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Heat pump as alternative for boiler in drying section in Kraft paper mill

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Abstract:- Heat pumps are used for heating and hot water supply in industries. By using heat pumps, we can make the best use of waste heat available in industries. In recycling paper industries we use boilers for production of steam, which is used in drying section, but here we are trying to use heat pump in place of boiler for production of steam, by which the efficiency of the drying section increases. We designed a heat pump model for the setup and simulated using ASPEN PLUS software. For our design we selected methanol as refrigerant.

Keywords:- heat pump, recycling Kraft mill, methanol, ASPEN PLUS, boiler.

I. INTRODUCTION

Applications of heat and high temperature water for heating, disinfection and washing can be widely found in factories, plants, etc.. Although the combustion of fossil fuels including heavy oil, natural gas, etc., has been used for these heat applications until now, from the perspective of saving energy and reducing CO2 emissions, heat pumps, which make the best use of waste heat, are attracting attention and are beginning to enter into industrial use in applications such as heating and washing in processes, air conditioning and other uses. This technology extracts heat from the atmosphere and thermal effluent and generates hot water making effective use of heat. Here we are using the heat pump in Re-Cycling paper mill.

First of all papers will be sorted out into different grades and will be separated from large contaminants and is wrapped into tight bundles and is send to paper mill. The various paper grades, such as newspapers and corrugated boxes, are kept separate, because the paper mill uses different grades of recovered paper to make different types of recycled paper products.

The paper will be loaded on conveyer belt which dump them in the pulper, which contains water and other chemicals. Pulper chops the recovered paper into small pieces and turns into a mushy mixture called pulp. The pulp is forced through screens containing holes and slots of various shapes and sizes. The screens remove small contaminants such as bits of plastic and globs of glue. This process is called screening. Mills also clean pulp by spinning it around in large cone-shaped cylinders. In cylinders the contaminants will be separated by centrifugal action. Heavy contaminants like staples are thrown to the outside of the cone and fall through the bottom of the cylinder. Lighter contaminants collect in the center of the cone and are removed. This process is called cleaning. After which any ink particles present in it will be removed by de-inking process. It is a combination of two processes namely washing used for removal of small particles and flotation where larger particles and stickies are removed with air bubbles. And then during refining, the pulp is beaten to make the recycled fibers swell, making them ideal for papermaking. If the recovered paper is colored, color stripping chemicals remove the dyes from the paper.

Now the clean pulp is ready to be made into paper. The recycled fiber can be used alone, or blended with new wood fiber (called virgin fiber) to give it extra strength or smoothness. The pulp is mixed with water and chemicals to make it 99.5% water. This watery pulp mixture enters the headbox, a giant metal box at the beginning of the paper machine, and then is sprayed in a continuous wide jet onto a huge flat wire screen which is moving very quickly through the paper machine. On the screen, water starts to drain from the pulp, and the recycled fibers quickly begin to bond together to form a watery sheet. The sheet moves rapidly through a series of felt-covered press rollers which squeeze out more water.

The sheet, which now resembles paper, passes through a series of heated metal rollers (drying section) by which we dry the paper. Finally, the finished paper is wound into a giant roll and removed from the paper machine. One roll can be as wide as 30 feet and weigh as much as 20 tons! The roll of paper is cut into smaller rolls or sometimes into sheets.

Nomenclature

Q_R	Energy supplied to refrigerant, KW
C_p	Specific heat at constant pressure.
T_{hi}	Temperature of hot water inlet for HE. °C
Tci	Temperature of cold water inlet for HE. °C
Tho	Temperature of hot water outlet for HE. °C
Tco	Temperature of cold water outlet for HE. °C
U	Overall heat transfer coefficient for HE. w/m2k
A	Area of heat exchanger. m^2
L	Length of the tubes. m
D	Diameter of tube. m
N_t	Number of tubes.
P_t	Triangular pitch. m
C	Clearance, m
De	Equivalent diameter of shell. M
h	heat transfer Co-efficient w/m^2k
COP	Co-efficient of performance.
De	Equivalent diameter of shell, m
Nu	Nusselt number.
Re	Reynolds number.
Pr	Prandtl number.

II. PROBLEM DEFINITION

In recycling paper mill at drying section generally steam is used to dry the paper, which is produced from boiler. The production capacity of boiler is 3.83 tons per hour with 4-5 bar pressure. For this capacity to be achieved nearly 1.21 tons of rice husk is consumed every hour. So it is somewhat cumbersome for the owner and also the pollution occurred by burning of natural fuels also increases and also the efficiency of boiler is low by which more fuel has to be used to obtain required energy.

