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Design and Optimization of Vapour Liquid Separator used in Distillery Plants

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Abstract— **Separation of liquid and vapour is the key process in distillery system. The main task set in this project work is to design and analysis of Vapour Liquid Separator i.e. VLS required in successive operation of distillation. There are various sub sources which generate the waste water through successive production cycle of distillery. Conventionally membrane technique is the simple way for purification of distillation. From the study of membrane system, its types, bioreactors of membrane and working process of distillation, it is clear that, the required expenditure, power and alimony is more. The optimization in design of Vapour Liquid Separator, in dimensional variables, it made to full proof against the working pressures and generated stresses.**

Design is carried according to ASME code and also ANSYS software results provide its validation.

Keywords— **ASME, Distillation, Optimization, Stresses, VLS**

I. INTRODUCTION

According to the requirement in various applications, the Pressure vessels play the role of the containers or pipelines. Hence it can be used to store, to receive or to carry the pressurized fluid or mixture of fluids. In current project application the pressure vessel is used to receive and sustain the liquids and gases successfully at the pressure and temperature distinct than atmospheric values. During the operation the fluid maintains its state as it is or it may going from the path joining two distinct states as in case of power boilers. As per the requirement number of equipment are the modified from the basic pressure vessels to perform required functions. Due to the failure interruption of Pressure vessel, the losses in production & money occurs with chance of affect on human life.

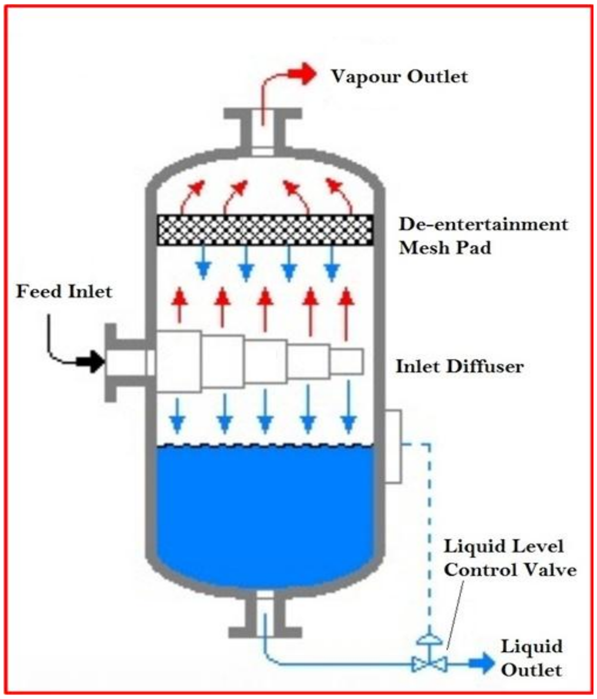

Figure 1.1: Schematic Layout of VLS

II. PROBLEM DEFINITION OF PROPOSED WORK

The main task set in this work is to design the VLS with the optimum thickness both at shell & dished end to sustain the working pressure considering effectiveness of cost also. The ASME section VIII Division I code used as the basic path for the calculation of design variables.

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Scientific theorems, observations concluding summary of previous research work and new concepts are simultaneously used in methodology action to create an optimize VLS.

A. Steps Followed in Methodology

1. Identification of Problem: The origin of problem is occurred in the conventional working method in distillery industry. To overcome it the task begins.
2. The opinions of expertise are considered to work on problem analysis. After that the path along which work proceeds is set.
3. Failure areas of pressure vessel are identified and these are shell, shell head and the base of shell due to improper thickness of respective parts.
4. So, identification of proper thickness is carried by using ASME section VIII Division I codes.
5. The corresponding design occurred from ASME codes are evaluated in ANSYS.
6. If there is any difference between the ASME and ANSYS solutions then again the cycle is repeated from start to till step.
7. After the proper validation the outputs are finalized for further fabrication work of VLS.

III. Mathematical Simulation Work

B. Design Data required/ utilized in the Work

1. Volumetric Capacity of VLS = 20000 liters = 20 m^3 (As specific gravity of content is 1)
2. Average Working Pressure Gauge = 0.378 MPa
3. Internal Design Pressure Gauge = 0.4908 MPa
4. External Design Pressure Gauge = 0.5991 MPa
5. Working Temperature (Max. to Min.) = 403.15^0 K
6. Design Temperature = $473.\ 15^0$ K
7. Hydrostatic Test Pressure at Top = 0.5148 MPa
8. Internal Allowance for Corrosion = 0 mm
9. External Allowance for Corrosion = 0 mm
10. Marking range of Radiography = RT-1
11. Radiography = 100%
12. Temperature range of Hydrostatic Test = 283.15^0 K to 321.15^0 K
13. Joint Efficiency = 1.00

C. Dimensional Data used in the Work

1. Inner Diameter of Shell = 0.99 m
2. Height of Shell = 2.5 m
3. Required Working Volume = 10000 liters
4. Support of VLS = Leg Type Support

D. Referred Documentary

1. Vessel = ASME Section VIII Division I
2. Material = ASME Section II A & D(M)

E. Details of loading application

Design Pressure both internal and external considered i.e. applicable as per the sub clause UG – 22 (a). Weight of the operating fluids and net weight of vessel under operating or test conditions with additional pressure due to static head of liquid is applicable according to clause UG – 22 (b).

