hydrogen liquefaction that compensate non –uniformity in feed specification has been developed and applied three liquid liquefier. The process in consideration has been modified to have equal hydrogen feed pressure, resulting in more consistent comparison. Decrease in feed pressure resulting in more power consumption but have high energy vice versa. The approach can be adapted in boundary condition that the liquefaction process will be subjected to a real energy system.	How much pre-compression will best suit at variable compression pressure
9	Valenti et al	International Journal of Hydrogen Energy	2008	Refrigeration is via four helium recuperative Joule–Brayton cycles arranged so that the refrigerant follows the cooling curve of hydrogen and the volume flow rates in compression and expansion processes are typical of axial-flow high-efficiency turbomachines, compressionis accomplished in 15 intercooled 8-stage devices derived from gas turbine technology. the predicted work of approximately 18 MJ kg^{-1} is half as much as the requirement of those liquefiers and corresponds to a second-law efficiency of almost 48%.	48% efficiency is predicted not achieved ,different arrangement with Bryton cycle and stages are still research of point to achieve high efficiency
10	Krasaein et al	International Journal of Hydrogen Energy	2010	A proposed liquid hydrogen plant using a multi-component refrigerant (MR) refrigeration system is explained in this paper. , it could represent a plant with the lowest construction cost with respect to the amount of liquid hydrogen produced in comparison to today's plant	Cost cutting in Cryo technology still a challenge in research.
11	Valenti et al	International Journal of Hydrogen Energy	2012	The work focuses specifically on the third issue by assessing the influence of the thermodynamic modeling of the fluid on the simulation outcomes. Numerical approaches to compute the heat capacities as well as the equations of state of hydrogen forms (ortho hydrogen and Para hydrogen) and their mixtures (equilibrium-hydrogen and normal-hydrogen) are described here. The attention is on equilibrium-hydrogen because it is highly exothermic and makes liquefaction process slow.	Work on heat losses over components not properly asses by computational work, experimental work to be done to get accurate results
12	David O. Berstad	International Journal of Hydrogen Energy	2010	An innovative large-scale, high-efficiency hydrogen liquefier based on mixed-refrigerant (MR) pre-cooling has been developed, the resulting figures for specific liquefaction power are 6.48 and 6.15kWh/kgLH2, respectively. Based on current models, a reduction in the range of 45–48% from that of state-of-the art may be obtainable.	Cost still a point of research because low cryo-technology still a challenge,
13	Nakano et al	International Journal of Hydrogen Energy	2010	To manufacture a small scale hydrogen liquefier a simple estimation method for the liquefaction rate and confirmed that the estimation method well explained the experimental result	Small scale and low cost hydrogen liquefier can be improve using more mathematical and statically tool.

