Design of Generator in Vapour Absorption refrigeration System

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ABSTRACT

With the depleting energy resources recycling of waste energy or recovery of energy from the exhaust of processes or engine is vital method and important of energy conservation. Refrigeration another absolute requirement that needs to be catered, conventionally the vapour compression cycle is the preferred method but it comes with an handicap that the non-conventional energy resources cannot be employed to operate the same. The vapour absorption system using ammonia as refrigerant on the other hand is a method which can be used to harness this recovered process heat or heat carried by the exhaust gases of the engine. The project aims at the design development analysis and performance evaluation of one such scaled system for volume size of 5 liters by utilization of vapour absorption system using ammonia as refrigerant. The project work includes the heat load calculation and design selection of components of system to suffice the requirements, The critical components of the system have been designed and developed using Unigraphix software and thermal analysis of the components has been done using Ansys Work bench 16.0.

Keywords: Waste heat recovery, Engine exhaust, Vapour absorption system, Ammonia, Thermal Analysis.

INTRODUCTION

The vapor absorption refrigeration system comprises of all the processes in the vapor compression refrigeration system like compression, condensation, expansion and evaporation. In the vapor absorption system, the refrigerant used is ammonia, water or lithium bromide. The refrigerant gets condensed in the condenser and it gets evaporated in the evaporator. The refrigerant produces cooling effect in the evaporator and releases the heat to the atmosphere via the condenser.

The major difference between the two systems is the method of the suction and compression of the refrigerant in the refrigeration cycle. In the vapor compression system, the compressor sucks the refrigerant from evaporator and compresses it to the high pressure. The compressor also enables the flow of the refrigerant through the whole refrigeration cycle. In the vapor absorption cycle, the process of suction and compression are carried out by two different devices called as the absorber and the generator. Thus, the absorber and the generator replace the compressor in the vapor absorption cycle. The absorbent enables the flow of the refrigerant from the absorber to the generator by absorbing it.

Another major difference between the vapor compression and vapor absorption cycle is the method in which the energy input is given to the system. In the vapor compression system, the energy input is given in the form of the mechanical work from the electric motor run by the electricity. In the vapor absorption system, the energy input is given in the form of the heat. This heat can be from the excess steam from the process or the hot water. The heat can also be created by other sources like natural gas, kerosene, heater etc. though these sources are used only in the small systems.

EXISTING METHOD

The existing methods use an electric heater or fuel burners as the heat source to the generator system. This is extra energy that has to be added to the system that brings down the COP of the system.

PROBLEM STATEMENT

With the depleting energy resources recycling of waste energy or recovery of energy from the exhaust of processes or engine is vital method and important of energy conservation. Refrigeration another absolute requirement that needs to be catered, conventionally the vapour compression cycle is the preferred method but it comes with a handicap that the non-conventional energy resources cannot be employed to operate the same. The vapour absorption system using ammonia as refrigerant on the other hand is a method which can be used to harness this recovered process heat or heat carried by the exhaust gases of the engine.

Widespread efforts are currently underway to utilize available energy resources efficiently by minimizing waste energy and develop replacements for the traditionally refrigerants (CFCs and HCFCs), which contribute to ozone depletion and greenhouse warming. Absorption chillers which are heat-powered refrigeration systems have got more and more attention, due to the recognition of rational utilization of energy and the concerns about ecological problem.

The ammonia-water mixture is environmental friendly, which is the only working pair currently used for refrigeration purposes in absorption systems, and despite of the new mixtures under investigation, the ammonia-The principle of the absorption is providing the necessary pressure difference between the vaporizing and condensing processes, which alternately condenses under high pressure in the condenser by rejecting heat to the environment and vaporizes under low pressure in the evaporator by absorbing heat from the medium being cooled.

Presently very few systems are in existence that works to recover the exhaust gas energy and harness it for refrigeration purpose.

