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Research Article

EFFECT OF FOULING ON THE PERFORMANCE OF VAPOUR ABSORPTION REFRIGERATION SYSTEM

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ABSTRACT

Refrigeration systems form important component for the industrial progress and effects the energy problems of the country at large. Hence, it is suggested to subject the base for conservation of energy and recuperation of energy from Vapour Absorption Refrigeration System (VARS). Absorption Refrigeration Systems (ARS's) requires low grade of energy for their performance. However, fouling plays a major role on the performance parameter of refrigeration system. The accumulation of the unwanted material over the surfaces are large enough to interfere the fluid flow significantly and thereby, gain momentum in the pressure drop which requires to sustain the required flow rate through the heat exchanger.

The objective of this paper is to present empirical relations for evaluating the characteristics and performance of a single stage Ammonia water (NH_3-H_2O) vapour absorption system under normal as well as fouled conditions. In the present work COP of the vapour absorption refrigeration system is decreased under fouling by keeping the constant value of overall conductance.

INTRODUCTION

Conservation of energy (i.e., energysaving is more desirable than the production energy) is today becoming a eye catcher of the present time and new processes to save energy, excluding of being fruitless, are being explored. Recapturing or recycling energy from the waste heat and/or using it effectively for improvement of the system efficiency (is fast) becoming frequent scientific temper and industrial practice today. The present energy issue has made the engineers and scientists around the world to encompass the energy conservation measures in various industries. Reduction in the thermal energy and electric power exhaustion are also advisable but cannot be avoided in a view of the rapid moving and competitive industrial progress all over the world. Refrigeration systems form important component for the industrial progress and effects the energy problems of the country at large. Hence, it is suggested to subject the base for conservation of energy and recuperationof energy from Vapour Absorption Refrigeration System (VARS). Although, the reviewsnoted in this work are kind of applied research but certainly can create a base for further (R&D) Researchand Development activities in direction of conservation of energy and recovery of heat options for the refrigeration systems and the analysis can be also utilized to other Refrigeration and Air Conditioning Systems. Coming apart from this, now recent studies have shown that the conventional working fluids which we are using in the vapour compression system are the main cause of the green house effects and ozone depletion. When the temperature requirement is lesser there we are mainly using the ammonia-Water (NH_3-H_20) mixture solutions and where we wanted the normal temperature there we may use water-lithium Bromide (H_20-LiBr). For e.g. in the case of air conditioning, and then the new constructed system is very much efficient than that of the previous one.

Vapour Absorption Refrigeration cycle

Vapour Absorption Refrigeration Systems (VARS) are like vapour compression refrigeration systems only. But the requisite input in case of the vapour absorption refrigeration system is in the form of heat which is different from vapour compression refrigeration systems. That is whythese systems are stated as either heat operated or thermal energy driven systems. The traditional absorption refrigeration systems are using liquids for the absorption of the refrigerant, due to this, these are also called as the wet absorption systems. Now, the vapour absorption refrigeration system are being commercialized and used widely in the applications of air-conditioning as well as various refrigeration applications. These systems are operated on the low grade thermal energy,

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they are only preferable when the low grade thermal energy like waste heat or solar energy is easily available.
Simple vapour absorption system comprises of

1. Absorber.
2. Generator.
3. Heat exchanger.
4. Pump.
5. Expansion device.
6. Condenser.
7. Evaporator

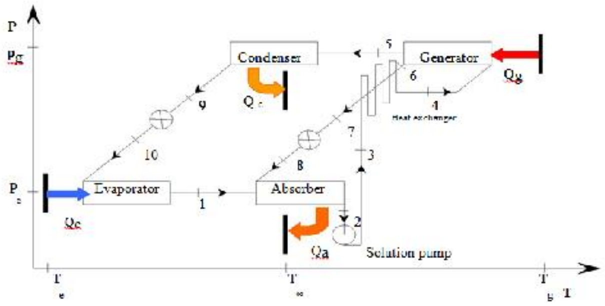


Figure 1 Basic vapour absorption refrigeration system alongwith solution heat exchanger [1]

