Design Development and Analysis of Cadbury/Chocolate Pulp Melting Tank : A Review

Mr. Atul V. Hase[1], Prof. S. B. Bawaskar[2]

[1]PG Scholar, Department of Mechanical Engineering, Sahyadri Valley College of Engineering and Technology, Rajuri, India.
[2]PG Guide, Department of Mechanical Engineering, Sahyadri Valley College of Engineering and Technology, Rajuri, India

ABSTRACT

Melting is the most important process in industry in order to prepare a final product. While preparing that product it is necessary that to melt a pulp in proper amount as well as the required condition. During melting of wax or pulp because of high temperature more amount of thermal stresses are developed and when that thermal stresses are exceeds certain limits then the welding section get weak and because of that there will be leakages problem at joint so that loss of thermal energy through joints. But if we design the tank for wax melting by applying the seamless welding process we are easily avoid those leakages at the joint. So there will be a need to design a tank by seamless welding process to avoid the thermal loss and reduce the thermal stresses. So in this paper we try to complete the design according to actual design dimensions and try to prepare the designed model with the help of catia software. After preparing that tank with that software I try to complete whole analysis with the help of ansys software . This analysis will be carried in order to get equivalent stresses, maximum principle stresses and the total deformation of the assembly. Also from the design and analysis it is clear that it is clear that the selected wall thickness of 5mm will be on safe side so there will be a optimization of thickness.

Keywords*: Pulp Melting, Analysis with Ansys, Thermal stresses. Principle stresses*.

1. INTRODUCTION

In all over the world, food is an essential for human in day to day life. Cadbury,chocolate and many other foods. While preparing such food the basic raw material is wax and it is very important to prepare a final product. For converting that raw material in to final product the device required is that melting tank. Melting tank is the device which is used to melt the wax under high temperature. Now in industry to melt the wax a pressure vessel are used. but the drawback of pressure vessel is the high thermal stresses are developed inside the vessel and the leakage problem at the joint, and because of that there will be a loss of thermal. So to avoid that we try to design and developed a wax melting tank for melting the wax. First we are try to check the design and then developed a tank according to the requirements of end users. Now my aim is to design a tank with some software like catia, pro-e, hyper mesh etc. because of my simplicity I select catia to design wax melting tank. In this design I try to complete design of tank. This tank include the different ports like inlet, outlet, inspection, manhole and drain along with left and right hand flange. As the seamless welding is provided so there will be no any leakages problem at the joints

Firstly, the pulp passed through the inlet to inside the tank after heating it will be collect through outlet section. Drain will be provided in order to remove unwanted material along with them manhole is provided for inspection purpose.

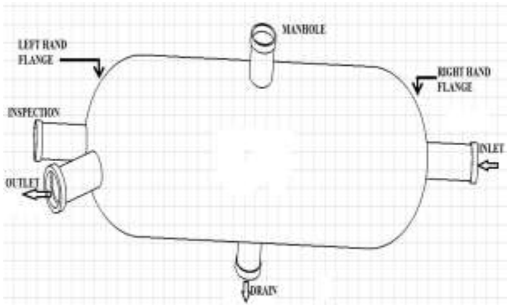

Figure.1. Pulp melting tank

1.1 Problem Statement:

Melting a wax is a serious task in any food industry. Now in industry they referred a cylindrical Pressure vessel for wax melting but the problem is that during wax melting high temperature are developed inside and due to that high thermal stresses are developed. Because of that there should be leakages of wax through welding joint and there will be a loss of thermal. It create serious problems at the time of working in site, to remove this we must assure about vessel design.