14	Yongliang Li et al	International Journal of Hydrogen Energy	2010	In this paper an optimization methodology for thermodynamic design of large scale gas liquefaction Systems proposed. The methodology has been applied to the design of expander cycle based liquefaction processes. High exergy efficiencies (52% for hydrogen and 58% for methane and nitrogen) are achievable based on very general consumptions.	Low exergy still the problem in all system of cryogenics .Various research methodology like computational ,experimental can be done to improve the efficiency
15	Mahabadipour H. et al	Applied Thermal Engineering	2013	In this paper, two typical types of low temperature expander cycles for cold section of olefin plant are designed and simulated. . The results conclude that the expander cycle with one cooling stage surpasses the expander cycle with two cooling stages. The main irreversibility exists in the expander due to its large pressure difference. The net power of the expander cycle with one cooling stage is 3549 kW, the flow rate is 47.35 kg/s and the overall exergy efficiency is 50.18% for the considered cycle in this research.	
16	Hoseyn Sayyaadi	International journal of refrigeration	2010	An optimization of the LNG-BOG re-liquefaction system was presented, it was found that increasing of the pressure ratio for nitrogen compressors, leads to decreasing of the total product cost. However, increasing of the pressure ratio for the BOG compressor leads to increasing in the total product cost	LNG is auto fuel widely used as clean fuel but its cost still a problem, low cost production and installation of fast filling plant still a concerned to researchers
17	Mehmet Kanoglu	Applied Thermal Engineering	2004	A procedure is developed for the energy and exergy analyses of open cycle desiccant cooling systems. The analysis shows that an exergy analysis can provide some useful information with respect to the theoretical upper limit of the system performance, which cannot be obtained from an energy analysis alone. The analysis allows the determination of the sites with the losses of exergy, and therefore showing the direction for the minimization of exergy losses to approach the reversible COP.	Exergy analysis can be applied on other system for optimization
18	Abdullah Alabdulkarem	Applied Thermal Engineering	2012	In this open CO2 liquefaction cycle model was developed and its performance was investigated. An improvement was made on the conventional open CO2 liquefaction cycle that resulted in a 10.61% power savings over the conventional open CO2 liquefaction cycle.	Further research using single and 3 cascade system is power consumption can further be reduced
19	Dincer et. al.	Exergy (Second Edition) Energy	2013	In this a comprehensive exergy analysis is presented of a multistage cascade refrigeration cycle used for natural gas liquefaction, which is a cryogenic process. The multistage cascade cryogenic system is described and an exergy analysis of the cycle components and the minimum work required for liquefaction are provided.	Exergy analysis is power full tool of optimization. Cascade refrigeration analysis show very low exergy efficiency.
20	Cornelissen et. al	Energy Conversion and Manage ment	1998	More than half of the exergy loss takes place in the liquefaction unit and almost one-third in the air compression unit. The major cause of exergy loss is the use of compressors and to a lesser extent the use of turbines In this research is done on air separation unit.	Compressor and air separation unit show more exergy losses more research will be done for avoid losses in these unit.
21	Wood et. al	Cryogenics	1985	In this refrigeration optimization is presented based on the concept that the most appropriate and meaningful measure of the level of refrigeration is the product of entropy absorbed by the refrigerant at the cycle cold temperature, ΔS_c, and the temperature span, ΔT, over which it is pumped.	Optimization using other temperature measuring scale and use of various other term like para and fero magnetic unveil the new optimization methods.

22	Sorin Gherghinescu	U.P.B. Sci. Bull, Series D	2010	In this paper thermodynamic analysis of the two cycles reveals that the hydrogen cycle obtains a higher degree of reversibility, as well as a higher cryogenic efficiency. The Carnot efficiency of cryogenic cycle with hydrogen is higher than the Carnot efficiency of helium cycle, this it explicable by the fact that the minimum temperature of liquid helium is less than the one of hydrogen	Hyderogen and helium liquefaction still a challenge in front of researcher .Thermodynamic analysis provide useful information but thermodynamic analysis of component wise and whole plant involve high research data and future work still need of it
23	Yumrutaş et. al	Exergy	2002	It is found that the evaporating and condensing temperatures have strong effects on the exergy losses in the evaporator and condenser and on the second law of efficiency and COP of the cycle but little effects on the exergy losses in the compressor. The second law efficiency and the COP increases, and the total exergy loss decreases with decreasing temperature difference between the evaporator and refrigerated space and between the condenser and outside air.	Condenser and evaporator unit show effect on exergy efficiency of system ,proper research will be done to completely understand the multi stage condenser evaporator unit
24	Ahamed J.U.	Renewable and Sustainable Energy Reviews	2011	Among the components of the vapor compression system, much research showed that major part of exergy losses is occurred in the compressor. Nano fluid and Nano lubricant cause to reduce the exergy losses in the compressor indirectly, Other than it is found that exergy depends on evaporating temperature, condensing temperature, sub-cooling and compressor pressure. Different refrigerant used and exergy efficiency is analyzed on the basis of these.	Nano fluid used in cryogenics is completely new area of research ,use of Nano-fluid take cryo-technology to new heights
25	Kansha et al.	Separation and Purification Technology	2011	In this paper, a novel cryogenic air separation process that reduces energy consumption by self-heat recuperation is proposed. A simulation demonstrated that the energy consumption of the proposed cryogenic air separation process with self-heat recuperation decreased by more than 36% compared with the conventional cryogenic air separation process, when producing 99.99 mol% oxygen from air	Air separation unit in cryogenic system show high power consumption, new technology can be used to reduce losses.
26	Ham et al.	Energy	2010	Two process designs of a cryogenic ASU (air separation unit) have been evaluated using exergy analysis. The two process designs separate the same feed into products with the same specifications. They differ in the number of distillation columns that are used; either two or three. The three-column design destroyed 12% less exergy than the two-column design. Almost half of the exergy destruction is located in compressor after-coolers	Research on ASU and ther column design still a area of research in exergy losses, by further simulation technique on separation unit can lead to more reliable and cost effective results
27	Rizk J.	Energy	2012	Paper on Distillation columns research is done. Their inconvenient is their high energy consumption. A comparative exergy analysis between the distillation columns considered for cryogenic air separation shows that the exergy efficiency of a double diabatic column, with heat transfer all through the length of the column, is 23% higher than that of the conventional adiabatic double columns. In a simple adiabatic distillation column, most of the exergy losses occur in the column itself (57%)	In ASU high exergy losses occur, more research are to be done to reduce further losses of exergy by using advance technology like ceramic.