Fouling

Fouling is the process of incorporating the deposit of unwanted material over the heat transfer surface during the long lasting of the heat exchanger. Whatever may be the cause or the exact essence of accumulation of the material, by adding the extra resistance to heat transfer which inaugurates over the surface and it correspondingly reduces the functional potential of the heat exchanger. but mostly we can see that the accumulation of the unwanted material over the surfaces are large enough to interfere the fluid flow significantly and thereby, gain momentum in the pressure drop which requires to sustain the required flow rate through the heat exchanger. For this reason while the designing of the heat exchanger, the effect of fouling upon the heat exchanger fouling during the desired operational lifetime must be considered by the designer and make planning in his design for the sufficient additional capacity to make certain that the heat exchanger will definitely meet process details up to shut down for cleaning.

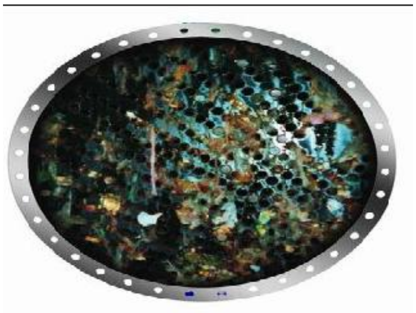


Figure 2 Heat exchanger used in steam power plant fouled by macro fouling

Effect of Fouling on Heat Transfer

1. Thermal efficiency of the heat exchanger decreases.
2. It reduces the heat flux.
3. On the hotter side temperature rises.
4. On the colder side temperature reduces.
5. Under-deposit corrosion may induced.
6. Use of the cooling water increases, and many more.

Above all the factors are well enough to decrease the operation of the heat exchanger and then heat exchanger will not perform its operation properly. Also may damage the diversity of components due to very high temperature. In order to prevent the heat exchanger from fouling we have to make some allocation for its periodic removal.

Removal of Fouling

If we cannot arrest the fouling from forming, then it is very necessary to make the allocations for removal of fouling periodically. By the means of chemical actions some deposits can be removed totally for e.g., with the help of chlorination we can totally remove the carbonate deposits. There are so many cleaning techniques that are the specialized art and must be undertaken only under the supervision of the specialist. However, in the process of chemical cleaning that is to use where it does not require for the removal of equipment or disassembly of their piping, chemical cleaning is one of the most of cleaning techniques in those cases.

Mechanically, there are numerous of techniques for the removal of fouling. Also, Scraping and rotary brushes are limited to the surfaces which can be reached by the scraping tool uses the trick so that it can be eased by the shell side or by the use of very large clearances between tubes or the using the rotating square tune layout.

As the high velocity water jets are used to both inside and outside of the tubes, the jets will not be that much affective for the shell side, deep inside a large tube tank.

The objective of this report is to evaluate thermodynamic properties. Heat rate and mass flow rate in each components of the system are obtained in this report. For the various range of temperature the coefficient of performance (COP) of the system is determined. The result of this dissertation can be used for calculating the COP for fouled condition for heat exchangers.

Solution Methodology in Engineering Equation Solver (EES)

EES. It includes the various programming structures of C and FORTRAN incorporated with iterator in itself, thermodynamic property relations, numerical integration, transport property relations graphical capacities and many more other useful mathematical functions are inbuilt in itself. The assembly of equation that has to be solved simultaneously, with the very high rate of computational speed EES is proficient to function. By using the correlations which are developed by Ibrahim and Klein in 1993 properties of ammonia-water mixture properties can easily be calculated.EES is incorporated with many thermodynamic and transport property functions for different fluids including dry and moist air and water. In the property database are thermodynamic properties for R134a, R1234yf and R1234ze mixtures are also incorporated. Any information between quotation marks [“] or braces [{}] is an optional remark. Variable names must start with a letter.

