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Design and Development of Shell and Tube Heat Exchanger for Harar Brewery Company Pasteurizer Application (Mechanical and Thermal Design)

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ABSTRACT: *A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact* ***[1]****.From different types of heat exchangers the shell and tube heat exchangers with straight tubes and single pass is to be under study. Here the redesign takes place because of temperature fluctuation at the 9th zone of the pasteurizer in the Harar Brewery Company. Thermal and mechanical design is run in order to optimize the output temperature of the cold fluid at the last heat exchanger in which it is sprayed on the beer ready for customer use. In thermal design part geometry optimization is done through trial and error. And for Mechanical design part the natural frequency& vortex shedding of different components of heat exchangers are investigated through governing equations of vibrations under dynamic fluid with in tubes. Using computational fluid dynamics (CFD) the heat transfer of the two fluid is investigated using FEM* ***simulation software's Gambit1.3 and Fluent 6.1****and the performance of the STHEx determined in terms of variables such as pressure, temperature, flow rate, energy input/output, mass flow rate and mass transfer rate that are of particular interest in STHEx analysis.*

KEYWORDS: *Enthalpy, Gambit 2.4.6 and Fluent 6.1, Simulation, CFD, STHEx, Pasteurizer*

I. INTRODUCTION

In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multicomponent fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak**[1]**.But because of vibration induced due to the dynamics of the fluid in the tube there may be linkage in the baffle and the shell wall. The use of the baffles in heat exchangers is to enhance heat transfer through turbulence of the shell side flow and to reduce the vibration (Natural frequency) of the tube.

The STHEx under study for this paper is found in Harar Brewery Company at the 9th zone of the pasteurizer. Here the pasteurizer works in engineering principle's in order to make the bottles adopt for water with maximum temperature and that of minimum temperature. The detail of the working principle of machine is shown in Figure 1 below.

Here for the STHEx in Harar brewery company the two system fluids in which heat is going to be exchanged is water and steam(H_2O in gas state). Steam with mass flow rate of 6000kg/hr enters at 160^0C shell side in which a cool water at 25^0C enters the tube side and out at a designed temperature of 35.5^0C and steam with outlet temperature of shell side at 80^0C but the problem is the out let temperature of the cold fluid will fluctuates frequently and this result in undesirable test in the beer. Having the above information at hand geometry optimization is run using general thermal equations for STHEx heat transfer Q (heat load), pressure drop across the system and optimum insulation insulation cost is calculated. And geometry optimization is done considering tube length, thickness and tube patterns (Triangular or Rectangular Pattern) by doing so the overall heat transfer, Pressure drop and cost are studied and the allowable design is chosen from thermal design point of view. This paper is different from the other papers on STHEx is that here both mechanical design and thermal design is considered including Simulation to investigate the heat transfer of the two fluids.Simulation refers to process of comparing information on the behavior &characteristics of the real system by analyzing, studying or observing the model of the system such a model may be subjected to a variety of operating and environmental conditions and theperformance of the of STHEx determined in terms of variables such as pressure, temperatureflow rate, energy input/output, mass flow rate and mass transfer rate that are of particular interest in STHEx analysis.

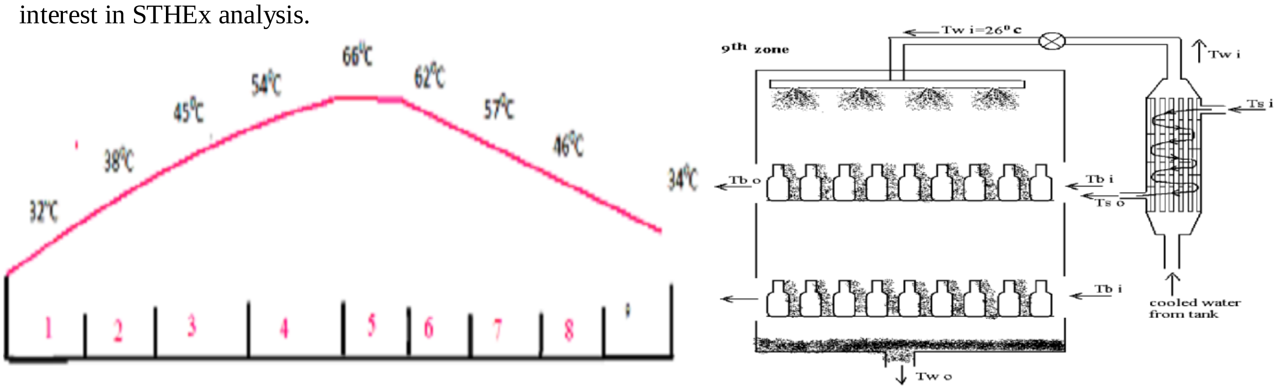


Figure1. Shows a) 9 Zone Temperature (^{0}C) Vs. Time (min) b) 9th zone bottle pasteurized using STHEx9