28	Syed et. al.	International Journal of Hydrogen Energy	1998	Solar hydrogen system get light in research. Economic analysis of three hydrogen liquefaction systems with an associated cost comparison. The analysis showed that the cost of liquefying hydrogen is lowest for an optimized large-scale type liquid hydrogen plant and is highest for a simple conceptual liquid hydrogen plant.	Solar technology merge with cryogenic technology open new era of technology .One time cost of solar system lead to overall less cost of system in operation
29	Agrawal et al	Gas Separation & Purification	1991	Through exergy analysis, inefficiencies were identified in the distillation system. Two solutions using two vaporizer/condensers in the bottom section of the low pressure (LP) column were suggested, which reduce the exergy loss of the cryogenic part of the plant by 8–9.5%. A process in which nitrogen is condensed in both the vaporizer/condensers located in the bottom section of the LP column yielded the lowest exergy losses for the distillation system.	Use of liquid nitrogen I n condenser side put positive result in system .Advance design in stages lead to high efficiency.so research on this part lead to more efficient design
30	Agrawal et al.	Encyclopedia of Separation Science, Academic Press, Oxford	2000	In this a brief history of air distillation process is discussed with continuous advancement in them over the age. Various columns here to describe the air distillation processes	Brief history helps us in understanding the current present work of ASU. Considering this more efficient system can be developed
31	Gaelle Gosselin	KTH industrial engineering and management	2012	Oxygen separation from air, preference is given to polymeric membranes and from a few years also to ceramic-based membranes. The diffusion of some gas compounds through polymeric membranes is driven by pressure difference between the two sides of the membrane.	Selection and research on polymeric membrane in cryogenic system can be apply to for multi gas separation ASU.
32	Sun et al.	Advances in Cryogenic Engineering	1996	In this loss mechanisms of an Oxford Stirling cryo-cooler are examined using a new simulation model together with second law analysis. The simulation employs a new correlation for heat transfer and friction in oscillating flow. The significant exergy destructions in the cryo-cooler, due to viscous dissipation, heat transfer, mixing processes, shuttle heat transfer and heat conduction in the solid members, are evaluated independently	Proper Heat dissipation in cryogenics system result in improve efficiency, Research should be done on the thermal analysis of system
33	Ray Radebaugh	Low Temperature and Cryogenic Refrigeration ,NATO Science Series	2003	This paper presents a review of the pulse tube refrigerator from its inception in the mid-1960s up to the present. . Efficiencies as high as 24% of Carnot at 80 K and temperatures as low as 2 K have been achieved in pulse tube refrigerators. Pulse tube refrigerators operate with oscillating pressures and mass flows and have no moving parts in the cold end.	Pulse tube refrigerators are used in space so more research on these cryo system improve the space technology.
34	Sinyavski Yu. V.	Chemical and Petroleum Engineering	1995	Compressor alternatives may be electrocaloric cooling. But The numerical value of the integral electrocaloric effect at temperature T= 10-300 K for a change in the external field in the interval 0-25 kV/cm generally are no greater than tenths of a degree and only in some materials do the maximum values of delta T reach one degree .This has been the main reason why the electrocaloric effect for a long time was not considered as an alternative for realization of the cooling process T > 10 k	More research need to be done to overcome the limitation of electro caloric technology in cryogenic field
35	Minta et al	Advances in Cryogenic Engineering	1984	An Entropy Flow Optimization Technique for Helium Liquefaction Cycles is discusses. The intensity of the effort to design efficient cycles is reflected in the numerous discussions of optimization techniques in the literature	Optimization is tool to reduce cost and get economical design of system .Entropy generation that cause of irreversibility