1.2 Methodology:

In order to design a pulp melting tank we try to replace it with the help of pressure vessel. Methodology consists of application of scientific principles, technical information and imagination for development of new or improvised wax melting tank to perform a specific function with maximum economy and efficiency. This project work will relate to design of tank, Optimization of stresses, and selection of proper method at joint to avoids leakage at the joints including:

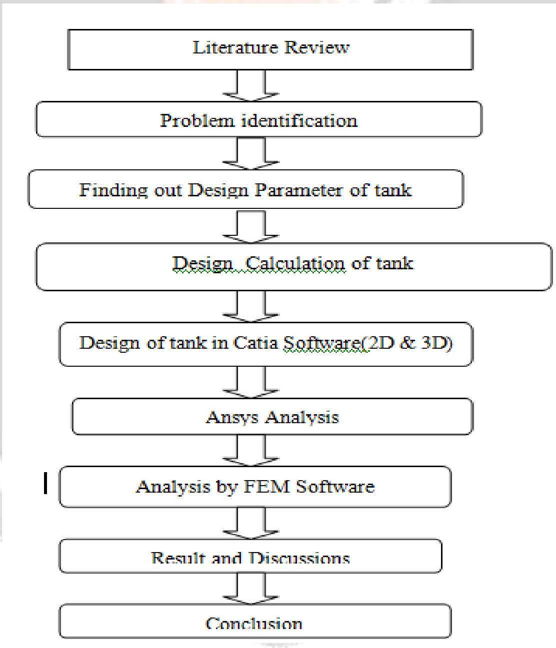

Figure. 2 Flowchart of methodology

1.3 Objectives:

The main objectives are

1. To design the tank with ASME code same as the pressure vessel.
2. To optimise the thickness of tank so that material cost saving.
3. To replace the welding method by seamless welding to avoid leakages at the joints.
4. To do the analysis of tank with ansys software.

2. LITERATURE SURVEY

Various researchers have worked for the development of wax melting with pressure vessel

Amol Mail, Hemant Bhosale [2017]: "A review on study of pressure vessels, design and analysis" In this paper the study carried out about the pressure vessels are containers used to handle fluids which are highly toxic, compressible and which work at high pressure. Pressure vessels have application in variety of industries such as oil and gas, petroleum, chemical industry, power generation industry, food industry, etc. failure of pressure vessels has adverse effect on the surrounding and the industry which can cause loss of life, property and damages. The design of pressure vessels depends on factors such as pressure, temperature, material selection, corrosion, loading and many other parameters depending on the applications. This paper elaborate the work done in design of pressure vessels to reduce failure in the pressure vessels and study of parameters such as material selection, operating pressure and temperature, design, analysis etc. which causes fatigue failure and stress concentration in vessels. The use of fem methods and analysis technique that provides results on failure of pressure vessels are to be studied [1]

Anandhu P.D., Avis A.[2017] "Design and analysis of horizontal pressure vessels and thickness optimization" this work deals with design and analysis of horizontal pressure vessels and also thickness optimization of vessels. In this design of pressure vessels safety is primary consideration due to potential impact of possible accidents. Efforts are made in this project to design a pressure vessels using ASME codes and standards of legalize design along with all the analysis carried out to do the optimization. [2]

Ajay V Patil, M.A. Kamoji.[2017] "Thickness optimization of thick walled circular cylinder by heat treatment" this state that the optimization of thickness based on analytically and numerical and the analytical natural frequency are compared with numerical and found percentage errors which is less than 3% and found that there is no any resonance condition. [3]

Summit V Duplet. [2014], "Review on Stresses in Cylindrical Pressure Vessel and its Design as per ASME Code". They found that different stresses which are exerted on the pressure vessel. The total design will be done on the basis of ASME code this analysis will give the exact values of the different stresses like maximum principle stresses, Equivalent stresses based on American society of mechanical engineering. [4]

Vshal V Sadpatil , Arun S. Thakare [2014] "Design and weight optimization of pressure vessel due to thickness using finite element analysis" In this study they state that the solid model of the component is subdivided into smaller element. Constraints and loads are applied container designed to hold gases or liquids at a pressure different from the ambient pressure. The end cap fitted to cylindrical body called as heads. The aim of this paper is to carry out the detailed design and analysis of pressure vessels used in boiler for optimum thickness, temperature distribution and dynamic behavior using FEA software. Model like material, thickness etc. the model is then analyzed in FE solver. The results are ploated in post processor and Ansys are used as a solver. [5]

