International Journal of Advance Research and Innovation
Vol. 2(3), Jul-Sept 2014, pp.101-104
Doi: 10.51976/ijari.231417
www.gla.ac.in/journals/ijari

Article Info
Received: 20 Jul 2014 | Revised Submission: 10 Aug 2014 | Accepted: 20 Aug 2014 | Available Online: 15 Sept 2014

Energy Exergy Analysis of a High Pressure Claude Haylentsystem for Liquefaction of Gases

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ABSTRACT

From various Cryogenics systems, lot of a detailed thermodynamic analysis ofcryosystems have been reported in literature however the modification of Claude systems for high pressure for high yield of liquefied mass of gases is very limited available in literature so far . A comprehensive energy and exergy analysis of Claude Heylandtcryogenic system for various gases is carried out in this paper by using various properties variables (i.e temperature, pressure etc) in system to find out the more efficient statics of system included exergy destructions in system .Numerical computations have been carried out for various gases in Claude Haylent system and it was observed that the Methane gas is more suitable than any other observed gas and 350 and 500 bar is best compressor pressure per kg of inlet gas.

Keywords: *Thermodynamics Analysis Claude Haylentsystem; Energy-Exergy Analysis; First and Second Law Analysis.*

1.0 Introduction

Cryogenic engineering is the application of low temperatures in which operating temperature below -150 oC .various gases like air, nitrogen, argon are liquefied. First vapour compression systems are used to achieve cryogenic temperature but used of these system worked is limited due to solidification temperature of the refrigerants .After this cryogenic industry find number of modes to achieve low temperature. Several liquefaction cycles exist [1]. Various processes are design and invent to achieve cryo temperature at different level of lower temperature Cryogenics is used in various important process at different level with different naming like cryobiology, cryonics, cryo-electronics, cryotrons, cryosurgery etc. Claude system is one of cryogenic system which is design to liquefy various particular gases like air, oxygen, nitrogen, feronetc,To improve perforamce of Claude system its modification is done in form of Haylentsystem. Haylent system is high pressure side Claude system but still Liquefaction plants are rather complicated with numerous components interacting with each other and consume a large amount of process energy, it is vital to develop efficient liquefaction processes for improving the overall system performance and economic competitiveness [2]. Various research and different method are employed to increase efficiency of cryo system. Exergy analysis is a strong method to identified inefficiencies of system and tells which part of system is critical and need to to be undertake study.From literature various data collected which help in optimization of cryosystem. The Bejan [3] work is bse of all exergetic analysis of heat exchangers. Various problems are studied related to exergy analysis which are mentioning or summarized in [4], from the vast study it noticed that most new methods differ only in the way that entropy generation is non-dimensional [5]. A good exergetic design of a heat exchanger would allow for an increase in the global efficiency of the process, by defining a thermodynamic cycle in which the exergetic losses would be limited [6]. The major cause of exergy loss is the use of compressors and to a lesser extent the use of turbines [7]. For optimization of Haylent system first and second law analysis is done but except to increase the whole Haylent system efficiency stress are done on particular parts of system and research are done on that systems. 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. This paper mainly dealed with thermodynamic (exergy and anergy) analysis of

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Haylent system for determining the effect of every component of system with varying conditions for maximum second law efficiency

2.0 Thermo Analysis of Claude Haylent System for Liquefaction of Gases

Compressor work:

$$\eta_c = \frac{W_t}{W_{comp}} \quad (1)$$

$$W_t = mRT ln\frac{P_2}{P_1} \quad (2)$$

$$-W_c = m * (T_1 * (s_1 - s_2) - (h_1 - h_2) \quad (3)$$

$$W_{reversible} = W_{actual} - T_0 s_{gen} \quad (4)$$

$$W_{net} = W_c + W_e \quad (5)$$

Expander:

$$\frac{T_8}{T_3} = (\frac{P_8}{P_3})^{(\frac{\gamma-1}{\gamma})\eta_{expander}} \quad (6)$$

$$W_e = m_e * h_2 - m_e * h_e$$

"Control volume except compressor"

$$y = ((h_1 - h_2)/(h_1 - h_f)) + r * ((h_2 - h_e)/(h_1 - h_f))$$

$$y = m_f/m$$

"Work done per mass of gas"

$$z = -W_{net}/m$$

"Work done per mass of liq gas"

$$t = -W_{net}/m_f$$

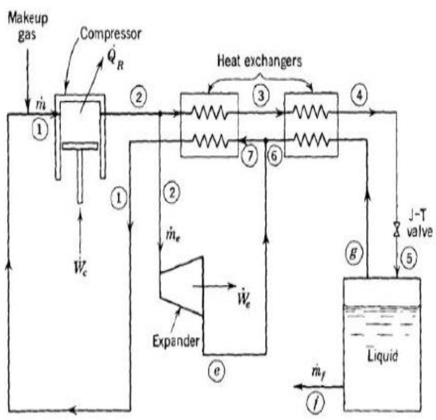
Coefficient of performance of system

$$COP = ((h_1 - h_f)/W_{net})$$

Second law analysis:

$$\eta_{2nd\ law} = ((((h_f - h_1) - T_0 * (s_f - s_1))/(W_{net}) * m_f) * 100)$$

Fig 1: Block Diagram of Haylent System



A complete analysis of Haylent Claude cycle is performing with the help of numerical computation technique for various gases. Haylent Claude cycle as shown in Fig 1 is taken for analysis.