36	Shen et al	Frontiers in Energy	2012	In this paper, the utilization of LNG cold energy in seawater desalination system is proposed and analyzed. A simplified model of the direct-contact heat transfer in this desalination system is proposed and theoretical analyses are conducted. The calculated results are in reasonable agreement with the available experimental data of the R114/water system	Bye changing the refrigerant with more effective and environmental friendly refrigerant lead to get more better result of sea water distillation
37	Gadhiraju Venkatarathnam	International Cryogenics Monograph Series	2008	Process simulation is a widely used technique in the design, analysis, and optimization of process plants. Simulators are computer programs that simulate the behavior of the process plants using appropriate mathematical models. Simulators are used for a variety of purposes	Different simulation tool used to get better and better result of a system that are practically very costly to check performance so more research in field of optimization using simulation technique.
38	Wouagfak et al.	Energy Systems	2011	In this paper thermo-ecological optimization criterion (ECOP) for three-heat-source refrigerators with linear phenomenological heat transfer law is done. The results show that the three-heat-source refrigeration cycle working at maximum ECOP conditions has a significant advantage in terms of entropy production rate and coefficient of performance over the maximum E and maximum R conditions.	Ecological optimization criteria is a complete new technique of optimization, more research by using different cryo system evolve to method to improve efficiency of system
39	. Erdt et al	Advances in Cryogenic Engineering	1994	The LINDE helium refrigeration plant combines an extremely compact construction with remarkably good cycle efficiency. It was in part achieved by arranging 3 expansion turbines in the temperature region below 20 K, one of which expands to roughly saturated liquid. The paper describes the system, the results of performance measurements.	
40	Belnov et al	Theoretical Foundations of Chemical Engineering	2007	The relationship between the plant efficiency and the duration of each of the operating cycle stages is studied using an ad hoc computer program for numerically solving the model equations. It is shown that optimization of the durations of cycle stages increases the thermodynamic efficiency of the plant to 20–22% in comparison to industrial plants.	Research can be proceed by knowing accurate timing of each stage and data can be utilized to get more useful result to increase any other cryo-plant efficiency
41	Brodyanski V. M.	Thermal Engineering	2006	In this It is shown that replacing water, which is traditionally used as a working medium for the thermal power cycle, by an ammonia-water mixture (the Kalina's cycle) or another substance that does not freeze at condensation temperatures ranging from −30 to −40°C allows the capacity of both nuclear and geothermal power stations to be increased substantially during most of the year.	Research on choosing right medium to get high efficiency of any nuclear and geo thermal plant
42	Manzagol et al.	Academic Journal	2002	Cryogenic expanders with work production have a predominant influence on refrigerator/liquefier reliability and efficiency. This paper presents a new cryogenic expander technology. This expander has been tested on a Brayton cycle refrigerator and reached an isentropic efficiency of 50 to 60% for inlet gas conditions of 35 K and 0.7 MPa.	Expander in different cryo with different pressure ratio still the area of concern due to great influence on optimization of a system
43	Elcock et al.	*Argonne National Laboratory*	2007	They found that TiO_2 nanoparticles can be used as additives to enhance the solubility of the mineral oil with the hydro fluorocarbon (HFC) refrigerant. Refrigeration systems using a mixture of HFC134a and mineral oil with TiO_2 nanoparticles appear to give better.	TiO_2 nanoparticles can be potentially used in refrigeration system.