II. LITERATURE

Shell-and-tube heat exchangers are commonly used in petro-chemical and energy industries for their relatively simple manufacture and adaptability to different operating conditions. Many thermal engineers try to increase the efficiency STHEx by considering different parameters which affects heat transfer between the shell and the tubes.An experimental investigation of heat transfer enhancement for STHEx has been done by the Xi'an Jiootong University, Xi'an, China, Department of Refrigeration and Cryogenics Engineering, School of Energy and Power Engineering**[2].**For the purpose of heat transfer enhancement, the configuration of a STHEx was improved through the installation of sealer in the shell side .the gaps between the baffle plates and shell is blocked by the sealers, which effectively decrease the short-circuit flow in the shell side.The result of heat transfer experiment show that the shell-side heat transfer coefficient of the improved heat exchanger increased by 18.2-25.5%, the overall coefficient of heat transfer increased by 15.6-19.7%, and the exergy efficiency increased by 12.9-14.1%.pressure losses increased by 44.6-48.8% with the sealer installation, but the increments of required pump power can be neglected compared with the increment of heat flux. The heat transfer performance of the improved heat exchanger is intensified, which is an obvious benefit to the optimizing of heat exchanger design for energy conservation**[2]**.

Other experimental investigation on heat transfer enhancement for STHEx has been done by Amirkabir university of technology, faculty of technology, Teheran iran they tried to obtain experimentally the heat transfer coefficient and pressure drop on STHEx for three different types of copper tubes (smooth, corrugated and with micro-fin) also experimental data has been compared with theoretical data available. and correlation have been suggested for both Nusseltnumber for the three tube types the experimental setup has three STHEx in conjunction with electric boilers and chiller as well as air cooled condenserFor comparison of experimental and theoretical results bell's method is used variation of Nu and Eu with respect to Re.Pr is shown and they tried to conclude the following points, first the experimental values of Nu are higher than the predicted values, especially for smooth and corrugated tubes, but are closer for micro fin tubes, two the experimental values for pressure drop are higher than those of predicted empirically this is due to complicated flow pattern at low Reynolds number is given it is seen that micro-fin having the lowest Nu this is may be due to trap of the fluid inside tiny space between fins which prevent mixing of main streams when the flow is not turbulent**[3].**The 3Rdproject in STHEx is enhancing the heat transfer performance of triangular pitch and tube evaporators using an spray technique by southern Taiwan university , department of

mechanical engineering this study show that in compact STHEx the dry out problem can be delayed by use of an interior spray method in which each heater tube within the bundle is sprayed simultaneously by to nozzles. The experimental results show that the shell side heat transfer coefficient obtained using the proposed spray technique are significantly higher than conventional flooded type evaporator the experimental setup was a refrigerant flow loop to circulate it through the test section the refrigerant is HCFC and the test section was fabricated from stainless steel the copper heater tube and nozzle tube fastened at opposite sides plates**[4].**

III. METHODOLOGY

Design is an activity aimed at providing complete descriptions of an engineering system, part of a system, or just of a single system component design methodology for a heat exchanger as a component must be consistent with the life-cycle design of a system.
There are two main design for this paper even for general design of STHEx

3.1. Thermal Design

Heat exchanger thermal/hydraulic design procedures top in involve exchanger rating (quantitative heat transfer and pressure drop evaluation)and/or exchanger sizing. Only two important relationships constitute the entire thermal design.Two of the simplest (and most important) problems are referred to as the rating and sizing problems.

3.1.1. Rating Problem

Determination of heat transfer and pressure drop performance of either an existing exchanger or an already sized exchanger (to check vendor's design) is referred to as a rating problem. Inputs to the rating problem are the heat exchanger construction, flow arrangement and overall dimensions, complete details on the materials and surface geometries on both sides, including their non-dimensional heat transfer and pressure drop characteristics (j or Nu and f vs. Re),{ fluid flow rates, inlet temperatures, and fouling factors. The fluid outlet temperatures, total heat transfer rate, and pressure drops on each side of the exchanger are then determined in the rating problem. The rating problem is also sometimes referred to as the performance orsimulation problem.

3.1.2. Sizing Problem

In a broad sense, the design of a new heat exchanger means thedetermination/selection of an exchanger construction type, flow arrangement, tube/plate and fin material, and the physical size of an exchanger to meet the specifiedheat transfer and pressure drops within all specifiedconstraints. However, in a sizingproblem for an extended surface exchanger, we will determine the physical size (length,width, height, and surface areas on each side) of an exchanger.For a STHEx a sizing problem in general refers to the determination of shell type, diameter and length, tube diameter and number, tube layout, pass arrangement, and so on. Inputs to the sizing problem are surface geometries (including their dimensionless heat transfer and pressure drop characteristics), fluid flow rates, inlet and outlet fluid temperatures, fouling factors, and pressure drops on each fluid side.

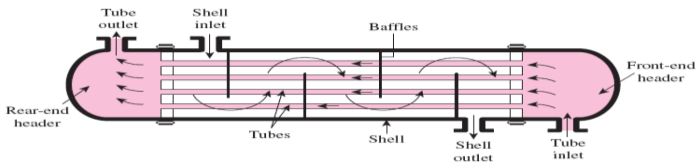


FIGURE 11–4
The schematic of a shell-and-tube heat exchanger (one-shell pass and one-tube pass).