LITERATURE REVIEW

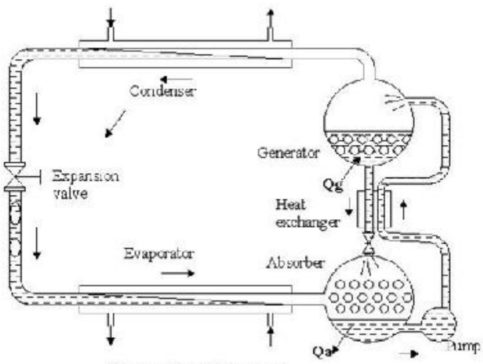
Bultman *et al*. (1995)) simulated the effect of partially blocked condensers of a 3-ton vapour compression system and reported that the COP was predicted to decrease by 7.6 percent when the airflow across over the condenser was reduced by 40% for a constant speed fan. It was noted that the increase in the power consumption had a logarithmic nature as did the decrease in COP. Pressure rise across the compressor is increased by 19 percent which is above its standard value of 1151 kPa, suggesting that reduction in the life of compressor might be the major economic consequence of condenser air flow blockage.[1]

Pak *et al*. (2005) investigated experimentally the effects of air-side fouling on the performance of numerous condenser coils found in unitary air-conditioning systems and inveterate that, under fouled conditions, the heat transfer performance degraded by 7-12 percent at the standard air face velocity of 1.53 meter per second.He also concluded the fouling on the front face of the coil is a mixture of dust and fibres in non-uniform distribution and decreases gradually from the front face to the first tube row. On the rear face, the fouling is in uniform distribution over the fins.[2]

Bell and Groll (2010) studied the effect of fouling on air-side pressure drop in plate-fin and micro channel coils. The heat exchanger were tested with two different dust's type, ASHRAE standard dust and Arizona road test dust, concluded that, ASHRAE dust results in much larger increase in air-side pressure drop, and Arizona dust results in much larger decrease in heat transfer than the ASHRAE dust. [3].

From the above literature survey it has been concluded that most of the work has been done on vapour compression system under fouled condition and almost no research work is available which has analyzed the performance of vapour absorption system under fouled condition.

Thermodynamic Analysis



Vapour absorption system

Ammonia water leaves the evaporator and enters the absorber where it dissolves and reacts with water to form $NH_3.H_2O$. This is an exothermic reaction, the amount of NH_3that can be dissolved in H_2O is inversely proportional to the temperature. Liquid NH_3-H_2O solution is then propelled to the generator. As the temperature is high the NH_3separates from the H_2O. Thus, creating high pressure. Vapour which inNH_3 passes through the analyzer (attached to the generator). Where, H_2O separates from the NH_3 vapours. This NH_3 vapours is then passed through rectifier where traces of H_2O are removed and sent back to the generator. High pressure pure NH_3 vapour continues its cycle by reaching to condenser where pressure is very high as well as temperature, followed by expansion device where temperature drops and then evaporator where pressure and temperature are very less.

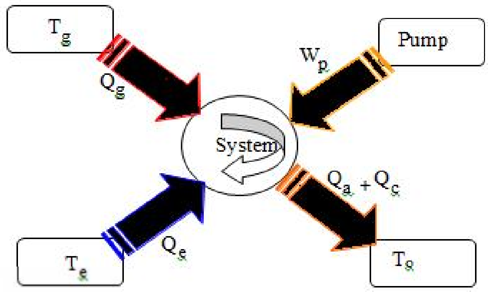
$$COP_{VARS} = \frac{Qe}{Qg+Wp} \approx \frac{Qe}{Qg}$$