44	Hindawi	Hindawi	2009	It has been carried out by experimental study on boiling heat transfer characteristics of R22 refrigerant with Al_2O_3 nanoparticles and found that the nanoparticles enhanced the refrigerant heat transfer characteristics by reducing bubble sizes	Nanoparticles can be used to enhance heat transfer capabilities
45	Eastman et al.	Mater Res Soc Symp Proc	1996	They investigated the pool boiling heat transfer characteristics of R11 refrigerant with TiO_2 nanoparticles and showed that the heat transfer enhancement reached by 20% at a particle loading of 0.01 g/L.	TiO_2 nano particles can be used to enhance the heat transfer capability of R11 refrigerants.
46	Liu et al.	Chemical Engineering and Technology	2006	They investigated the effects of carbon nanotubes (CNTs) on the nucleate boiling heat transfer of R123 and HFC134a refrigerants. Authors reported that CNTs increase the nucleate boiling heat transfer coefficients for these refrigerants.	CNT have an potential to increase the nucleate boiling heat transfer coefficient of the refrigerants.
47	Jiang et al.	International Journal of Thermal Sciences	2009	The experimental results showed that the thermal conductivity of carbon nanotubes (CNT) nanorefrigerants are much higher than those of CNT–water nanofluids or spherical nanoparticle–R113 nanorefrigerants. Authors reported that the smaller the diameter of CNT larger the thermal conductivity enhancement of CNT nanorefrigerant.	CNT with smaller diameter can be used to enhance the thermal conductivity of the refrigerants
48	Hwang et al.	Current Applied Physics	2006	They suggested that thermal conductivity enhancement of nanofluids is greatly influenced by thermal conductivity of nanoparticles and base fluid. For instance, thermal conductivity of water based nanofluid with multiwall carbon nanotubes has noticeably higher thermal conductivity fluid.	Multiwalled carbon nanotubes has the higher thermal conductivity among the other nano particles.
49	Yoo et al.	Thermochimica Acta	2007	They argued that surface to volume ratio of nanoparticles is a dominant factor. Surface to volume ratio is increased with smaller sizes of nanoparticles. Choi et al.[8] reported that 150% thermal conductivity enhancement was observed in poly (a-olefin) oil by addition of multiwalled carbon nanotubes (MWCNT) at 1% volume fraction.	Surface to volume ratio is an dominant factor to enhance the thermal properties of Nano fluid
50	Yang	University of Kentucky	2006	He reported, a 200% thermal conductivity enhancement for poly (a-olefin) oil containing 0.35% (v/v) MWCNT. It is important to note that this thermal conductivity enhancement was accompanied by a three order of magnitude increase in viscosity.	MWCNT nanoparticles can increase the thermal conductivity as well as viscosity
51	Eastman	Applied Physics Letters	2001	He observed 40% thermal conductivity enhancement for ethylene glycol with 0.3% (v/v) copper nanoparticles (10 nm diameter), although the authors also added that about 1% (v/v) thioglycolic acid helpful for dispersion of nanoparticles in base fluid. The addition of this dispersant yielded a greater thermal conductivity than the same concentration of nanoparticles in the ethylene glycol without the dispersant.	Dispersant can be used to enhance the conductivity.
52	Kang et al.	Experimental Heat Transfer	2006	They reported a 75% thermal conductivity enhancement for ethylene glycol with 1.2% (v/v) diamond nanoparticles between 30 and 50 nm diameter. Despite of these remarkable results, some researchers also measured the thermal conductivity of nanofluids and found no anomalous results.	Diamond nanoparticles can be used to enhance the thermal conductivity of ethylene glycol.