Figure2. Shows shell and tube heat exchanger**[5]**

IV. RESULTS AND DISCUSSION ANALYSIS AND DESIGN EQUATIONS OF STHEX

The beer from the 8th zone enters the 9th zone at 46^{0}C which is the desired temperature let us calculate the out let temperatures of the hot water in which it is going to be used to cool(decrease the final temperature) the beer for the final processing. Let us compute the mass flow rate of the beer in our zone. HBSC produce 90 million bottles of beer per year it works 6 days per week and 16 hours per day. so it works for(365-(13+4*12))/16=4864 hr\year the volume flow rate of the beer in this zone isV_b=90e6*0.33/48640=6160.0855 lit/hr or V_b=6.1258kg/sec.

1.1. Determination Of hi

The mass flow of water (hot water comes out of HEx) is determined from
(Mcp)beer=(Mcp)water
Equation1
but the specific heat of 2.16 and that of water is 4.186 the percentage presence of alcohol is 4.25% and the rest is water. so that the specific heat of Harar beer is determined from
Cpb=0.0425*2.16+0.9575*4.186=4100 J/kg`c
Hence the mass flow rate of the water to this zone per second is

Mw=6kg/sec
The heat lost from the beer during heat transfer process with the hot water in which the hot water absorbs heat. In the9th zone the total heat loss

$Q_{loss} = M_b * C_{cp} * \Delta T_b$ =301392W Equation2

To know the lost from one bottle beer the diameter at the base of the bottle is 6 cm so that the number of beer along the length and width of the 9th zone pasteurizer respectively is
NobL=3/0.06=50 bottles Nobw=4/0.06=66.03 bottles
The heat lost from one bottle = total heat lost/ total no of bottles=30139w/ 6600 =45.64 w
The convective heat transfer coefficient for the beer if we take the 9th zone as one system and the heat film condensation take place on the vertical bottles of beer as in tubes the beer is at a saturation temperature of 46^0C and
Assumptions-

- steady operation condition exists
- the bottles of beer is isothermal
- the bottles considered as a cylinder
- the convective heat transfer coefficient for the beer and the water is the same and also be the same properties each bottle are maintained at a surface temperature of 36^0C

Properties:-The properties of water at the saturation temperature of 46^0C are
hfg=2393e3 J/kg ρv=0.069 kg/m
The properties of liquid at the film temperature of

$T_f = \frac{T_{sat} - T_s}{2}$=$41^0$CEquation3

The modified latent heat of vaporization Equation4

Hfg*= $Hf_g + 0.68C_{pl}\,(T_{Sat} - T_S)$

Nothing that ρv<<<ρl(since 0.06<<<991) the heat transfer coefficient for a condensation on a single vertical (bottles) is determined and laminar film condensation takes place and the height of the bottle h=10.8cm
Now let us compute the temp at which the hot water leaves the heat exchanger and sprayed on the beer. We know that the heat lost by the hot beer is equal to the conduction heat transfer along the thickness of the bottle and the convective heat transfer to the hot water. This is given by

Qlost/bottle=$h_i*A_{internal}*\Delta Ti=k*A_{average}*\Delta T_0=h_o*A_{exter}*\Delta T_0$
$=h_i*A_{int}*(T_b-T_{si})=k*A_{avg}*(T_{s,i}-T_{s,o})/\Delta x=h_o*A_{exter}*(T_{s,o}-T_{w,o})$
The temperature of the internal surface Ts,i is
Q loss/bottle=$h_i*A_{int}\,(T_b-T_{s,i})$ Equation5
The conduction heat transfer
Q_{loss}/bottle= $h_o*A_{ext}*\Delta T_c/\Delta x$ Equation6
And the convection heat transfer
Q_{loss}/bottle=$h_o*A_{ext}*\Delta T_{conv}$hence$T_{w0}=32^0$C

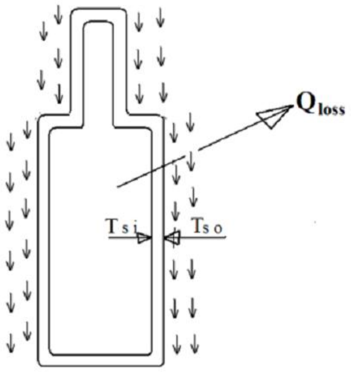


Figure3. Shows bottle beer under showering by hot H_2O

And from the first law of thermodynamics the heat lost by beer is equal to the heat absorbed by the hot water so that
$Mb=C_{pb}*\Delta T_w$ Equation7
So the inlet temperature of water is $T_{wi}=26.24^0$C which is inlet temperature for the 9^{th} zone tank and outlet temperature for this STHEx. So the out let temperature of the water from the tube becomes $T_{wi}=26.24^0$C which is the heat exchanger designed(desired) temperature
Steam with mass flow rate of 6000kg/hr enters at 160^0C shell side and in which a cool water at 15^0C enters the tube side and out at a designed temperature of 26.24^0C and the shell side at 80oc the shell and tube heat exchanger used now is Lm in length and parameters(Datas) from the company STHEx at the 9^{th} zone tank is as follows
tube outer dia Do=19.05mm pt=25.4mm shell inner dia Ds-i=155.18mm
length L=1.01m Clearance C=Pt-Do=6.35mm
pressure drop due friction during heat transfer

