Design Analysis and Optimization of 3 Stage Evaporator.

Adesh Patil[1], Yuvraj Ahire[2], Pankaj Jagdale[3], Rushikesh Shinde[4],Amol Kolhe[5]
1,2,3,4 UG Student in Department of Mechanical in MIT Academy of Engineering Alandi Pune, India

[1]adeshpatil@mitaoe.ac.in
[2]yrahire@mitaoe.ac.in
[3]pajagdale@mitaoe.ac.in
[4]rushi-shinde@mitaoe.ac.in

5Assistant Professor, School of Mechanical and Civil Engineering, MIT Academy of Engineering, Alandi, Pune, India
[5]amkolhe@mech.mitaoe.ac.in

Abstract: **As we all know production of sugar cane is one of the biggest competitive segments. Sugar cane production is important for the national economy. This paper presenting is about improving 'thermo economic' efficiency of the evaporation system by changing designed & use of optimized material. Data from sugar factories and sugar handbook were used for reference, the process parameters are defined by using that handbooks.. The methodology proposed is used to evaluate the steam consumed by the factory and the optimized design of the equipment.**

Keywords: **Extraction, Evaporation, Crystallization, Evaporator, Concentrated solution, heat exchange equipment, Thermo economic evaporation.**

I. INTRODUCTION

Evaporation is a process of concentration of a given solution by heating it by vaporizes water. Solution is expose to a higher surface area or heating it to a higher temperature. It reduces the time needed to achieve a desired concentration. But increase in temperature of operation or the residence time in an evaporator might degrade the solution.

In this we used falling film evaporator in multiple effect arrangement which is most popular method used in concentration of sugar cane solution. In this vapor from one evaporator outlet is fed inside the steam chest o f second evaporator. And again steam of second evaporator is fed inside the third evaporator, the operation becomes multiple effects. The heat of original steam is reused into second & third effect.

In construction of Multiple Effect Evaporator, Height of the vessel, Sight glasses, The calandria, Centre well, Tubes, Circulation of steam and vapor are important parameter of evaporator body.

Problem Statement:
Design analysis of a triple effect forward feed evaporator for the Concentration of sugar cane juice solution. The capacity of sugar cane juice concentrated solution is to increase to get optimum efficiency.

The main focus of project is on thermo economic' optimization of the evaporation system by changing designed and use of optimized material.

In this in initial stage concentration of sugar cane juice solution is 7 Wt % and it has to concentrated at 8

Wt % in its final stage means in final effect. Input feed is given at 50993 Kg/Hr. And input temperature of solution is 27°C. In first effect of a steam flow is supplied at 103.66 Kpa and a vacuum in last stage is maintained at 74.2(Abs.) mm of Hg. Heat loss is neglected. Heat can be loss due to radiations & by others entertainment. In each effect saturation temperature enter when Condensate is assumed.

II. LITERATURE SURVEY

In a research paper titled To Design and Implement a Reliable Sugar Evaporation Control System 2015 Vol I WCE 2015, July 1 - 3, 2015, London, U.K. It was concluded from that the main objective of this research was optimized Monitoring and controlling of evaporation process by user friendly system. There is mostly focus on energy saving.

In another research paper titled MULTIPLE EFFECTS EVAPORATION of SUGAR FACTORY. Applied Research the following things were observed. Again it is focusing on efficiency of a sugar factory, which is located at Tucummán (Argentiena). This is focused on analysis of evaporation stage. The research is done to acquire measures for effective evaporation. It measures all important working parameters of system and their periodic sampling and calculation of output and variability. The result of this calculation is well estimated in this paper. The most important term calculated under different operating conditions is global coefficient of heat transfer in each effect.

In another research paper titled falling film plate evaporators performance in reconstruct multiple-effect evaporation stations inside sugar factories by thermal science: voll. 10 (2006), suppl., no. 4, pp. 55- 61 is concluded that, European union is focusing on sugar factories and investing in technologies to make their product competitive. The main reason of the research is evaluation of falling film plate evaporators effects. From this research found is this type of evaporators have less energy consumption and more effective evaporation because of high values of heat transfer coefficients.