So we are designing a heatpump to compensate the boiler in drying section by which we can use available energy from atmosphere thus the input energy that must be given to system decreases and also efficiency of system increases. And we are simulating the heatpump setup in ASPEN PLUS V8.0 software.

III. PAPER PLANT SPECIFICATIONS

A. Production capacity specifications:-

Table 1- Kraft plant capacity

Quantity	Kraft plant
Paper production per hour (in Tons)	2.83
Paper production per day (in Tons)	68
Steam consumption per day (in Tons)	92.02
Steam required per Ton of paper (in Tons)	1.35

B. Drying section specifications:

Table 2 - Drying section specifications

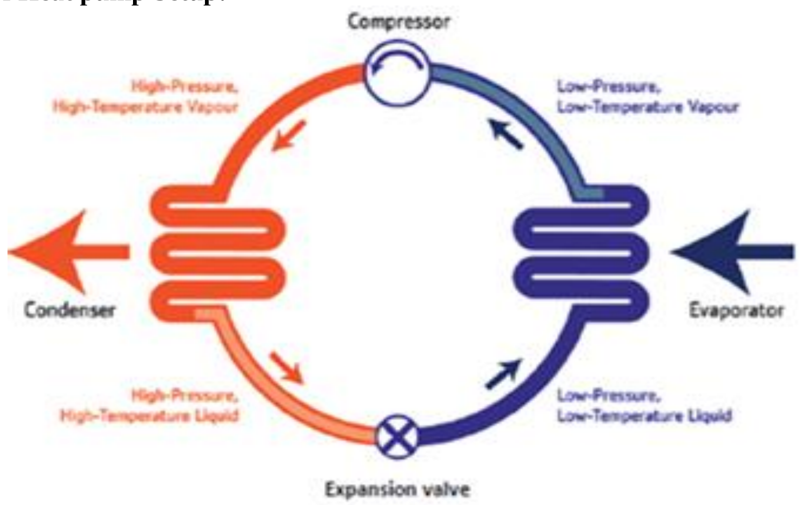
S.No	Component Name	Temperature (C)	Pressure (Bar)
1	Boiler outlet	180	3
2	Roller inlet	170	3
3	Roller outlet	90	1

IV. HEATPUMP

A. Working Of Heat pump:-

A heat pump works according to the same principles as refrigerators or air conditioners. In a refrigerator, for example, heat is rejected from inside the refrigerator to the surrounding air. On older models you can actually see the condenser coil on the outside. It is hot when the unit is running because heat from inside is being rejected through this condenser coil. The basic components of any such system are a compressor, evaporator coils, condenser coils, expansion valve or metering device, and a reversing valve. Figure I show how the components work together in the cooling cycle of a heat pump. Warm indoor air passes over the indoor evaporator coils and gives up heat to the refrigerant causing the refrigerant to change from a liquid to a vapour, or "evaporate". The compressor then pumps the vapour, increasing its pressure to make a hot, high-pressure vapour. When this hot vapour passes through the outdoor condenser coil, heat is given off to the air and the vapour condenses to form a liquid. This hot high pressure liquid passes through an expansion valve, which reduces the pressure, cooling the liquid. The cool liquid refrigerant then passes back through the evaporator and returns to a vapour form continuing the cycle. Thus, heat has been moved from inside the house to outside, cooling the inside space. The energy required to operate the cycle is the electrical energy which powers the compressor and fans.