Haylent Claude system is almost same as simple Claude system except arrangement of first expander. In Haylentsystem expander intake is at high pressure side before first intial heat exchanger other than this it also consist a compressor, expander, two heat exchangers with throttle valve and separator.

The fluids which have to liquefy first fed to compressor in its gaseous form at atmospheric pressure and temperature which circulate from all system and in last fractional mass of total mass get liquefied and remaining again fed in system with additional mass to recirculate in system again. Various results are drawn for particular inlet temperature, pressure and intermediate pressure for high pressure side of expander for different six type gases such oxygen, argon, methane, air ,fluorine and nitrogen are considered for study.

3.0 Results and Discussion

Various results are drawn on the basis of numerical equations of system. In fig 2 variation of liquefaction temperature is directly proportional to inlet pressure as we increseses the pressure Liquefaction temperature raises.

Fig 3 show fall of liquefaction mass with increase of inlet temperature where as fig 4 shows first inctresse of liquification mass with increase of inlet pressure but after 3.5 bar it start decreasing, but this decriment with increase of inlet pressure is very slow.

Fig 5-7 show variation in second law efficiency with intlet temperature, intermediate mass and inlet pressure respectively.

Graph analysis of these 5-7 fig shows that second law efficiency is decreses with increase of inlet temperature and intermediate mass whereas it is increses with increase of inlet pressure.

Fig 8 -9 show variation in COP of system with inlet pressure and temperature. They show that increase in pressure is desirable for system and COP of system is increses with increase in inlet pressure while it is decreseing with increase in inlet temperature.

From above graph study it determinded that increses in inlet pressure is between 3 and 4 bar is desriable for system and increase in temperature in very concern reange is good for optimization of Haylentclaude system.