N.A. Kakulte, G.V. Shah[2014] "Analysis and optimization of pressure equipment swing check valve by using FEA methods" in this study they complete analysis and optimization of check valve. In this optimization of check valve the shape, weight and size parameters considered. Less thickness and less materials in the valve and cas leads to failure of the valve and maximum thickness leads to cost implication. As per ASME standards conducted structural analysis by using FEA methods. Results are validated by using numerically calculated stresses. Also validates results by experimental setup which are matches with FEA results. [6]

Antonio Ramos [2014] "The melting process of storage materials with relatively high phase change temperatures in partially filled spherical Vessels". This paper they studied that the different melting processes of storage material with relatively high phase change material when temperatures in partially filled spherical Vessels. [7]

H. Darijani [2014] "Wall thickness optimization of thick-walled spherical vessels using thermo-elasto-plastic concept" they studied that thick-walled spherical vessels under steady-state radial temperature gradients using elasto-plastic analysis is reported. By considering a maximum plastic radius and using the thermal autofretage method for the strengthening mechanism, the optimum wall thickness of vessel for a given temperature gradient across the vessel is obtained. Finally in the case of thermal loading of the vessel, the effect of convective heat transfer on the optimum thickness is considered, and a general formula for the optimum thickness. [8]

S Ravinderet. [2013] "Design and analysis of pressure vessel assembly for testing of missile canister sections under differential pressure". This paper gives the information about Design and analysis of pressure vessel assembly during the working on site for testing of missile canister sections under differential pressure and this testing will be carried out for different pressure conditions. [9]

Shivappa H.A.[2013] "Design, optimization and numerical analysis of pressure cylinder assembly" this paper state that the failure problem of component of pressure vessels, so they carry the design and from analysis they optimize the stresses and try to keep the stresses within limits and to provide the safety of component. [10]

Apurva R. Pendbhaje [2012] "Design and analysis of pressure vessel". This paper states that to carry the design of pressure vessel to melt the wax and total analysis will be carried out with the help of analysis and also in this paper they try to explain the detailed design which is to be carried out with the help of ASME codes and different sections of manufacturing. After that how to carried out the detailed analysis of pressure vessel. [11]

Heru susiawan widiharso [2012] "Thickness optimization of pressure vessel for minimum weight using finite element method" this paper state that design parameters optimization based on FEM simulation is presented here. The aim of this paper is to perform the detailed design and analysis of pressure vessel for optimum thickness using fem based on commercial software ANSYS. Several geometrical methods of pressure vessels are proposed and compared by optimization methods. The diameter and length of pressure vessels are varied. It is shown that a direct optimization gives a maximum weight of pressure vessels with optimum thickness. [12]

M.Rahimi,A.A.Ranjbar[2012] "A combine experimental and computational study on the melting behavior of a medium temperature phase changes to rage material inside shell and tube heat exchanger". This gives the information about experimental and computational study on the melting behavior of a medium temperature phase changes to rage material inside shell and tube heat exchanger.[13]

S.K.Raparla[2012] "Design and analysis of multilayer high pressure vessels" they studied that design and analysis of multilayer high pressure vessels features of multilayered high pressure vessels, their advantages over mono block vessels are discussed. Various parameters of solid pressure vessels are designed and checked according to the principles specified in American society of mechanical engineers(ASME) Sec-VIII Division-1. Various parameters of multilayered pressure vessels are designed and checked according to the principles specified in American society of mechanical engineers(ASME) Sec-VIII Division-1. Along with them they studied that the stress developed in solid wall pressure vessels and multilayered pressure vessels is analyzed by using Ansys, a versatile finite element packages.[14]