$\Delta Pf = \frac{fLNp}{di} * \frac{PV^2}{2gc}$ Equation8

1 pass tube &shell $Ntube = \frac{Mw}{\rho * Ain * V}$ $Ren = \frac{Vm * Dh}{v}$

N_{ud}=hDh/k=0.023*Red$^{0.8}$*Pr$^{0.4}$
hi=Nud*k/Dh &f=(0.79lnRed-1.64)
from the above equations we have the following result in the table1 below
From the table by optimization it is selected a row with tube internal diameter of 18mm and tube number of 28 and pressure drop of 199.54 (less).

0.015	Vm	N	Red	f	Nud	hi	ΔPf(kpas)
	1.773	40	29047.79	0.02382	179.79	7253.93	253.72
	2.2166	32	36305.65	0.02258	213.71	8622.48	375.71
	2.533	28	41499.19	0.02188	237.84	9596.06	475.67
	2.627	27	43039.23	0.02169	244.84	9879.69	507.19
	1.555	37	28125.74	0.02401	174.23	6367.39	178.19
0.01656	1.818	32	32882.69	0.02312	197.43	7215.25	234.53
	2.078	28	37585.39	0.02239	219.72	8029.89	295.31
	2.155	27	38978.39	0.02220	226.21	8267.05	316.42
	2.530	23	45760.84	0.02139	257.18	9398.87	420.22
	1.539	32	30256.89	0.02359	184.72	6210.69	157.77
0.018	1.759	28	34582.11	0.02284	205.56	6911.38	199.54
	1.824	27	35860.02	0.02265	211.61	7114.79	212.78
	2.239	22	44018.96	0.02158	249.32	8382.69	305.47
	2.59	19	50978.64	0.02086	280.38	9426.99	396.03

1.1.1. Shell side design (Estimation of ho)

First the tube side layout is to be selected considering different important points which enhance heat transferand from maintenance point of view in our case the HBScSTHEx has triangular pitch arrangements, so from table for 1 pass shell and tube and tube outer diameter of 19.05mm has Pt=25.4mm
Calculating the hydraulic diameter of the triangular pitch

$$De = 4 * \left[\frac{\frac{Pt(0.86*Pt)}{2} - \frac{\pi Do^2}{8}}{Do/_2}\right]$$ **Equation9**

Now let us estimate the shell side Pressure drop & the heat transfer coefficient but the cross sectional area

$$As = \frac{DsCB}{Pt}$$ **Equation10**

but the optimum baffle spacing from TEMA standardization the baffle spacing is somewhere between 0.4 and 0.6 of shell inner dia (Ds). With optimum design baffle spacing of 0.5Ds so that B=0.5*0.2205=0.11026m
We know that the shell side velocity is limited to 0.6 - 1.5 m/s &assuming Vs=1.5 m/s maximum shell characteristics area using equation

1.1.2. The mass velocity

The velocity in the shell in the range of 0.6 - 1.5, taking 1.5 m/s let us calculate **ho** by counter checkin2e3<Res<1e6

$$Red = \frac{VsDe}{kf} \quad Nus = \frac{hoDe}{kf}$$ **Equation11**

From the above equation ho can be calculated

$$ho = \frac{Nus*kf}{De}$$ **Equation12**

Since the heat exchanger operates in counter flow manner so that the mean temperature difference ΔTlm relation is different unlike the parallel flow and others types of flow and derivate by the factor F_t which is called temperature correction factor

$T_{lm} = F_t * \Delta T_{lm} * C_f$In our case Ft=<1 **Equation13**

F can be found by calculating first the S&R ratios which are called temperatures effectiveness and heat capacity ratio respectively where

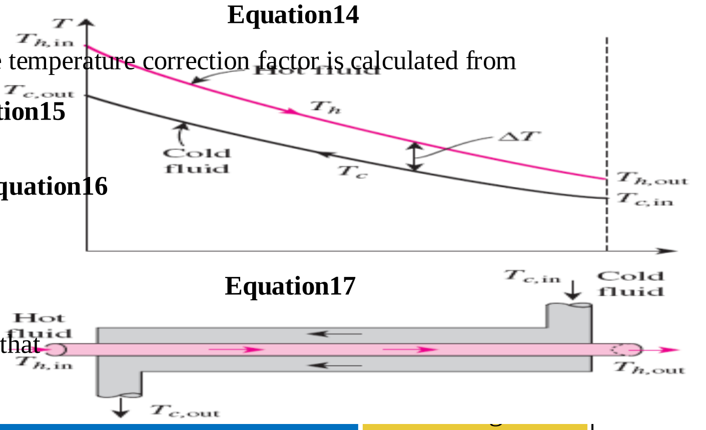
$$S = \frac{t_o - t_i}{T_i - T_o} = \frac{\Delta Tactu}{\Delta Tmax} \text{and} R = \frac{T_i - T_o}{t_o - t_i}$$ **Equation14**