SOLUTION

The vapour absorption system using ammonia as refrigerant on the other hand is a method which can be used to harness this recovered process heat or heat carried by the exhaust gases of the engine.

The paper aims at the design development analysis and performance evaluation of one such scaled system for volume size of 5 liters by utilization of vapour absorption system using ammonia as refrigerant. The project work includes the heat load calculation and design selection of components of system to suffice the requirements, The critical components of the system have been designed and developed using Unigraphix software and thermal analysis of the components has been done using Ansys Work bench 16.0.

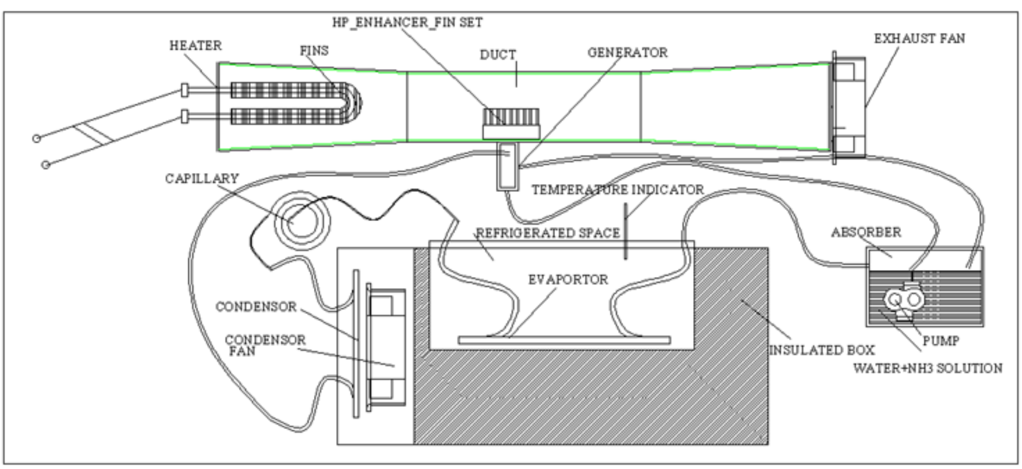
The performance evaluation of the system has been done by experimental test and trial and the COP of the system has been calculated at various flow rate of the refrigerant. The optimization is further done using Minitab software to predict the optimal flow rate so as to attain the maximum temperature gradient.

OBJECTIVES

A) Heat load calculation to determine the overall cooling load and thereby determination of the total cooling capacity of the system.

B) Design Selection and Analysis of System components to satisfy the desired cooling capacity and thus justify the selection of the components.

Schematic of Vapour absorption system utilizing waste heat recovery mixture is the only one with a clear future



Heat load calculation

Heat load calculation to determine the overall cooling load and thereby determination of the total cooling capacity of the system

Cooling load calculation

Transmission load

Q = U x A x (Temperature out – Temperature in) x 24 ÷ 1000.

QT = 0.019 kWh/day ---------------------------------this is the load due to infiltration of heat

Product load – Product exchange

Q = m x Cp x (Temperature enter – Temperature store) / 3600.

Qp = 0.040 kWh/day

Product load – Product respiration

Q pr= m x resp / 3600

Qpr = 0.010 kWh/day

Total cooling load

To calculate the total cooling load we will just sum all the values calculated = 0.019+ 0.040

Total Heat load = 0.06 Kwh /day

Safety Factor

We should also then apply a safety factor to the calculation to account for errors and variations from design. It's typical to add 10 to 30 percent onto the calculation to cover this, We have assumed with 60% in this example so well just multiply the cooling load by a safety factor of 1.6 to give us our total cooling load of 0.096 kWh/day

Refrigeration cooling capacity sizing

The last thing we need to do is to calculate the refrigeration capacity to handle this load, a common approach is to average the total daily cooling load by the run time of the refrigeration unit. For this I am estimating the unit to run 24 hours per day which is fairly typical for this size and type of store. Therefore our total cooling load of 0.096 kWh/day will sufficiently meet this cooling load ---rounding off to 0.1 kwh as total heat load.