53	Lee et al.	International Journal of Heat and Mass Transfer	2008	They revealed that optimum combination of pH level and surfactant leads to 10.7% thermal conductivity enhancement of 0.1% Cu/H2O nanofluid. They also concluded that during nanofluid preparation stage thermal conductivity of nanofluid is affected by pH level and addition of surfactant.	PH level and surfactant potentially used to enhance the thermos-physical properties.
54	Jiang et al.	International Journal of Thermal Sciences	2009	They added that thermal conductivity of nanofluids also depend on the nanoparticles size and temperature	Size and temperature can be affected to the thermal properties of nano-particles.
55	Wu et al.	Journal of Engineering Thermophysics	2008	They observed that the pool boiling heat transfer was enhanced at low TiO_2 nanoparticles concentration in R11 but deteriorated under high nanoparticles concentration.	Low concentration of TiO_2 in R11 can affectively enhanced the pool boiling heat transfer.
56	Trisaksri and Wongwises	International Journal of Heat and Mass Transfer	2009	They investigated TiO_2 in HCFC 141b in a cylindrical copper tube and found that the nucleate pool boiling heat transfer deteriorated with increasing nanoparticle concentrations especially at higher heat fluxes.	Increasing concentration nd heat flux can badly affect to the thermal properties of nano particles.
57	Hao et al.	International Journal of Refrigeration	2009	They investigated flow boiling inside a smooth tube at different nanoparticles concentration, mass fluxes, heat fluxes, and inlet vapor qualities in order to analyze the influence of nanoparticles on the heat transfer characteristics of refrigerant-based nanofluid. Authors observed that the heat transfer coefficient of refrigerant-based nanofluid in flow boiling is larger than that of pure refrigerant and the maximum enhancement is about 29.7% when observed with a mass fraction of 0–0.5 wt%.	Nanoparticle can enhance the heat exchange capability of refrigerants.
58	Hao et al.	International Journal of refrigeration	2010	They studied experimentally the nucleate pool boiling heat transfer characteristics of refrigerant/oil mixture with diamond nanoparticles. The results indicate that the nucleate pool boiling heat transfer coefficient of R113/VG68 oil mixture with diamond nanoparticles is larger than that of R113/oil mixture by 63.4%. Enhancement in same factor increases with the increase of nanoparticles concentration in the nanoparticles/oil suspension and decreases with the increase of lubricating oil.	Refrigerant/oil mixture with diamond nanoparticles can be used to enhance the thermal conductivity.
59	Wang et al.	Proceedings of the 4th symposium on refrigeration and air condition	2006	They carried out an experimental study of boiling heat transfer characteristics of R22 with Al_2O_3 nanoparticles and found that nanoparticles enhanced the refrigerant heat transfer characteristics by reduction of bubble sizes that moved quickly near the heat transfer surface.	R22 with Al_2O_3 nanoparticles showed the better thermal properties
60	Li et al.	Proceedings of the 12th symposium on engineering thermo physics	2006	They investigated the pool boiling heat transfer characteristics of R-11 with TiO_2 nanoparticles and showed that the heat transfer enhancement reached by 20% at a particle loading of 0.01 g/L.	R-11 with TiO_2 nanoparticles and showed the pool boiling heat transfer characteristics.
61	Peng et al.	International Journal of Refrigeration	2009	They investigated the influence of CuO nanoparticles on the heat transfer characteristics of R-113 refrigerant-based nanofluids and presented a correlation for prediction of heat transfer performance of refrigerant based nanofluids. Authors reported that the heat transfer coefficient of refrigerant-based nanofluids is higher than that of pure refrigerant, and the maximum enhancement of heat transfer coefficient found to be about 29.7%.	CuO in 113 refrigerant-based nanofluids can enhanced the heat transfer characteristics.

62	Kumar and Elansezhian	J Front Mech Engg	2014	They experimentally investigated the effect of varying concentration of ZnO nanoparticles on various performance parameters like COP, suction temperature, input power and pressure ratio with 152a as working fluid in vapour compression refrigeration system. They found that 0.5% v ZnO nanoparticles with R152a gives maximum COP of 3.56 and 21% reduction in power input. Pressure ratio decreases with increase in ZnO concentration.	
63	Mahbubul et al.	International Journal of Heat and Mass Transfer	2013	They measured thermo physical properties, pressure drop and heat transfer performance of Al_2O_3 nanoparticles and R-134a mixture. Thermal conductivity of Al_2O_3/R-134a nano refrigerant increased with temperature and augmentation of particle concentration. It was also observed that pumping power, viscosity, pressure drop, and heat transfer coefficients of the Nano refrigerants show significant increment with the increase of volume fractions. The frictional pressure drop also shows rapid increment with 3 vol. % particle fraction.	The pumping power, viscosity, pressure drop, and heat transfer coefficients of the nano refrigerants shows significant increment with the increase of volume fractions.

3. Conclusion and Recommendation

From the literature review it is found that various research and different method are employed to increase efficiency of cryo system. Second law efficiency are very low in all above said cryogenic systems like hydrogen ,helium liquefaction etc. and its value ranging from 3% to 23 % for most of systems. Advance technology like different cryo fluid include Nano one (Nano fluid and Nano lubricants) are also tried to reduces the losses. Ceramic technology is also used in separator to increase the high output with less losses. Low increase in exergy efficiency is noticed in various different systems. Exergy efficiency are mainly depend upon the inlet condition of system and in most of cases the inlet conditions are NTP (normal temperature pressure) conditions that is 298 K temperature and one atmosphere pressure.