B. Design Of Heat pump Setup:-



C. Specifications of Components Of Heat pump Setup:-

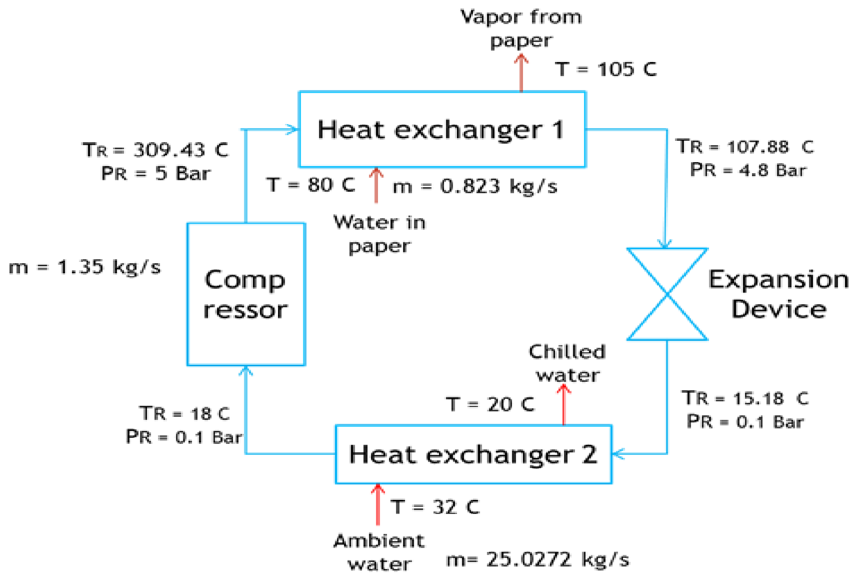


Table 3- Compressor Specifications

1	**Bore (in Meters)**	**0.828**
2	**Length (in Meters)**	**1.242**
3	**Speed (in R.P.M)**	**1200**
4	**Bore to Length ratio**	**2:3**
5	**Swept volume (in m^3)**	**13.38**
6	**Efficiency**	**0.75**
7	**Power required (in Kw)**	**890**

Table 4- Condenser Shell Specifications

1	Inside shell diameter	0.95 m
2	Shell to bundle clearance	0.005 m
3	No. of tube passes	2
4	No. of sealing strip pairs	2
5	Exchanger orientation	Horizontal
6	No. of shells in series	1

Table 5- Condenser Tube Specifications

1	No. of tubes	520
2	Length	4.5 m
3	Inner diameter	16 mm
4	Outer diameter	20.5 mm
5	Pitch	25.625 mm
6	Material	Copper
7	Thermal conductivity	401 Watt/m-K
8	Pattern	Triangular shape
9	Type	Bare tubes

Table 6- Condenser Baffle Specifications

1	Baffle type	Segmental baffle
2	No. of baffles	6
3	Baffle cut	0.0678 m
4	Tube sheet to 1st baffle spacing	0.064 m
5	Baffle to baffle spacing	M

Table 7 - Evaporator shell specifications

1	Inside shell diameter	1 m
2	Shell to bundle clearance	0.005
3	No. of tube passes	2
4	No. of sealing strip pairs	2
5	Exchanger orientation	Horizontal
6	No. of shells in series	1

Table 8 - Evaporator tubes specifications

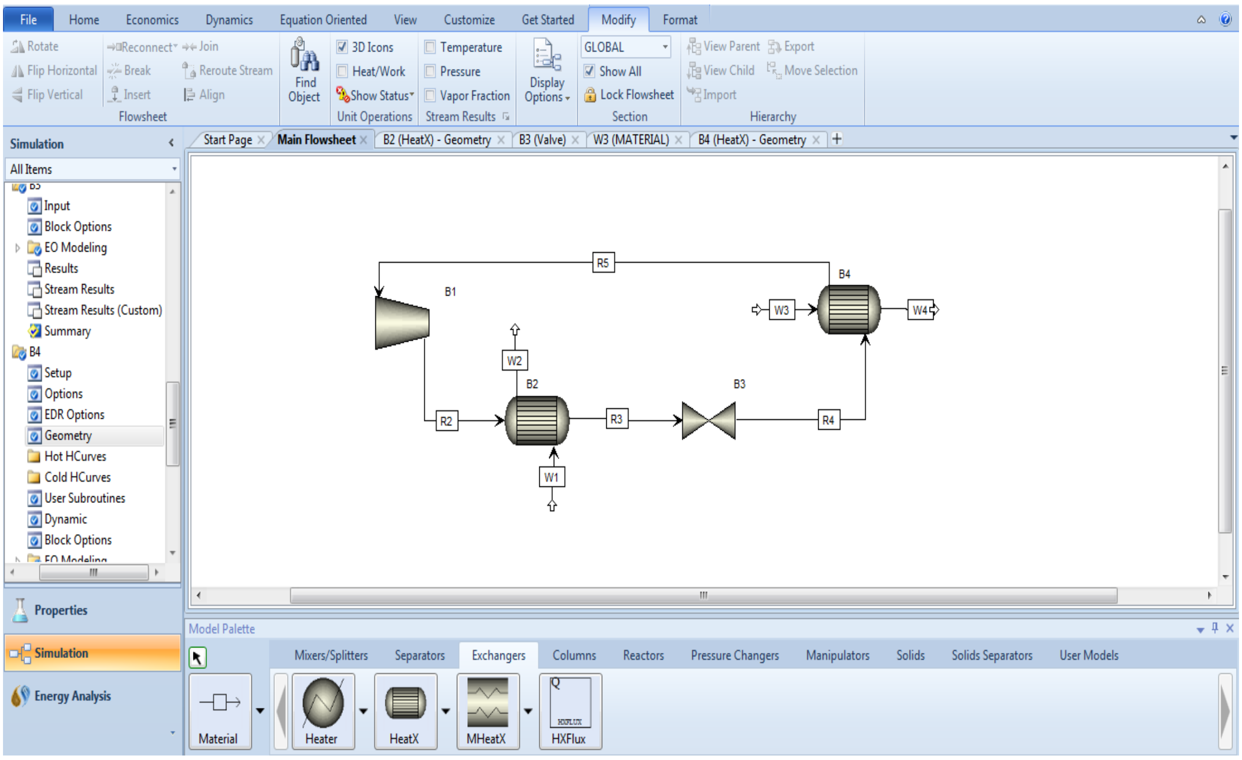
1	No. of tubes	498
2	Length	2.65 m
3	Inner diameter	16 mm
4	Outer diameter	20.5 mm
5	Pitch	25.625 mm
6	Material	Copper
7	Thermal conductivity	401 Watt/m-k
8	Pattern	Triangular
9	Type	Finned tubes
10	Fin height	0.889 mm
11	No. of fins per unit length	1102 per meter