Converting the total heat load to Power result in watt

Power requirement equivalent to 0.1 kwh for 24 hours = 4.2 watt

Thus, the design of the equipment components will be done for 4.2 watt

Design and selection of heat recovery system components

As the aim of the project is develop a scaled prototype to test and prove the application of waste heat recovery we have taken the approach to create the effect of waste heat recovery artificially heated air by use of heater thus the primary part would be selection of the heater.

The arrangement of the generator heat source using heat pipes and air heater (that resembles the exhaust gas heat recovery) is as follows:

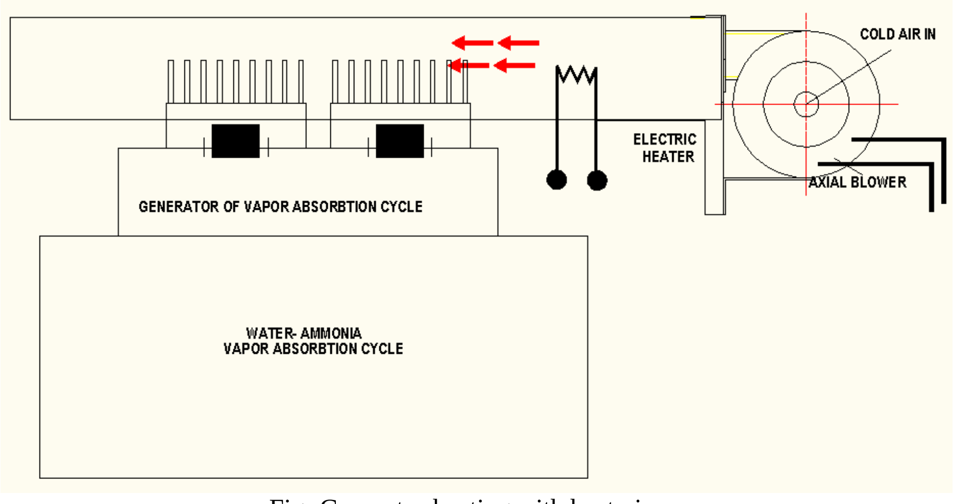


Fig- Generator heating with heat pipes

Input data:

Refrigeration load = m CP Δ T = 4.2 watt

Refrigeration load = heat rejected = m CP Δ T = 4.2 x 60/1000 = 0.252 K cal/min

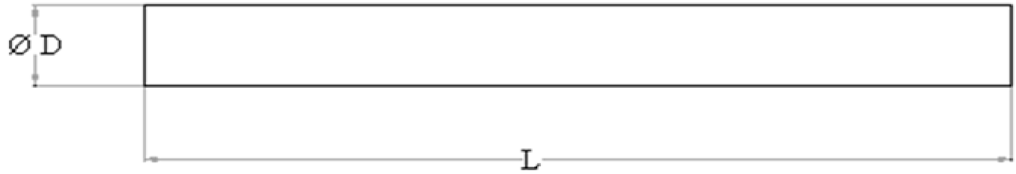
Actual heat supplied = Refrigeration load/ Actual COP = 0.252 /1.49 = 0.17 Kcal /min

Coversion of Kcal/min = 0.17 Kcal/min x 60 = 102 Kcal/hr to wattage is done using convertor from;
102 Kcal/hr = 118 watt
Assuming a factor of safety = 2
Hence selecting a 300-watt air heat assuming around 50 % thermal efficiency of the finned heat pipe system.