Fig 2: Variation of Liquefaction Temperature with Inlet Pressure

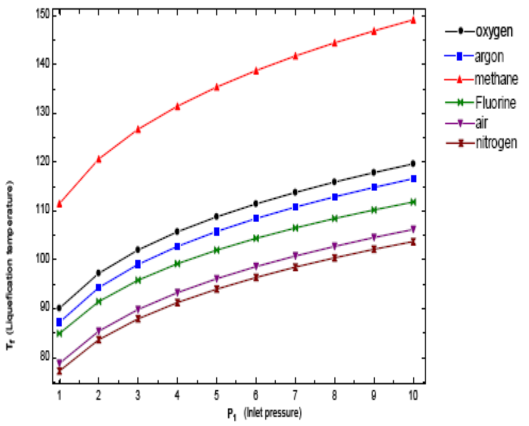


Fig 3: Variation of Liquefied Mass with Inlet Temperature

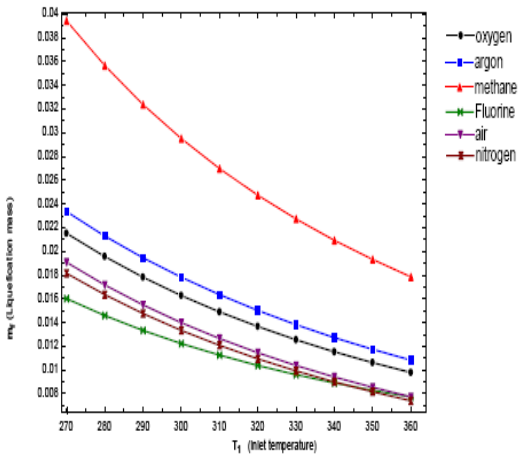


Fig 4: Variation of Liquefied Mass with Inlet Pressure

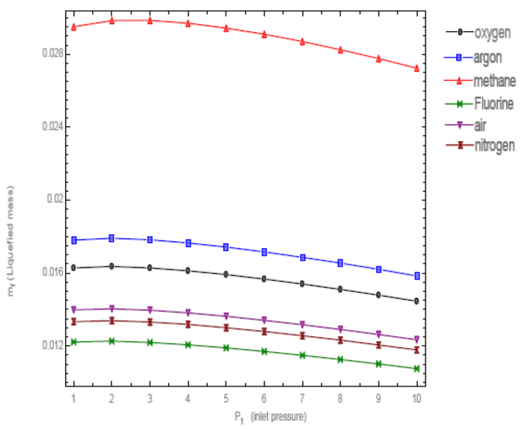


Fig 5: Variation of 2nd law Efficiency with Inlet Temperature

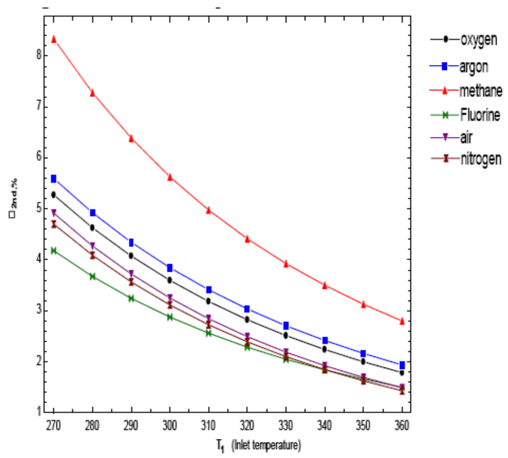


Fig 6: Variation of 2nd Law Efficiency with Intermediate Mass Ratio

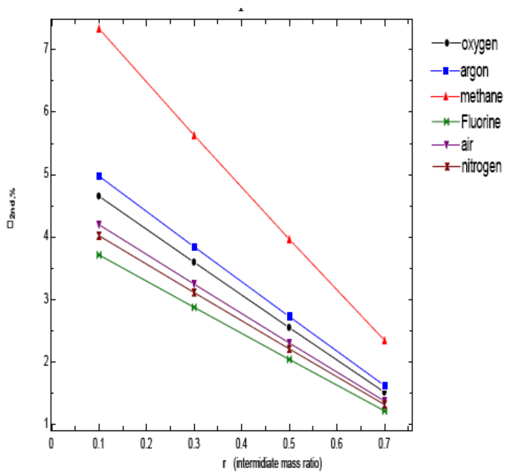


Fig 7: Variation of 2nd Law Efficiency with Inlet Pressure

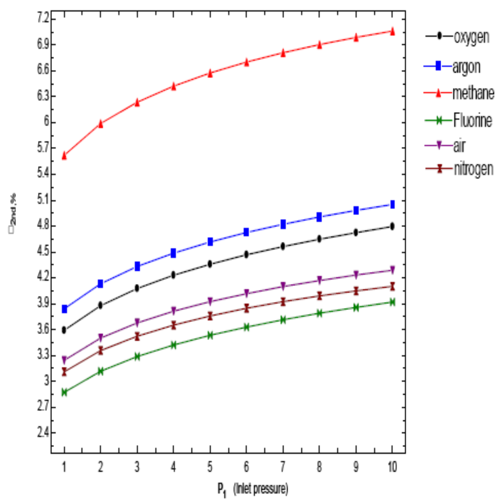


Fig 8: Variation of COP with Inlet Temperature

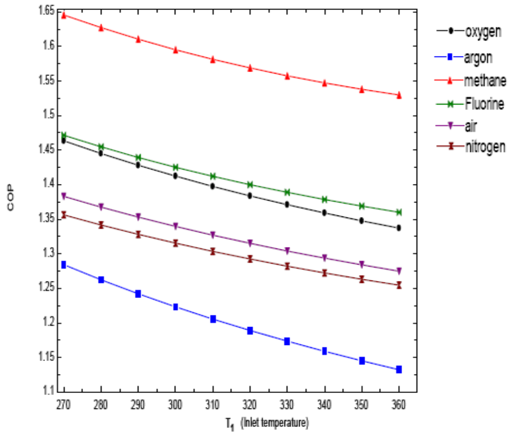
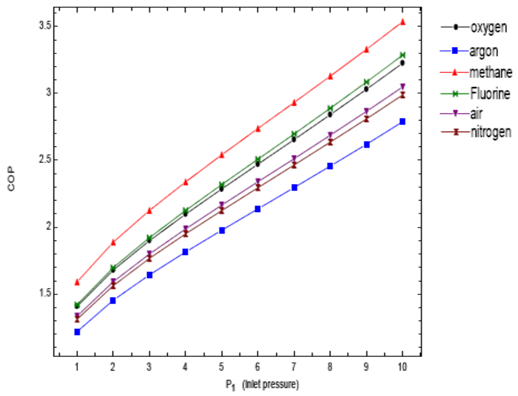


Fig 9: Variation of COP with Inlet Pressure



4.0 Conclusion

From above study following results are concluded

1. The optimize range of inlet pressure is 3 .5 bar for considered variables such liquefaction mass, liquidation temperature and second law efficiency.
2. Intermediate pressure of high pressure side expander should be in minimum range for high second law efficiency.
3. Increase in inlet temperature deteriorate the performance of system and various Like COP, second law efficiency ,liquefaction mass are decrease with increase in inlet temperature

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Nomenculture

M = Total mass of gas
m_f = liqified mass of gas
m_4 = mass of air in second heat exchanger
m_8 = mass of air liquefied in the separator
h = Enthalpy
S = Entropy
X = Dryness fraction
T = temperature
P = Pressure
ηcomp = Efficiency of compressor (approx. 80%)
ηexpander = Efficiency of expander (approx. 80%)
η2nd law = Second law efficiency
Ɛ = Effectiveness of heat exchanger (approx. 80%)
C = Specific heat capacity fluid or gas
W_t = Work of reversible isothermal compression
W_c = Shaft work supplied to compressor per unit mass
R = Universal gas constant
W_{net} = Net work done in system