M.Balusko, F.Belusko [2012] "Experimental investigation of dynamic melting in a tube-in-tank PCM system" It is found that a considerable research has been conducted on heat transfer enhancement of phase change materials (PCM) in thermal energy storage systems, heat transfer enhancement techniques such as the use of conductors like graphite, carbon fibers have been proven to be effective. Shell and heat exchangers which utilized many tubes in the PCM system have also show a good heat transfer performances. It was found from experiments that dynamic melting was more effective than those without dynamic melting. The time taken to complete the phase change processes was also found to be shorter when dynamic melting was utilized. It can be concluded from experiments that dynamic melting is an effective technique for enhancing heat transfer.[15]

M. Maleki [2010] "Residual stress analysis of autofretage thick-walled spherical pressure vessels" in this study residual stress distribution in autofretage homogeneous spherical pressure vessels subjected to different autofretage pressure are evaluated. Results are obtained by developing an extension of variable material properties (VMP) method. The modification makes VMP method applicable for analysis for spherical vessels based on actual material behavior both in loading and unloading considering variable bauschinger effect. The residual stresses determined by employing finite element method are compared with VMP results and it is demonstrated that using of simplified material methods can causes significant errors in estimation of hoop residual stresses. [16]

2.1 Comments on Research paper

From the above review paper it is found that many of the researcher works on only pressure vessels and do the modification in pressure vessel parameters itself and no one can concentrate the problem of the pressure vessels.

2.2 Research Gap

From the above literature review it is clear that many of the researcher works on design of cylindrical pressure vessel, heat exchanger, study of melting behavior, someone do the stress analysis of that vessels, but anyone cannot do the work on design of tank for wax melting application can't concentrate on problems on leakages. Along with them it was found that no design will carried on CATIA and FEA analysis by optimization of thickness.

3. EXPERIMENTAL VERIFICATION

To carry out the experimental validation we first take the tank which is to be design with catia software. Basically in this particular validation we perform the seamless welding processes to avoid the leakages at the joints. And finally Hydro test will be carried out for checking of strength of the tank.

3.1 Tank Design

Formulae:
Cylindrical Shell Thickness
Vessel Height = Shell OD
Shell OD = 650 mm
So vessel height also 650 mm
Height for static Head calculation
Height for static Head = vessel Height. + Top Nozzle projection + Bottom Nozzle Projection
=650+150+150
=950 mm

Maximum Possible Static Head,H (mm) = 1500 mm
(rounded , considering all (Max. Distance Between Topmost and possible Tolerance) Bottom Most Pressure Parts.)

Figure.3 Actual Tank Model

Design Internal Pressure including Static Head for Calculations:
Density of Contents, 1000(Kg/m^3)
Static Head pressure (P)
P =ρ * g * H
=$1000*9.81*1500*10^{-6}$
= 0.01471 MPa
= 0.015 MPa
Design Pressure = P + Pressure due to Static Head
= 0.491 + 0.015
= 0.505 MPa
Hydrostatic Test Pressure = (MAWP x Ratio x 1.5)
= 0.491 x 1.000 x 1.50
= 0.736 MPa
= 7.508 Kg/cm^2
As per L & T Datasheet Hydro test to be carried out at 5.25 Kg/cm2 in shop in Vertical position only.

Table 1 : Specifications Of Tank

Melting Capacity	200 Kg.
Size of Tank	Φ 1470 x 975mm.
Tank Material	S.S.304
Heating Element	Uniformly heated by electric flat heaters.
Control	Temperature controlled by Digital A' meter Phase indicates by lamps, Auto controls by Thermo states
Electrical Parts	Standard CE Marked.
Rating	6 K.W.