DESIGN AND ANALYSIS OF FIN SYSTEM FOR EFFECTIVE HEAT RECOVERY HEAT PIPE GEOMETRY-SIZE SELECTION

Heat pipes are available in standard diameters from 3 to 12mm and in lengths from 50mm to 250 mm, shape is as shown in figure below:

HEAT TRANSFER CAPABILITY FOR ABOVE HEAT PIPE



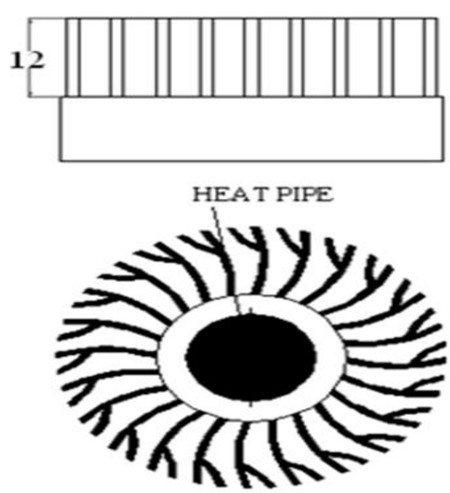
Standard Diameter –D = 32mm , Standard length = L= 12mm ,Material = Copper
Cooling Fluid = Sintered copper powder ,Tolerance for Dia = (+0.00,-0.05)Tolerance for Length = (+0.5, -0.5)

MAXIMUM WATTS AT DIFFERENT TEMPRATURE

DIAMETER	20^0C	30^0C	40^0C
32 mm	64 WATT	96 watt	120 watt

- The power handling figures are for heat pipe working in horizontal position.
- Length 12 mm long
- Evaporator length 5mm
- Condenser length = 5mm
- Adiabatic length =2mm
- Sintered Copper Powder

SPIRAL RADIAL HEAT PIPE FIN ENHANCER



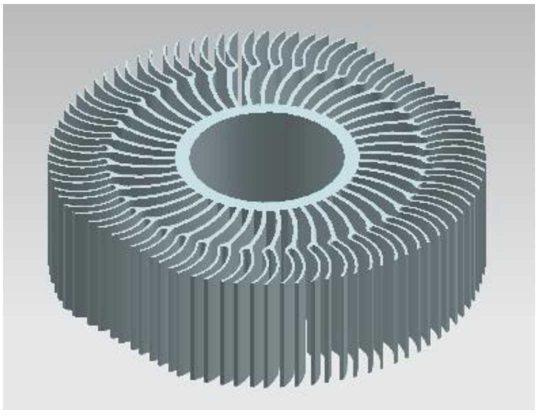
Overall width (W)=100mm ,Gap between fins (d) =5mm, Length = 100mm,Width = 3mm,height of fin =12mm,Number of fins =56, Heat pin fin set no =1Surface area = A=0.256 m^2,Heat Pipe= Wick Structured Sintered Copper,Working Fluid = Water

DESIGN OF FINS STRUCTURE

Material of fins aluminium (thermal conductivity K) = 225 W/m^0c
Perimeter of fin system P = π x d = 3.142 x 0.1 = 0.3142 m
Area of c/s of fin structure = $0.03142m^2$

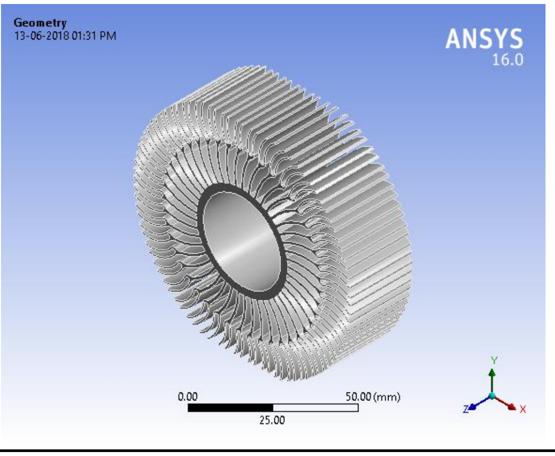
Fin base temperature = 65 ^{o}C
Fin tip temperature = 40^{o}C
Convective heat transfer coefficient (h) = 20 W/m^{2o}C
Heat transfer from the fin system is given by ,
Q = k A m (ΔT) -- neglecting fin efficiency
Q = 225 *0.03142 *m * (65-40) ---------------------------(65-40) is the temperature difference
Where m = Sq.rt (h *P / K*A) = sq. rt (20 x 0.3142 / 225 x 0.03142) =0.94
Thus,
Q = 225 * 0.03142 * 0.94 * (65-40)
Q = 166 .13 Watt
Assuming fin efficiency to be 80 %
The actual heat transfer possible by the fin structure = 166.13 *0.8 = 132 Watt
As the Heat transfer by fin system (132 Watt)> the heat rejected by the heater system (118 watt) the selected fin structure arrangement is safe.