3.1. Conclusions

Exergy analysis of cryogenics systems in which first six system with different gases and rest systems such as hydrogen, Collin, improved Collin system are evaluated on the basis of pressure ratio, compressor outlet temperature, and expander mass flow ratio. Experiment has been done on the vapour compression system to give valuable suggestion for increasing efficiency of cryogenics systems. Following results are concluded from study.

(1) During off design condition, performance of cycle does not hamper within the specific range of cyclic pressure ratio, for particular considered system there is always appropriate operating pressure ratio range for each working gas on which system work better

(2) All six system are compared on the basis of performance parameters at different pressure ratio, form the data observation it observed that simple Claude cycle is most suitable system because the three heat exchanger help in achieving more refrigerant effect which is in turn optimize the performance of the system.

(3) During PR increase, there is an imbalance in mass flow of forward and return stream of heat exchanger HX. Second law efficiency with the help of increasing pressure ratio which variate and create specific heat imbalance to overcome the mass imbalance.

(4) Variation in expander mass flow has highly influence the refrigeration effect of expander and overall performance of system. Optimum range of EXP flow fraction (r) producing refrigeration effect is 0.55 to 0.7. Liquid production rate is highly influenced by refrigeration effect of expander.

(5) Inlet temperature of expander also plays an important factor to determine the refrigeration effect while other parameters in the system are constant. As the mass flow fraction increases through EXP, the output temperature of expander T_e also decreases which in turn lower the inlet temperature of input temperature of$T_{in\ EXP}$.

(6) In all gases methane gas show highest performance parameters in most of system while argon show lowest.

(7) The performance of hydrogen liquefaction cycle does not much deteriorate during off design condition when it is operated in selected operated range of PR 20-52 bar (the compressor suction pressure is atmospheric).

(8) Exergetic efficiency of the heat exchanger (HXD) at the lowest temperature of a hydrogen liquefier can be improved by increasing the pressure ratio because the mass imbalance gets compensated by the specific heat imbalance.

(9) While designing the hydrogen liquefaction cycle, owing to their lower exergetic efficiencies, additional care should be taken for ensuring superior heat transfer performance by the high temperature heat exchanger HXA and the lowest temperature heat exchanger HXD.

(10) Initial feasible range of pressure ratio in hydrogen liquefaction system is 20 to 87 bar, COP of the system decrease at very rapid rate but after that the rate of

reduction in COP with increase PR start becoming constant with very less change while the second law efficiency show a constant reduction with increase in PR.

(11) Design parameter NTU for HX is carefully study for best performance of system. NTU term continuously decrease in hydrogen liquefaction system upto 70 bar for the J-T heat exchanger HXD and minimum at 70 bar while the variation in NTU term for HXA and HXB is quite different due to the different cold stream temperature of exchangers

(12) Improved Collin system show high efficiency as compared to Collin system, the nitrogen chamber and extra expander gives extra refrigerant effect which enhance liquefaction rate in the system and increasing the performance parameters of systems.

(13) The improved Collin system at PR 11 bars show highest exergtic efficiency of 54.19% keeping the expander ratio of all three expander is 70%,10%,10% respectively while simple Collin helium liquefaction system show 3.54% exergtic efficiency keeping the both expander flow ratio 35% and 50% respectively

(14) Experiment is done to give valuable suggestion for increasing efficiency of cryogenics systems.. Test results show that the parameters such as exergy efficiency, heating capacity of the considered system improved in the range of 1.9-5.96% and 26-82% respectively by using 0.06 Vol% silver Nano fluid compared to water as cold based fluid for considerable range of cold base fluid flow rate.

(15) Exergy destruction decreases in the range of 29-31.28%, 65.77-70.01%, 14.31-16.03%, 17-23% in compressor, condenser, evaporator and expansion valve respectively. whereas 0.015 Vol% silver Nano fluid shows very less effect on performance parameters of system for different base fluid mass flow rates.

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