Since our HEx is a single shell, single tube pass so that the temperature correction factor is calculated from

$$f_t = \frac{\sqrt{R^2+1}\,\ln\frac{1-S}{1-RS}}{(R-1)\ln\frac{2-S(R+1-\sqrt{R^2+1})}{2-S(R+1+\sqrt{R^2+1})}}$$ **Equation15**

ΔT1=Ti-to and ΔT2= To-ti from the figure4 below **Equation16**
And the log mean temperature difference is evaluated from the relation

$$\Delta T_{ln} = \frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}}$$ **Equation17**



But the flow includes both counter flow and cross flow so that

$\Delta T1m = Ft * \Delta T1m * cf$
Therefore let us calculate the desired length at the out let
temperatures of tube by counter check methodFigure4. Shows temperature of cold and hot fluid**[5]**
$Q = UA\Delta T1m.cf = UN\pi PoL\Delta T1n$ **Equation18**
The overall heat transfer Co-efficient

$$U = \frac{1}{h_i}\frac{D_o}{D_i} + \frac{1}{h_o} + \frac{\frac{D_o}{2} * \ln\frac{D_o}{D_i}}{k} + R_{fi}\frac{D_o}{D_i} + R_{fi}$$ **Equation19**

Table2. Shows design of the STHEx total length

V(m/s)	Res	Nus	ho	U	L(m)
0.6	43920.29	145.39	5517.01	1846.81	1.69
0.9	85880.44	181.72	6895.37	1891.39	1.58
1.0	73200.49	192.56	7306.69	1921.39	1.56
1.2	87840.58	212.78	8077.38	2065.64	1.52
1.3	95160.63	222.45	8440.92	2088.65	1.50
1.4	102480.68	231.709	8792.07	2109.49	1.48
1.5	109800.73	240.67	9132.11	2128.51	1.47

The final design length at the assumed V=1.5 m/s is
L=1.87m Res=109800.73 Nus= 240.67 ho=9132.11 U=2027

1.1.3. Tube side pressure drop

Tube side pressure drop is a quantity of interest in shell & tube heat exchanger, in the analysis of tube flow is important parameter. Since this quantity is directly related to the power requirement of the pump to maintain flow then the required pumping power for this HEx to over come
A specified pressure drop ΔP is determined from
$Wpump = V*\Delta P = m*\Delta P/\rho$ **Equation20**

The Reynolds number from the calculation result at the corresponding velocity is greater than 4000. So that the flow is turbulent in this shell& tube HEx design. which is much shorter than the total length of the tube therefore, we can assume fully developed turbulent flow in the entire length tube. The surface temperature Ts of the tube at any location can be determined from the tube cross sectional and heat transfer area
$Ac = \pi * Di^2/4 A_{hta} = PL q_s = Q/A Ts = Tm + qs/hi$ **Equation21**

1.1.4. The shell side pressure drop

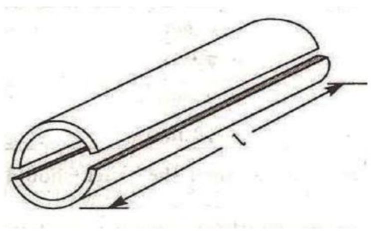
Pressure drop for the shell side is given by
$\Delta Ps = f*(Nb+1)Ds/De*\rho V^2/2gc$ **Equation22**
The number of baffles is determined from
$(Nb+1)B = L$**Equation23**

1.2. MECHANICAL DESIGN

1.2.1. STRESS ANALYSIS ON SHELL

Considering our cylindrical shell as a pressure vessel of thin shell in which the wall thickness of the shell (t) is less than 1/10 of the internal diameter of the shell (d) or the internal fluid pressure is less than 1/6 of th e allowable stress then it is called a thin shell. In our case the shell are and there are pipes in which water flowing outside the pipe so that our shell is an example of open and pressure vessel, so that the circumferential or hoop stresses are induced by the fluid pressure when a thin cylinder shell is subjected to an internal pressure , it is likely to fail in the following two ways

1. It may fail along the longitudinal section (i.e. circumferentially) splitting the cylinder into two troughs as shown in figure below



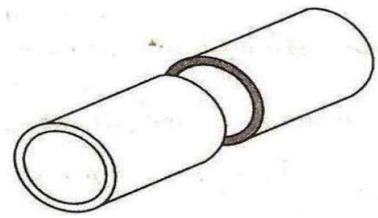


Figure5. Circumferential failure**[6]** **Figure6**. Transverse section (longitudinally)**[6]**

2. It may fail across the transverse section (longitudinally) splitting the cylindrical in two cylinder shell Circumferential or hoop stress a tensile stress acting in a direction tangential to the circumferential or hoop stress

$$t = \frac{pd}{2\sigma_{ti}}$$ **Equation24**

In case of ductile materials circumferential stress$\sigma_{ti} = 0.8\sigma_y$

For brittle material$\sigma_{ti} = 0.125\sigma_u$

1.2.1.1. Longitudinal stress

Consider a thin cylindrical shell subjected to an internal pressure. Tensile stress acting in the direction of the axis is called longitudinal stress in this case the total force acting on the transverse section (along Y-Y) Intensity of pressure cross sectional area is

$$\sigma_{t2} = \frac{pd}{4t}$$ **Equation25**

From the above we see that the longitudinal stress is half of the circumferential stress therefore the design of a shell pipe must be based on the maximum stress i.e. hoop stress