ANALSYSIS OF FIN :

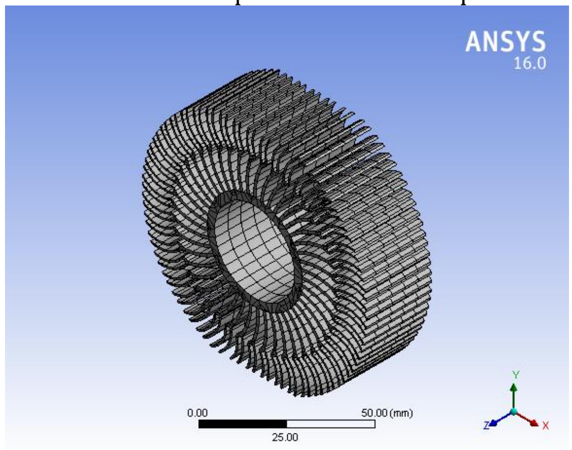


Measurement Mass Properties
Displayed Mass Property Values
Volume = 44370.921173957 mm^3,Mass = 0.118026650 kg
Weight = 1.157447095 N, Radius of Gyration = 31.867822937 mm
Centroid = -0.000882324, -0.001446557, -13.000000000 mm
===
Detailed Mass Properties
Analysis calculated using accuracy of 0.990000000Information Units kg – mm
Density = 0.000002660,Volume = 44370.921173957,Area = 102813.439157077
Mass = 0.118026650

Considering heater of 300 watt the heat flux = 0.07 watt /mm2
Geometry

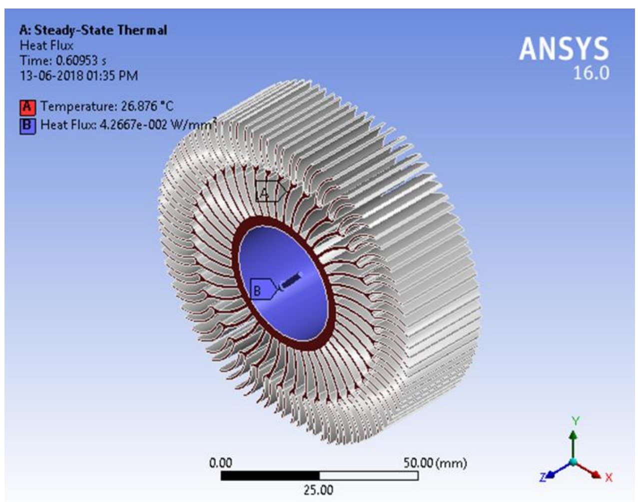


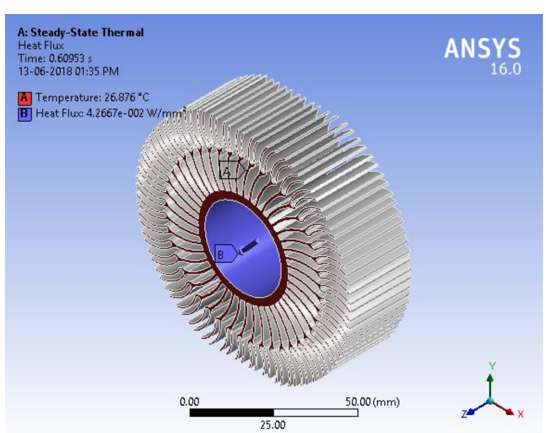
Geometry was developed in UG –Nx and the step file was used as input to the Ansys.