1. Hydro test body metal Temperature =17°C above MDMT & need not Exceed 48°C [Ref.UG-99 (h)].
2. MAWP is assumed same as Design Pressure as per UG-99, (Note: 34, Page:74 of code).
3. Service Classifications is normal (non-Lethal).
4. Overpressure Protection as per UG-125 is in Client's Scope

$$t = \frac{P*R}{S*E-0.6*P}$$

$$t = \frac{0.49*44.5}{(815.2*1)-(0.6*0.49)}$$

t = 0.27 cm
t = 2.7 mm

$$P = \frac{S*E*t}{R+0.6*T}$$

$$P = \frac{0.49*1*0.27}{44.5*0.6*0.27}$$

P = 4.92 Kg/ cm^2

Hence Internal Design Pressure (Pi) = 4.92 Kg/ cm^2 = 0.483 MPa

Maximum Allowable Stress(S) $S = \frac{P*R*0.6*t}{E*t}$

$$s = \frac{0.495*44.5+(0.6*0.27)}{1*0.27}$$

S = 814.75 Kg/ cm^2

S = 79.95 MPa

Inside Radius (Corroded) (R) = R+ CA = 495.000 + 0.000 = 495.00 mm

Provided Thickness (Nominal) = 5.00 mm

$$t = \frac{P*R}{S*E-0.6*P}$$

$$t = \frac{4.99*44.5}{(815.2*1)-(0.6*4.99)}$$

t = 0.27 cm

t = 2.7 mm

$$p\,\frac{S*E*t}{R+0.6*t}$$

$$P = \frac{0.49*1*0.27}{44.5+0.6+0.27}$$

P= 4.92 Kg/ cm^2

Joint Efficiency (E) = 1.00

Joint Efficiency Factor = 0.385SE =85 * 80 * 1 = 30.80 MPa

Minimum Required Thickness =

$$t = \frac{4.99*44.5}{(815.2*1)-(0.6*4.99)}$$

t = 0.37 cm

t = 3.7 mm

Longitudinal Stress (Circumferential Joints) when the effect of supplementary loads as per UG-22 is absent

Joint Efficiency (E) = 1.00

Joint Efficiency Factor =1.25SE

= 1.25 * 80 * 1 = 100 MPa

Minimum Required Thickness =

$$t = \frac{P*R}{2*S*E+0.4*P}$$

$$t = \frac{4.99*44.5}{(2*815.2*1)+(0.4*4.99)}$$

t = 0.137 cm

t = 1.37 mm

Minimum required thickness shall be > 2.5 mm (3/32 in.) excluding Corrosion Allowance is 2.50 mm.

t = Greater of (3.70 , 1.37 , 2.50)

Governing thickness + Corrosion Allowance = 3.70 + 0.00 = 3.70 mm

CHECK: Required Thickness= 3.139 mm< 5.000 mm (Provided) Thickness is Optimum

External Pressure Calculation

Corroded thickness (t) = 5.00 mm

Total Length between stiffing Ring (L) = 1750.00 mm

Outside Diameter of Cylindrical shell (Do) = 1000 mm

L/Do Ratio (L/Do) = 1.750

Do /t Ratio (Do /t) = 200

Factor A from Fig G (A) = 0.00125

Factor B from chart CS-2 (B) = 2250

Pa = 4B/3(Do/t)(x)

$$Pa = \frac{4*2250}{3*(200)}$$

Pa = 15 MPa

Maximum Allowable External Pressure [MAEP] (Pa) = 15 MPa
Required thickness under external pressure (t)
t = (3PDo/4B)+CA(xi)
t = (3 * 4.99* 1000 / 4 * 2250) + 1.5
t = 3.16 mm
t_f= 3.16 + 1.5 = 4.66 mm
Hence shell thickness is safe at 5.00 MM
External Pressure Maximum Allowable Working Pressure at given thickness, corroded [MAWP]