If, $W_p <<<<<<<< Q_g$

Then, neglectingW_p

$$COP_{VARS} = \frac{Qe}{Qg}$$

Maximum COP of VAR System



$$\frac{Qe}{Qg} = \frac{Tg-To}{To-Te} \times \frac{Te}{Tg} = COP$$

RESULTS AND DISCUSSION

Input parameters

Condenser pressure	:	20.3 bar
Evaporator pressure	:	2.1 bar
Generator temperature	:	156°C
Absorber temperature	:	40°C

When condenser and evaporator both under fouling

COP = 0.2579

COP_f = 0.2351

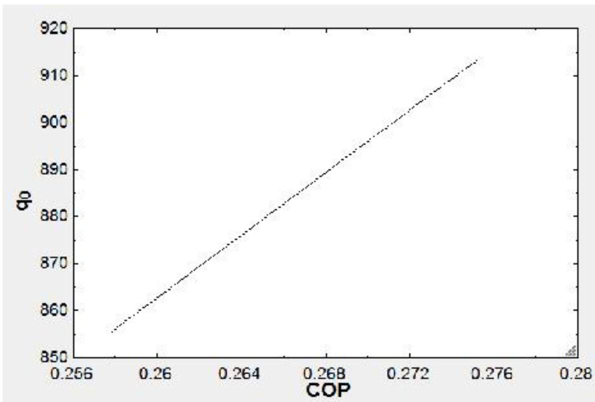
η_{II} = 6.951

$\eta_{II,f}$=6.761

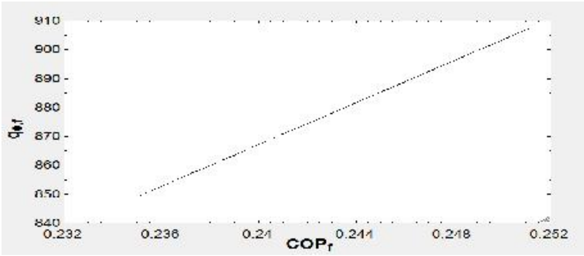
Percentage decrease in COP $= \frac{COP-COPf}{COP} \times 100$

$= \frac{0.2579-0.2351}{0.2579} \times 100 =$ 8.81 %

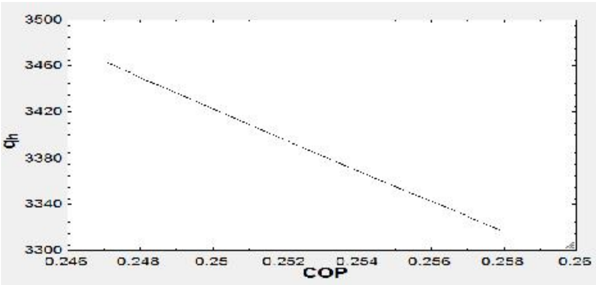
Percentage decrease in η_{II} = 2.73 %



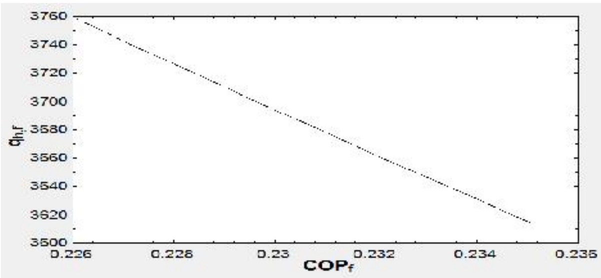
A. Variation of COP with $q_0$under normal condition



B. Variation of COP_f with $q_{0,f}$ under fouled condition.



C. Variation of COP with q_h under normal condition.



D. Variation of COP_f with $q_{h,f}$ under fouled condition.

CONCLUSIONS

This present work has been set out to get the values of coefficient of performance of the vapour absorption refrigeration system under normal and fouled condition. In the present work the performance analysis of the ammonia-water (NH_3-H_2O) vapour absorption refrigeration system under fouled condition in the overall system has been carried out. Here, the performance of the VARS is degraded under fouled condition. So that it is necessary to clean the heat exchanger after the period of time.

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