Table 9 - Evaporator Baffle specifications

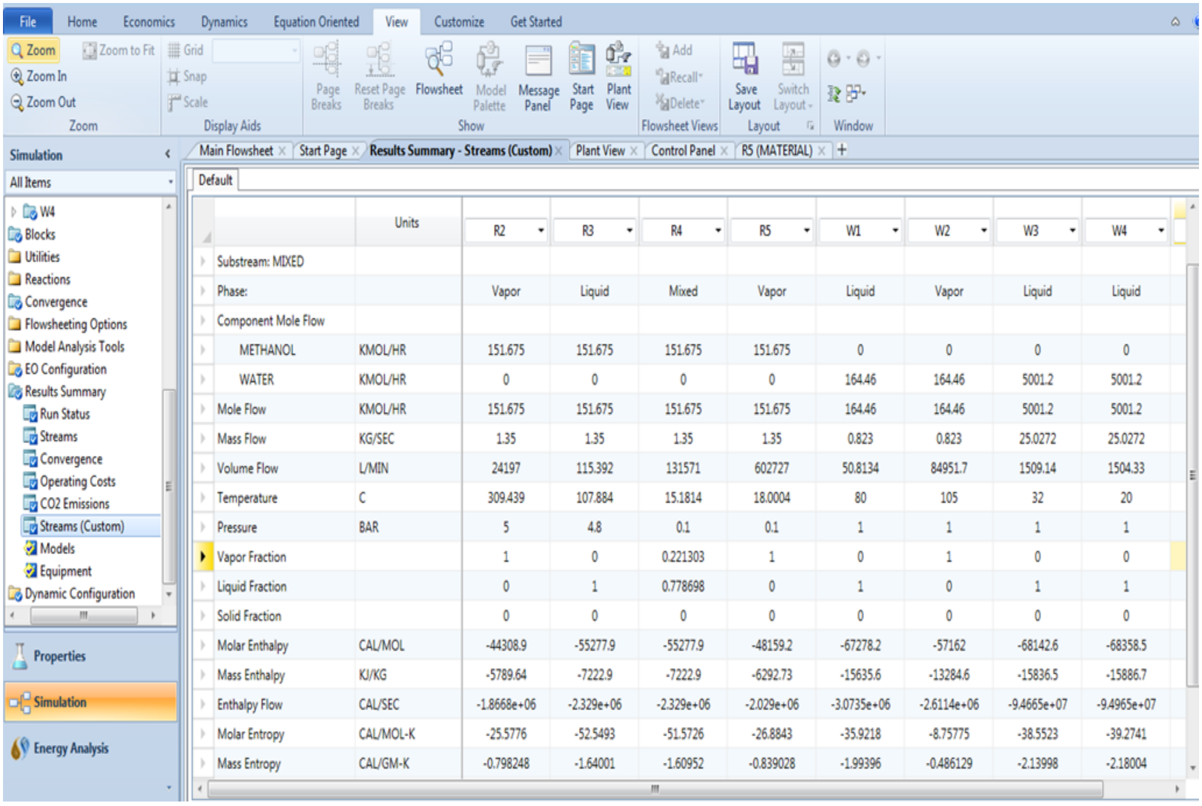
1	Baffle type	Segmental baffle
2	No. of baffles	4
3	Baffle cut	0.005 m
4	Tube sheet to 1st baffle spacing	0.6 m
5	Baffle to baffle spacing	0.6 m

V. RESULTS

We have chosen ASPEN PLUS V8.0 software in which all the components of heatpump are available. We connected the components of heatpump in a closed loop and then simulated.



