Design and Analysis of Multi Nozzle Jet Spray Condenser using MATLAB

Anitha L[1] Jitendra Jayant[2]
[1]M.Tech Student [2]Assistant Professor
[1,2]Lakshmi Narain College of Technology, Indore, India

Abstract— To fulfil the requirements of vacuum in sugar & pharmaceutical industries, condenser plays very important part. So the selection of condenser is very vital, in the present study a Multi-nozzle jet spray condenser (Barometric) has been designed and analysed instead of a single nozzle jet spray condenser. This work has been done for the sugar department of the Armstrong Infrastructure Pvt. Ltd. Single jet spray condenser gives an efficiency of 59% in the sugar factory but after using Multi Nozzle Jet spray condenser an efficiency of 79% has been find. After studying and analysing the data given by sugar division regarding their requirements of condenser design and capacity a thorough study has been done and results show that condenser efficiency and vacuum efficiency comes out to be 78.54% and 98.92% respectively. A correlation between vacuum and time has also been established $P_v=0.0681\times T^{1.24}$. The characteristics curves have also been drawn.

Key words: Multi Nozzle Jet Spray Condenser, MATLAB

I. Introduction

Armstrong infrastructure Pvt Ltd., it is a leading manufacturer of pharmaceutical grade sugar. It is a unique supplier for the sucrose having very close limit of grain size, which is specialized need of pharmaceutical industry. To increase the sugar content of the pan where final refined sugar is separated from (mother) liquor that is recycled to the process developed by SCHUTTE & KOERTING, and first introduced in 1940, was a third type – a concurrent condenser of the multi-spray type.

Upgrades in energy and procedure efficiency in the sugar plants can make the factories vitality independent and make them fit for sending out excess power to the national network [1]. The sugar business can possibly support ESKOM in its advancement of energy efficiency rehearses while executing its own particular restoration and modernisation program in addition to enhanced business opportunities through supportable power generation for export. This helps ESKOM to put set up particular quick and long haul measures to avoid future power outages. South Africa has seen noteworthy levels of development in electricityconsumption and ESKOM has depended on expanding the measure of power imported from CahoraBassa in Mozambique [2].

When surface temperature of a solid is lower than the saturation temperature of a gas condensation occurs. There are two forms of condensation: film wise and drop wise condensation. The latter gives higher heat transfer coefficients [3]. Research was performed to optimize high-efficiency jet ejector geometry by varying nozzle diameter ratios [4]. Another researcher examines jet impingement cooling of EDIFICE with a dielectric coolant and the influence of fluid properties, micro spray characteristics and surface evaporation [5].

A researcher studied the crystallization of sucrose, involves the complex processes that require the correct design of vacuum pans and precise operation, as well as high efficiency condenser are required for creating the vacuum that is proper crystallization is depend upon the vacuum [6]. Another studied on improving operational efficiency by automation of the crystallization process in the manufacturing of raw cane sugar by automation of the crystallization process in manual sugar boiling coupled by the proper evaporation system to improve the quality of the product [7].

Researcher compared two-phase electronic cooling using free jets and sprays unconfined liquid jet cooling [8]. They describe the application of the temperature oscillation thermograph method to spray cooling system in order to measure the spatial distribution of the heat transfer coefficient [9]. Design of evaporation system heaters networks in sugar cane factories sugar production is done basically in several steps: juice extraction, juice clarification and evaporation, syrup treatment and sugar boiling, crystallization, centrifugation and drying. Much heat exchange equipment is used in this process [10].

The S&K Multi-spray barometric condenser offers a number of advantages in its design which provide efficient performance. The parallel flow design with top vapour inlet effectively prevents flooding under all circumstances. Also the absence of distribution trays in multi-spray design is a distinct advantage, because trays could sometimes be clogged or fouled and gives poor water distribution, thus permitting steam to reach the air pump. In the counter-current condenser the pressure drop between the side vapour inlet and top air pump increases with vapour load water flow. This serious disadvantage is entirely overcome using multi-spray design. In addition, the required shell diameter is less, offering savings in space and cost. The distribution of injection water in the form of conveying sprays insures an excellence mixing of the water and incoming vapours. Also the downward direction of sprays creates a suction effect which eliminates pressure drop in the condenser chamber. To meet varying load and temperature conditions, the water can be throttled to a minimum pressure drop across the chamber.

II. Working Principle

The principal feature of barometric condenser is that injection water may be discharged through a tail pipe by gravity, without requiring a pump. Another advantage of such condensing equipment is its immunity from flooding. In most plants, the vapour exhausted connection of vacuum apparatus is located at considerable elevation above ground level. The barometric condenser here permits shorter exhaust vapour line and provides two further advantages: first a reduction of leakage hazard second lower cost. Since there are no moving parts, maintenance is low. The condenser requires little space and is easily installable. The operation of any condenser is described by a single heat balance.