1.2.1.2. Maximum shear stress

We know that according to maximum shear stress theory the maximum shear stress is one half the the algebraic difference between the maximum and minimum principal stress i.e the hoop stress and longitudinal stress. Therefore maximum shear stress

$$S = \frac{\sigma_{ti} - \sigma_{t2}}{2}$$ **Equation26**

1.2.2. INTEGRAL FLANGE DESIGN FOR TUBE SHEET

Dimensions of A flange joint for a stainless steel shell pipe 220mm dia to carry a pressure of 0.4 $N/mm^2$and from table for stainless steel allowable tensile stress t=14 N/mm^2c=9mm

Therefore thickness of the pipe

$$t = \frac{pd}{2\sigma_t} + c$$ **Equation27**

Other dimensions of a flanged joint for a cast iron shell pipes may be fixed as follows. Nominal dimensions of the boltd=0.75t+10 **Equation28**

Number of bolts n= 0.0275D+1.6, Thickness of the flange, t_f=1.5t+3, Width of the flange, B=2.3d, Outside diameter of the flange Do=d+2t+2B, Circumferential pitch of the bolts Pc=πDp/n = π*300/8Pc =117.8 mm. In order to make the joint lack proof the value of Pc should be between$20\sqrt{d_i}$ and $30\sqrt{d_i}$where di is the bolt holedia

Since the circumferential pitch as obtained (117.8mm) above is within 100 to 150 therefore the design is safe.

$$N = \frac{d_o - d_i}{2}$$ **Equation29**

$$\frac{D_o}{D_I} = \sqrt{\frac{y - Pm}{y + (Pm + 1)}}$$ **Equation30**

While there is an enormous variety of specific design features that can be used in shell and tube exchangers, the number of basic components is relatively small. These are shown and identified.

1.2.3. VIBRATION ANALYSIS

1.2.3.1. Flow Induced Vibrations (FEI) In STHEx

Of the different excitation mechanism of flow induced vibration, only fluid elastic instability is the primary concern in all flow mediums. Others mechanisms have less importance in certain flow media. For example turbulent buffering is not primary concern in gas flow since the low of the gas does not result in a very high hydrodynamic force.Hence, design restrictions are imposed to limit acoustic resonance and FEI.

1.2.3.1.1. Approaches to fiv analysis

Two approaches are normally followed to predict FIV effect of shell and tube heat exchanger:

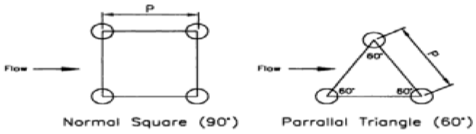
- **Finite element method modeling technique**This model simulates the time- dependent motion of a multi-span heat exchanger tube in the presence of tube and baffle plate clearance, and the resulting wear is determined. This approach is normally followed for heat exchanger especially STHEx.

- **Limiting amplitude of vibration**This approach linearizes the structural by assuming as classical beams with support plates offering simple support at the intermediate points and clamped at the tube sheet ends.

1.2.3.1.2. Empirical Nature of FIV Analysis

It is important to note that flow-induced vibration of shell and tube heat exchanger is physical phenomenon that cannot be explained by simple empirical correlations. It is most difficult to analyze due to reasons like:

- Tube bank dynamic is a multi-body problem. The tubes are supported by multiple baffles with holes slightly larger than the tube diameter.
- The interaction between the tube and the support plates is characterized by impacting as well as sliding motion. This makes the system nonlinear in nature.
- The tube and surrounding fluid form a fluid form a fluid-structure coupling that results in motion-dependent fluid forces that rise to added mass, couple models, and damping.
- Generally the flow field is quite complex, non- uniform, and quite unsteady, and the incidence of flow on the tubes is at variable angles to the longitudinal axis.
- Structural complexity arises due to time-variant flow-dependent boundary conditions. Mechanical tolerances, initial straightness, fit-up, and tube buckling due to manufacturing process add complexities in defining boundary conditions.
- Effect of tube bundle parameters such as transverse and longitudinal pitches, tube layout pattern, pass partition lanes, shell to tube bundle clearance, number of tube rows, etc. on the Occurrence of FIV cannot be correctly evaluated. For this reasons, most of the method in the analysis of the tube bank dynamics are semi-empirical in nature. To render the problem amenable for most analytical studies and experimental investigation. The flow conditions are idealized as:
- The flow is uniform and steady
- The incident of the flow is either axial or normal to the tubes
- The tube motion is linearized and it is assumed that the frequencies are well defined.
- The baffles support provides a simply supported condition.