From all this survey we find out our scope is in sugar cane production system most of energy is consumed in evaporation section and the main contributor and the complex in control. Controlling of evaporator is a problem that has been widely reported in the sugar industries. Evaporators are the one who more contributed for largest energy consumer. Because of all these major points effective evaporator control has very high influence on overall factory efficiency . As we know evaporation is one of the most energy intensive processes used in all any type of industries nowdays, There is need of focus and work on evaporation for economical energy utilization as well as process effectiveness. This can be done only if the equipment design is done in effective way and best efficient selection of material manufacturer is able to improve in the percentage of concentration required, and energy costs.

II. METHODOLOGY

A. Designed Layout

The layout of evaporator body was drawn which gave us the overview of the parts and its location in the system

B. Material Selection by Ashby Standard

It is very important process involved in any project. As we know density and strength were important factors so, for this project we selected density vs strength property chart by Ashby.

By using Ashby chart reference and importing geometry data to it, we were able to find the candidate material.

Materials	**Properties**		
	Yield Strengths	**Tensile Strengths**	**ρ (g/cc)**
Brass	310	469	8490
Copper	206	620	8000
SS 304	206	517	8000

Table No I- Properties of Materials

Description	**Value**	**Unit**
Juice in feed	3569.51	Kg/Hr
Feed Rate	14.16	Kg/Sec

Tale No. 02- Input conditions

It is very necessary to identify the function of the element or part for which the material is to be selected. In this case we aim to Table

HEAT BALANCE				
Enthalpy of Vapor Leaving	2487	2583	2543	KJ/Kg
Heat Transfer Rate	11634.75	9130.13	9784.98	KJ/Sec
Area	232.32	228	235	m²

No. 03- Heat Balancing

improve the strength of the part. There are three methods for quantitative material selection, they are as Table follows;

1. Cost per unit method
2. Weighted Properties Method
3. Digital Logic Method

The properties of the materials are scaled based on the weight factor of the physical property which is also known as the weight factor of the property. The scaled property chart is given below,

Materials	Scaled Properties		
	Yield Strengths	Tensile Strengths	ρ (g/cc)
Brass	100	75.6451	100
copper	66.4516	100	94.2285
SS304	100	75.645161	100

Table No. 04- Scaled Properties

Then, Performance index is calculated for each material. This performance index is then multiplied with the relative cost of that material to get the final material values or say total performance index. The material with the maximum total performance index is selected as the material for the particular part.

Material	Relative Cost	Performance Index	Total Performance Index
Brass	1.2	68.05354446	81.66425335
Copper	1	90.92928893	90.92928893
SS304	1.1	66.94087934	73.63496728

Table No. 05- Performance Index

Through the table plotted above it is clear that the highest calculated performance index is showed by the material copper and hence this material is finalized for the screw feeder part of the injection moulding machine

A. Calculations and Designing

There are various calculations involved before we actually start making the part. For designing any part these calculations are very important. With the help of calculations we are able to find the dimensions of the part. Other parameters like flow rate, various temperatures, pressure is found out with help of it

Description	Evaporator 1	Evaporator 2	Evaporator 3	Unit
Evaporation Rate	4.3	4.3	4.3	Kg/Sec
Outlet From	9.86	5.56	1.26	Kg/Sec
Outlet of Concentrated solution	10	17.8	79	Wt %
BPR (Boiling Point Rise)	0.5	1.5	10.4	°C
Heat Transfer Coefficient (U)	2325	1275	1031	W/m°C
Δt	21.54	32.3	21.64	°C
Actual Boiling Point	78.54	45.7	22.56	°C

Table No. 06- Input conditions

Tube Details:

Description	Value	Unit
Outside diameter (do)	42.164	mm
Inside Diameter (di)	32.46	mm
Length	10	ft
Tube Pitch (Δ)pT	52.705	mm
Surface area	0.4037	m^2
Number of Tubes (N)	619	
Area occupied by Tube	0.7445	m^2
α	60	°
Actual Area	0.827	m^2
Downcomer Area	0.432	m^2

Downcomer Diameter	0.742	m
Total Tube Sheet Area	1.259	m²
Tube Sheet Diameter	1.27	m

Table No. 07- Tube Details

MECHANICAL DESIGN:

INPUT

Description	**Value**	**Unit**
Vacuum Pressure in drum	0.4162	Bar.
Amount of Water Evaporated	15479	Kg /Hr
Heat Surface required Area	232.1	m²
Steam at first effect	1.03	Bar.
Density of Liquid	1019	Kg/Hr
Density of Water Vapor	0.258	Kg/m³
Design Pressure	1.1023	Kg f /cm

Table No. 08- Mechanical Design

MATERIALS

Evaporator Body: Low Carbon Steel

Tube: Brass

Description	**Value**	**Unit**
Permissible Stress of Low Carbon steel	979.9	Kg /cm ²
Modulus of Elasticity of Low Carbon Steel	18×10^5	Kg / cm ²
Modulus of Elasticity of Brass	9.4×10^5	Kg/cm²
Conical Head at Bottom, cone Angle	121	°
Conical Head at top, Cone Angle	121	°

Table No. 09- Material specification

Description	**Value**	**Unit**
Calendaria sheet Thickness (ts)	9.99	mm
Tube sheet Thickness (tts)	21	mm
Evaporator Drum Diameter	3.89	m
Evaporator Drum Height	3.81	m
Drum Thickness	15	mm
Gasket Design		
Gasket Width	6.0	mm
Diameter of Gasket	1300	mm
Estimation of Bolt Load (H)	0.15	MN
Controlling Load (Wg)	0.17	MN
Bolt Area, Bolt Size	M20 × 2	
Number of Bolts	8	
Flange Thickness	30 (including corrosion allowances)	mm
Bracket Design		
Diameter of Vessel	1269	mm
Height of Vessel	3.80	m
Clearance from Bottom	1001	mm
Density of Carbon steel	7821	Kg / m³
Density of Brass	8451	Kg / m³
Wind Pressure	128.6	Kg / m³
Number of Bracket	04	
Diameter of Bolt circle	3140	Mm
Height of Bracket from foundation	2250	mm
Tension stress	11400	Kg / cm²

Compression Stress	1233	Kg / cm²
Bending Stress	1575	Kg / cm²
Weight of Tube	9150	Kg
Weight of Tube Sheet	495	Kg
Total Weight	10728	Kg
Base Plate		
Compressive Load	2857	Kg
Thickness	6	Mm
Web Plate		
B.M. at each Plate	73246	Kg/cm²
Thickness	4 to 6	Mm
Column support		
Size	150 × 75	
C.S. Area	20.89	Cm ²
Modulus of Section (Zyy)	19.47	cm²
Radius of Gyration (ryy)	2.22	cm²
Weight of section	16.40	Kg/m
Height from Foundation (I)	2250	mm
Equivalent Length (le)	1125	mm
Slenderness Ratio	51.0	
Combined Load	7805.13	Kg/cm²
Permissible Compression Stress	8104.12	Kg/cm²
Base Plate for Column		
Size of Column	150 ×75	
Width	100	mm
Length	182.5	mm
Bearing Pressure (Pb)	107.03	Kg/cm²
Stress in Plate	12.84	Kg/cm²
Plate Thickness	4 to 6	mm

Table No. 10- Mechanical Design

With help of 3D CAD software such Solid works the Evaporator body and tubes were designed on the basis of basic dimensions to be analysed for further investigation.

B. Analysis

There are various types of analysis carried out on a part. For the body and tubes we used Finite Element analysis. It reduces the cost of actual prototyping and testing. Numbers of tests are carried out with help of soft wares to optimize the product and develop it faster.