The results obtained from simulation are given below



	Units	R2	R3	R4	R5	W1	W2	W3	W4
Substream: MIXED									
Phase:		Vapor	Liquid	Mixed	Vapor	Liquid	Vapor	Liquid	Liquid
Component Mole Flow									
METHANOL	KMOL/HR	151.675	151.675	151.675	151.675	0	0	0	0
WATER	KMOL/HR	0	0	0	0	164.46	164.46	5001.2	5001.2
Mole Flow	KMOL/HR	151.675	151.675	151.675	151.675	164.46	164.46	5001.2	5001.2
Mass Flow	KG/SEC	1.35	1.35	1.35	1.35	0.823	0.823	25.0272	25.0272
Volume Flow	L/MIN	24197	115.392	131571	602727	50.8134	84951.7	1509.14	1504.33
Temperature	C	309.439	107.884	15.1814	18.0004	80	105	32	20
Pressure	BAR	5	4.8	0.1	0.1	1	1	1	1
Vapor Fraction		1	0	0.221303	1	0	1	0	0
Liquid Fraction		0	1	0.778698	0	1	0	1	1
Solid Fraction		0	0	0	0	0	0	0	0
Molar Enthalpy	CAL/MOL	-44308.9	-55277.9	-55277.9	-48159.2	-67278.2	-57162	-68142.6	-68358.5
Mass Enthalpy	KJ/KG	-5789.64	-7222.9	-7222.9	-6292.73	-15635.6	-13284.6	-15836.5	-15886.7
Enthalpy Flow	CAL/SEC	-1.8668e+06	-2.329e+06	-2.329e+06	-2.029e+06	-3.0735e+06	-2.6114e+06	-9.4665e+07	-9.4965e+07
Molar Entropy	CAL/MOL-K	-25.5776	-52.5493	-51.5726	-26.8843	-35.9218	-8.75775	-38.5523	-39.2741
Mass Entropy	CAL/GM-K	-0.798248	-1.64001	-1.60952	-0.839028	-1.99396	-0.486129	-2.13998	-2.18004

VI. CONCLUSIONS

From analytical calculations I got the C.O.P of 2.56 for the existing Kraft plant design. For the newly designed model I got the C.O.P of 2.94 from the simulations. As the C.O.P of the new design is higher than existing design we can say that the efficiency of the new design is higher than existing design.

REFERENCES

[1]. Prashant Kumar, Rahul Sharma, "Design of Capillary Expansion Device Used in Vapor Compression Refrigeration System", International Journal of Latest Research in Science and Technology. May-June (2012).

[2]. R. A. Peixoto, C. W. Bullard, "A Simulation And Design Model For Capillary Tube-Suction Line Heat Exchangers", International Refrigeration and Air Conditioning Conference, School of Mechanical Engineering, Purdue University Purdue e-Pubs, 2008

[3]. Torge Pfafferott, Gerhard Schmitz, "Modeling And Simulation Of Refrigeration Systems With The Natural Refrigerant Co2," International Refrigeration and Air Conditioning Conference , School of Mechanical Engineering, Purdue University Purdue e-Pubs, 2002.

[4]. Necati Kocyigit, Huseyin Bulgurcu, Cheng-Xian Lin, "Fault Diagnosis of a Vapor Compression Refrigeration System with Hermetic Reciprocating Compressor Based on P-H Diagram," International Journal of Refrigeration, 2014.

[5]. J. Perko, V. Dugec, "Calculation and Design of the Heat Pumps," third international youth conference on energetic 2011.Portugal.

[6]. Seongwoo Woo, Dennis L. O'Neal, "Reliability Design of the Newly Designed Reciprocating Compressor for a Refrigerator," International Compressor Engineering Conference School of Mechanical Engineering. Purdue University Purdue e-Pubs, 2006.