1.2.3.1.3. Fiv (Flow Induced Vibration) mechanisms

Some of the mechanisms in shell and tube heat exchanger are as follows:

1.2.3.1.3.1. Vortex shedding

Consider a bluff body such as cylinder in cross flow with the tube axis perpendicular to the flow. As the fluid flows past the tube the wake behind the tube is no longer regular as a result of vortex shedding the following conditions happened.

- The vortex shedding frequency shifts to the structural frequency, developing the condition called "lock-in" or "synchronization." The lock in phenomena leads to high-amplitude vibration with substantial energy input to the tube.
- The lift force becomes a function of structural amplitude.
- The drag force on the structure increases. However, the magnitude of the oscillating drag force is smaller than the oscillating lift force.
- The strength of the shed vortices increases.

The criteria for avoiding lock-in due to vortex shedding in the first two to three rows in a tube bank are :

a. If the reduced velocity for the fundamental vibration mode (n=1) is satisfied by the relation

$\frac{U}{f_n D} < 1$ For n=1 **Equation31**

Both lift and drag direction lock-in are avoided.

b. For a given vibration mode if the reduced damping C_n is large enough,

$C_n > 64$

Then lock-in will be suppressed in that vibration mode.

c. If for a given vibration mode

$\frac{U}{f_n D} < 3.3$ $C_n > 1.2$then lift direction lock-in is avoided and drag direction lock-in is suppressed.

d. The reduced damping C_n is calculated by the equation

$M_n = \int_{L_i}^{L_o} m(x)\varphi^2{}_n(u)du$ **Equation32**

1.2.3.1.3.2. TURBULENCE-INDUCED EXITATION MECHANISM

1.2.3.1.3.2.1. Turbulence

In general, higher flow rates promote and maintain high turbulence in the fluid, which is desirable for enhanced heat transfer, but the high turbulence is a source of structural excitation. STHEx tubes responds in a random manner to turbulence in the flow field. In addition to structural excitation, turbulence in the flow can affect the existence and strength of other excitation mechanism, namely, vortex shedding.

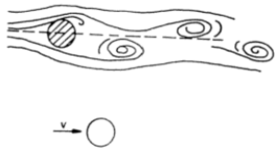


Figure7. shows vortex shedding past single tube**[6]**

1.2.3.1.3.3. FLUID ELASTIC INSTABILITY

Fluid flow across an array of elastic tubes can induce a dynamic instability, resulting in very large amplitude tube vibrations once the critical cross-flow velocity is exceeded. This is a relatively common occurrence in shell and tube heat exchangers. Once the critical cross flow velocity is exceeded, vibration amplitude increases very rapidly with cross flow velocity V, usually as $V^n$where n=4 or more compared with an exponent in the range 1.5 <n< 2.5 below the instability threshold.

A sudden change in vibration patterns within the tube array indicates instability and is attained when the energy input to the tube mass-damping system exceeds the energy dissipated by the system.

1.2.3.1.3.3.1. ACCEPTANCE CRITERIA TO AVOID FEI

To avoid FEI, acceptance criteria are:

Normal criterion$U_{cr} < U$ **Equation33**

Conservative criterion$\frac{U}{U_{cr}} <= 0.5$ **Equation34**

1.3. Simulations (Computational Fluid Dynamics CFD)of STHEX

Simulation refers to process of comparing information on the behavior &characteristics of the real system by analyzing, studying or observing the model of the system such a model may be subjected to a variety of operating and environmental conditions and the performance of the of STHEx determined in terms of variables such as pressure, temperature flow rate, energy input/output, mass flow rate and mass transfer rate that are of particular interest in STHEx analysis.

There are several reasons for simulating a system behavior through its mathematical &numerical model in this respect simulation can be used to

- Evaluate different designs for selection of an acceptable design
- Study system behavior under design conditions
- Determine the effects of different design behavior variables for optimization
- Improving or modifying existing systems
- Investigate the sensitivity of the design to different variables with regards to the extent of their influenced or significance

In this case simulated 2D of the shell and tube heat exchanger and we have observed the different parameters that affect the operation of exchanger. The following are some of them; first to simulate we have start with creating geometry.

Let us start by drawing the two dimensional geometry of the problem (STHEx) which is done by simple sketch by hand and then drawn and defined on the gambit software to be meshed

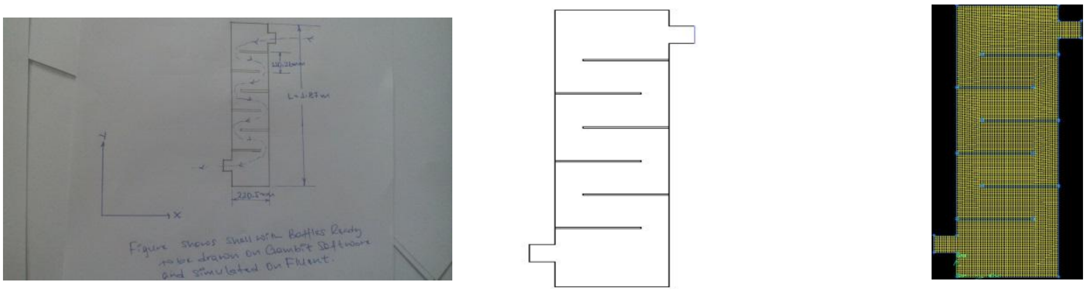


Figure8. a).STHEx drawn by hand b).STHEx drawn on Gambit c). STHEX Meshed on Gambit

As u can see the mesh is fine as a result of giving large interval count along each sides to have good results of simulation. Then after defining the boundary condition and entity we just exported in to the fluent. There the beauty of the thermal is shown. Contours are colorful graphics which indicates the properties and the results of the system.