$$P = \frac{2 * S * E * t}{L * M + 0.2t}$$

But M = 1.54

$$P = \frac{2 * 815 * 1 * 0.05}{99 * 1.54 + 0.2 * 0.05}$$

P = 0.53 Kg/ cm^2
Maximum Allowable Pressure at Cold & New Condition [MAP]:

$$P = \frac{2 * S * E * t}{L * M + 0.2t}$$

Crown Radius (L) = 990.00 mm
Knuckle Radius (r) = 99.00 mm
But M = 1.54

$$P = \frac{2 * 815 * 1 * 0.05}{99 * 1.54 + 0.2 * 0.05}$$

P = 0.53 Kg/ cm^2
SF required thickness
Minimum Required Thickness

$$t = \frac{P \times R}{(s \times E - 0.6 \times P)} + CA$$

$$t = \frac{0.53 \times 44.5}{(815 \times 1 - 0.6 \times 4.99)} + 0.00$$

t = 0.29 cm t = 2.9 mm

External Pressure Calculation
P = 1.67 x External Design Pressure
= 1.67 * 6.114
= 10.21 Kg/ cm^2
= 1.002 MPa
Required thickness, t = P * L*M / (2 * S * E - 0.2 * P)
t = 10.21 * 99 * 1.54 / (2 * 815 * 1 - 0.2 * 10.21)
t = 0.95 cm
t = 9.5 mm
Requirement for Cold Forming As Per Ucs- 79 From the above table I, we have proved that the strain values observed in experimental result with FEA result with marginal acceptable error.

From all the calculation it is clear that whatever thickness we provided that should be on the safe side. So there should be

4. CONCLUSION

From this Design calculation we can conclude that there will be a Required Thickness= 3.139 mm< 5.000 mm (Provided) Thickness is Optimum External Pressure Calculation i.e. it is in safe zone .Also From the external pressure calculation we made the conclusion that there will be Requirement for Cold Forming As Per Ucs- 79 as the calculated thickness will be 9.5mm.From the FEA analysis should be clear that all the design should be on the safe side.

5. REFERENCES

1.Amol Mail, Hemant Bhosale[2017], “A review on study of pressure vessels, design and analysis”
2.Anandhu P.D., Avis A.[2017], “Design and analysis of horizontal pressure vessels and thickness optimization”.

3.Ajay V Patil, M.A. Kamoji.[2017] “Thickness optimization of thick walled circular cylinder by heat treatment”.
4. Summit V Duplet. [2014], “Review on Stresses in Cylindrical Pressure Vessel and its Design as per ASME Code”. .
5. Vshal V Sadpatil , Arun S. Thakare [2014] “Design and weight optimization of pressure vessel due to thickness using finite element analysis”
6. N.A. Kakulte, G.V. Shah[2014] “Analysis and optimization of pressure equipment swing check valve by using FEA methods”
7.Antonio Ramos [2014] “The melting process of storage materials with relatively high phase change temperatures in partially filled spherical Vessels”.
8.H. Darijani [2014] “Wall thickness optimization of thick-walled spherical vessels using thermo-elasto-plastic concept”
9. S Ravinderet. [2013] “Design and analysis of pressure vessel assembly for testing of missile canister sections under differential pressure”.
10. Shivappa H.A.[2013] “Design, optimization and numerical analysis of pressure cylinder assembly”
11. Apurva R. Pendbhaje [2012] “Design and analysis of pressure vessel”.
12. Heru susiawan widiharso [2012] “Thickness optimization of pressure vessel for minimum weight using finite element method”
13. M.Rahimi,A.A.Ranjbar[2012] “A combine experimental and computational study on the melting behavior of a medium temperature phase changes to rage material inside shell and tube heat exchanger”.
14. S K Raparla [2012]“Design and analysis of multilayer high pressure vessels”.
15. M.Balusko, F.Belusko [2012] “Experimental investigation of dynamic melting in a tube-in-tank PCM system”.
16. M. Maleki [2010] “Residual stress analysis of autofretage thick-walled spherical pressure vessels”.