In sugar pan industries, sugar crystallization and refinery process has been done but quality of it sugar crystallization is depends on the vacuum efficiency of the condenser also water quantity removed by the condenser. For increasing the efficiency by applying multi nozzle jet spray condenser in sugar industries. The Multi nozzle jet spray condenser has 12 nozzles near the top portion of the condenser; some inclination has also been provided to the nozzle for the purpose of cross water spray inside the condenser, so that maximum contact of water with condenser can be achieved. When some non-condensate vapours comes in contact with the multi nozzle jet spray condenser all the vapours get converted into the water.

The operation of any jet spray condenser is describes a simple heat balance. The heat added to the system is the quantity of steam being condensed, expressed in pounds per hour and multiplied by latent heat of vaporization expressed in BTU per pound. This must be equal to the heat removed by condensing water which is the quantity of water expressed in pounds per hour multiplied by temperature rise from inlet to outlets, times the specific heat. Therefor the larger the temperature rise of condensing water, smaller the amount of water required. Under theoretically perfect condition, a condenser could be operated under a vacuum corresponding to its tail and discharge temperature.

A. Design of Multi Nozzle Jet Spray Condenser

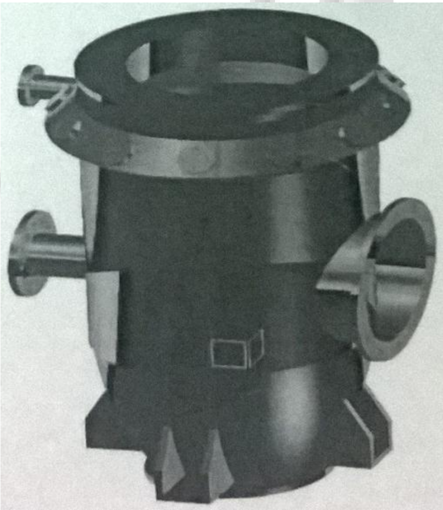

Fig. 1: sketch of Multi nozzle jet spray condenser

III. RESULT AND DISCUSSION

Inlet cooling water temperature to condenser	Saturation temperature at condenser pressure	Temperature of outgoing water from condenser
28	56	50
28	56	51
28	56.04	50
28	55	51.5
28	55	49
28	56	50

Table 1: Multi nozzle jet spray condenser readings

A. Multi Nozzle Jet Spray Condenser Efficiency

It is the ratio of rise in temperature of cooling water to the difference between saturation temperature of steam and inlet temperature of cooling water.

$$\text{Condenser efficiency} = \frac{\text{Rise in temperature of cooling water}}{\text{Temperature corresponding to vacuum in condenser} - \text{Inlet temperature of cooling water}}$$

$$\eta_c = \frac{T_a - T_i}{T_s - T_i}$$

Where,

T_a=Temperature of outgoing water from condenser (50°C)

T_i=Inlet cooling water temperature to condenser (28°C)

T_s=Saturation temperature at condenser pressure (56.02°C)

$$\eta_c = \frac{50 - 28}{56.02 - 28}$$

$$\eta_c = 78.54\%$$

B. Multi Nozzle Jet Spray Vacuum Efficiency

The lowest pressure or highest vacuum which can exist in the condenser is the saturation pressure of the steam corresponding to steam temperature entering into the condenser. But the actual pressure in the condenser is always greater than the ideal pressure by an amount.

$$\text{Vacuum efficiency} = \frac{\text{Actual vacuum in the conderser}}{\text{Ideal vacuum in the condenser}}$$

$$\eta_v = \frac{P_b - P_t}{P_b - P_i}$$

Where,

P_b=Barometric pressure (1.0321 bar)

P_i=Absolute ideal vacuum (0.1574 bar at 55°C)

P_t=Absolute total vacuum (0.1666 bar)

$$\eta_v = \frac{1.0321 - 0.1666}{1.0321 - 0.1574}$$

$$\eta_v = 98.92\%$$

1) Correlation Analysis

Assume:

P_v= Vacuum in inches of Hg

T=time in second

N=constant

C=constant

Using the law of curve fitting

$P_v = C \times T^N$

Taking the log on both sides,

$\log_{10}(P_v) = \log_{10}[C \times T^N]$

$\log_{10}(P_v) = \log_{10}(C) + \log_{10}(T^N)$

$\log_{10}(P_v) = \log_{10}(C) + N \times \log_{10}(T)$

Let assume,

$Y = \log_{10}(P_v)$

$X = \log_{10}(T)$

$A = \log_{10}(C)$

Method of group average,

– Group-1

S.No.	X= $\log_{10}$(T)	Y= $\log_{10}$(P_v)
1	1	0
2	1.3011	0.3979
3	1.4771	0.6021
4	1.6027	0.8451
5	1.6989	1.0212
6	1.7781	1.1139
n=6	$\sum X_1$ =8.8579	$\sum Y_1$ =3.9803

Table 2: Method of group average test

– Group-2

S. No.	X= $\log_{10}(T)$	Y= $\log_{10}(P_v)$
1	1.8451	1.1767
2	1.9031	1.2041
3	1.9542	1.2431
4	2	1.3011
5	2.0414	1.3617
6	2.0792	1.3979
7	2.1139	1.4232
n=7	$\sum X_2$ =13.9368	$\sum Y_2$ =9.1071

Table 3: Method of group average test

From table 2

$X_1=\sum X_1/n=8.8579/6=1.4762$, $Y_1=\sum Y_1/n=3.9803/6=0.6634$

From table 3

$X_2=\sum X_2/n=13.9368/7=1.9904$, $Y_2=\sum Y_2/n=9.1071/7=1.3011$

Putting the values in the equation, we get

$0.6634=A+N\times1.4762$

$1.3011=A+N\times1.9904$

Using above two equations we get,

N=1.24, A= -1.167

$A=\log_{10}(C)$

C=0.0681

Final relation,

$P_v=0.0681\times T^{1.24}$

Using a MATLAB code value of vacuum has been determined and a graph of related values has been represented on a graph shown below.

Different values of time have been selected. For example: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120 and 130. Finally a graph has been plotted between the time and vacuum.

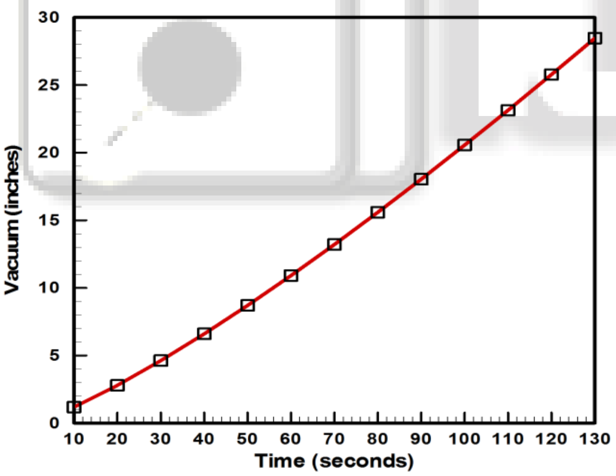

Fig. 2: Characteristics curve

IV. CONCLUSION

- Effectiveness of multi nozzle jet spray condenser is more than the previously used single jet spray condenser in the industry.
- By making a computer program it's become very easy to analyse the effect of various parameters in condenser design.
- Characteristics curve can be very easily drawn with the help of software. Software also helps in determining the values of vacuum range with respect to time.
- As per the requirements of sponsored industry the condenser is designed with vacuum efficiency of 98.92% and condenser efficiency of 78.53%, which can produce a vacuum 635mm of Hg required for crystallization of sugar.
- By finding the empirical correlation and plotting a characteristics curve between the vacuum and time helps in finding the vacuum at any period of time considered.

REFERENCES

[1] Rebecca M.., 2007. Case study: Energy efficiency improvement and cogeneration in the sugar milling industry.

[2] South Africa.Info, 2012. Gateway to the nation, R2bn toward energy efficiency.

[3] Jim Lang, Condenser design on aspen-plus software heat exchanger design with a phase change

[4] Charles J Glover (2005), Optimization of a high efficiency jet ejector by computational fluid dynamics software

[5] Dhir V (2005), Micro-electromechanical system-based evaporation thermal management of high heat flux electronics

[6] Rein, P.W., (2004), Circulation in vacuum pan, that require the correct design of vacuum pans and precise operation

[7] Sing, H. and Romaindra (2003), Improving operational efficiency by automation of the crystallization process

[8] Estes, K.A., (1995), Comparison of two-phase electronic cooling using free jets and sprays unconfined liquid jet cooling

[9] Freund, S. and Pautsch A.G. (2006), Local heat transfer coefficient in spray cooling system measured with temperature oscillation IR thermography.

[10] Ensinas, A.V., (2007), Design of evaporation system and heaters network in sugar cane factories using a optimization procedure.