The software we used for the analysis of body and tubes is solid works. The parameter applied was torsional force. The result was obtained in the form of stress, strain, displacement and factor of safety

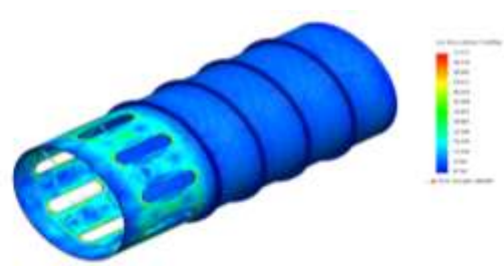

Fig: Analysis of the body for the nodal stress

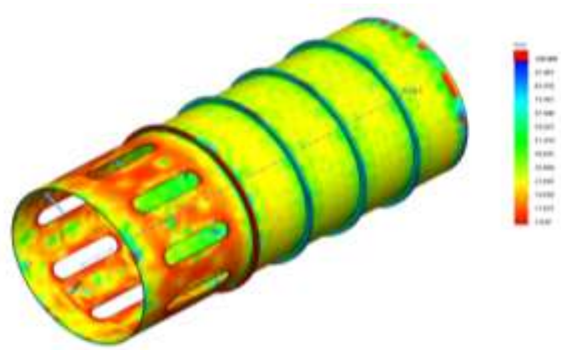

Fig: Analysis of the body for the factor of safety

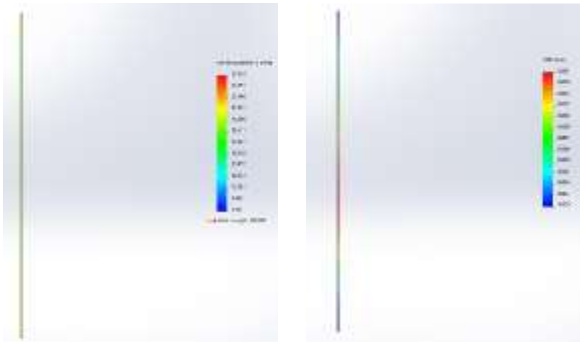

Fig: Analysis of Tube for Stress and Displacement

III. RESULTS

The material SS317 for Body and material Brass and SS304 for showed good results through the software. Both the materials showed high strength. However the displacement was same for both the materials of Tube.

BODY

Material	F.O.S.	Yield strength
SS304	2.84	2.06807e+08 N/m^2
SS317	3.82	2.78e+08 N/m^2

Table No. 11- (A) Result

TUBE

Material	Displacement	Yield strength
Copper	0.115mm	2.58646e+08 N/m^2
Brass	0.086mm	2.39689e+08 N/m^2
SS304	0.087mm	2.06807e+08 N/m^2

Table No. 11- (B) Result

IV. CONCLUSION

The initial design of the body and Tube of the Evaporator was studied and based on that it was redesigned with respect to dimensions and material to gain a control over the output. The capacity of the concentrated juice solution was optimised taking the inputs and constraints into consideration. The analysis was performed on the designed body and tube to check or verify its functioning under working conditions. It was found out SS317 as a material would be best to select for the body and Brass as a material for Tube. The calculations and analysis were successfully completed.

REFERENCES

[1] HANDBOOK OF CANE SUGAR ENGINEERING by E Hugot

[2] To Design and mplement a Reliable Sugar Evaporation Control System 2015 Vol WCE 2015, July 1 - 3, 2015, London, U.K

[3] MULTIPLE-EFFECT EVAPORATION N A SUGAR FACTORY. A MEASURED VARIABLES STUDY by Latin American

[4] www.innoleague.com

[5] www.iaeng.com

[6] thermalscience.vin.bg.ac.yu

[7] dergipark.org.tr

[8] Garg, Akhil, Yogesh Bhalerao, and Kang Tai. "Review of empirical modelling techniques for modelling of turning process", International Journal of Modelling Identification and Control, 2013

[9]www.enq.ufsc.br