1.3.1. VELOCITY CONTOURS

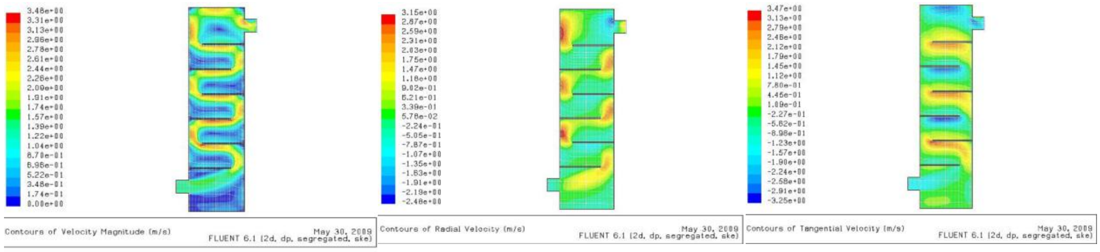


Figure9.a).Velocity magnitudeb).Radial Velocity c). Tangential Velocity

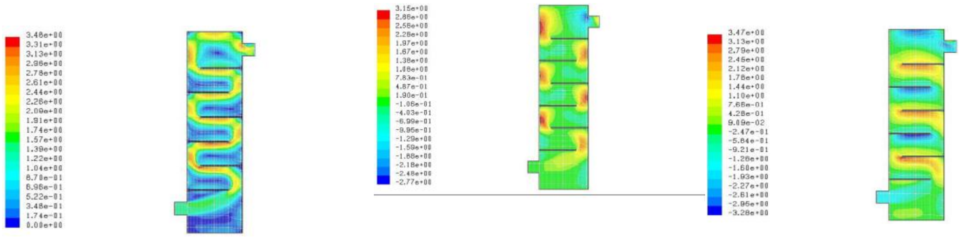


Figure10.a).Relative Velocity b).Relative Y Velocityc).Relative Tangential Velocity

1.3.2. PRESSURE CONTOURS

Which shows the pressure difference down the length of the heat exchanger from the color we observed that the pressure drop increases

- Because of the presence single segemental baffles and
- Gradient

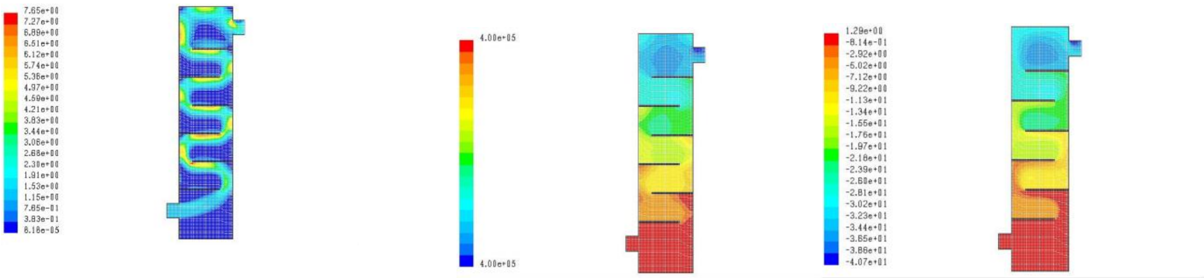


Figure11.a).Contours of dynamic pressure b).Absolute pressure c).Total pressure

1.3.3. TEMPERATURE CONTOUR

The temperature contour is as you can observe from the diagram it is uniform becuose

- Only single fluid is analyzed since there is no heat transfer

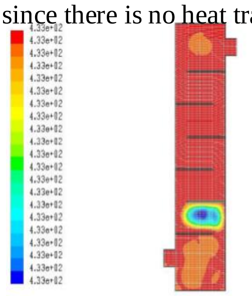


Figure12. Temperature contour

V. CONCLUSION

As all knows shell and tube heat exchanger are the most important devices in that installed to assist some plants and several industries like Harar Brewery Share Company but here the STHEx at the 9th zone was malfunctioned that is the temperature of the cold fluid would fluctuate between 35^0C-40^0C.Then some optimization and redesign of the machine is done for both mechanical and thermal designs and the simulation fo the heat transfer between the two fluid is analyzed using the concept of CFD (Computational Fluid Dynamics) using Gambit and Fluent software's. The final result of the STHEx in HBSC which is the redesigned STHEX can achieve or efficiently work to achieve the required outlet temperature 34^0C the temp at which the beer is ready for customer for use.

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Bibliography

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"There's no place like home except Grandma's. This paper is dedicated to My Grandmother who spent 15 years of her life with me. I love you my grandmother Yeshiye Wedneh."