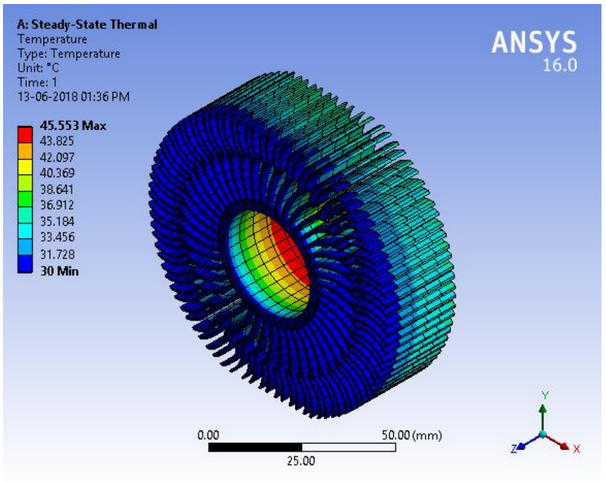
Meshing was done using Ansys free mesher and the parameters found were as below

Statistics	
Nodes	41347
Elements	5570
Mesh Metric	None

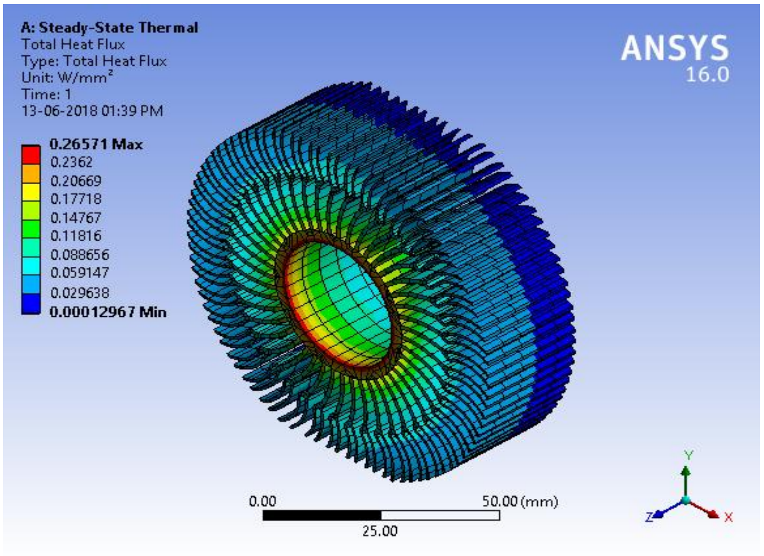




The heat flux of 0.07 watt/mm^2 was applied at the heat pipe end where the fins are exposed to ambient temperature of 30 degree.



The figure above shows the temperature distribution across the fin structure with maximum temperature at the heat pipe end indicating that the generator end will receive the maximum temperature gradient and thereby evaporate the ammonia as desired function in the generator



The figure above shows that the maximum heat flux is 0.26571 indicating that maximum heat is transferred to the working fluid i.e. ammonia ,thus the system will effective act as generator given the high performance of the fins.

Conclusion :

1. Heat load calculations were performed for the refrigeration system and the cooling capacity requirements were found to be o.1 Kwh /day
2. The heater unit was selected of 300 Watt which can easily generate the heat requirement of 118 Watt which is required for development of desired refrigeration effect in the system
3. he fin selection done for the generator section showed good temperature distribution and total heat flux of 0.26571 watt /mm2 against the requirement of 0.07 watt/mm2.
4. The system component thus selected is apt to get desired refrigerating effect.

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