Where the static reactions from weight of attached accessories (sub clause UG – 22 c), internal attachments (sub clause UG – 22 d) are not applicable. Thermal and pressure reactions due to equipments and accessories (sub clause UG – 22 e) is also not applicable. Also wind reaction, seismic reaction, snow reaction, impact reaction due to fluid shock, temperature gradient and differential thermal expansion, abnormal pressure are also not applicable.

F. Internal Pressure including Static Head

Static Head = Height of Vessel + Total Nozzle Projection (Bottom & Top)

Static Head = 1+ 0.15 + 0.15 = 1.30 m

By considering all tolerances and the maximum distance between the part from top and bottom end, the static head value round off to the 1.5 m.

As, Density of Contents (ρ) is 1000 Kg/m^3

So static Head Pressure (P) can be calculated according to formula, Static Head pressure (P) = ρ X g X H

P = 1000 X 9.81 X 1.5
P = 14715 Pa
P = 0.014715 MPa

Design Pressure = P + Pressure due to Static Head
Design Pressure = 0.4908 + 0.014715
Design Pressure = 0.505515 MPa

Hydrostatic Test Pressure $(P)_{HT}$
$(P)_{HT}$ = (MAWP x Ratio x 1.5)
$(P)_{HT}$ = 0.4908 x 1.000 x 1.50
$(P)_{HT}$ = 0.7362 MPa

G. Selection of Materials

To fabricate the Shell and Dish of the Vapour Liquid Separator the material SA 240 TP 304 is selected according to the ASME Section II Division I.

H. Cylindrical Shell Thickness

As per ASME codes the design of shell can be subdivided in two main sub parts according to the type of weld joints.

I. For Longitudinal joints

Internal Design Pressure (Pi) = Circumferential Stress
Joint Efficiency Factor = 0.385 X S X E
Joint Efficiency Factor = 0.385 X 80 X 1 = 30.8 MPa
As, (P = 0.4908 MPa) < (Joint Efficiency Factor = 30.8 MPa) so, The Longitudinal Joints are safe for Shell.

Now, as per the code, the shell thickness (t) can be find by
t = (P X R) / [(S X E) – (0.6 X P)]
Where,
t = Min. required thickness for safe working
P = Design pressure in Internal working area
S = Max. Stress Value allowed
R = Internal Radius of Shell or core
Since, in given data value of internal diameter is provided as 0.990 m.
Therefore, (R) = (0.990 / 2) = 0.445 m
Allowance for Corrosion (C_{all}) = 0.00 mm
Therefore, (R) = 0.445 + 0 = 0.445 m
t = (0.4908 X 0.445) / [(80 X 1) – (0.6 X 0.4908)]
t = 0.00274016 m
t = 2.74016 mm

Also, (P) = (S X E X t) / (R + 0.6 X t)
(P) = (80 X 1 X 0.00274016) / (0.445 + 0.6 X 0.002714016)
(P) = 0.4908 MPa

J. For Circumferential joints

Internal Design Pressure (Pi) = Longitudinal Stress
Joint Efficiency Factor = 1.25 X S X E
Joint Efficiency Factor = 1.25 X 80 X 1 = 100 MPa
As, (P = 0.4908 MPa) < (Joint Efficiency Factor = 100 MPa) so, The Longitudinal Joints are safe for Shell.

Now, as per the code, the shell thickness (t) can be find by
t = (P X R) / [(2 X S X E) + (0.4 X P)]
t = (0.4908 X 0.445) / [(2 X 80 X 1) + (0.4 X 0.4908)]
t = 0.0013633 m
t = 1.3633 mm

According to criteria of Minimum required thickness, it should be greater than (3/32 inches).
So, $(t)_{min}$ > 0.002381 m

Now the thickness of shell must be greater from 0.00274016 m, 0.0013633 m, and 0.002381 m so, it can be selected as 0.00274016 m.

Now, Shell thickness + Allowance for Corrosion = 0.00274016 + 0.00 = 0.00274016 m
t = 0.00274016 m = 2.74016 mm

As the provided thickness for VLS is 5 mm and it is greater than the required thickness of shell against internal working pressure so, it is safe against it.

K. External Pressure Calculations

Provide thickness (t) = 0.005m
Data provides the External Pressure (Pe) = 0.5991 MPa
Outer diameter of VLS shell (d_o) = 1 m
Total Length of VLS (L) = 1.75 m
L/Do Ratio (L/Do) = 1.75
(d_o /t) = (1 / 0.005) = 200
Under external pressure required thickness (t),
t = (3 X Pe X d_o / 4 X B) + C_{all}
t = (3 X 0.5991 X 1 / 4 X 2.25) + 0.0015
t = 0.0016997 m
t = 1.6997 mm

Final thickness (t_f) = 0.0016997 + 0.0015 = 0.0032 mm
(t_f) = 3.2 mm
As the provided thickness for VLS is 5 mm and it is less than the required thickness of shell against external working pressure so, it is safe against it.

L. Elliptical Head Thickness

Internal Pressure for Design (Pi) = 0.4908 MPa
External Pressure (Pe) = 6.11 Kg/ cm^2 = 0.5991 MPa
Allowance for Corrosion (C_{all}) = 0
Skirt's inner diameter of (d_i) = 0.991 m
Radius of Knuckle (r) = 0.991 m
Radius of Crown (L) = 0.991 m
Verticals length of Dished End (h) = 0.415 m
Nominal thickness (t) = 0.005 m
Efficiency of Joint E = 1
Minimum required thickness calculated according to the codes as,
(t) = t'/ E
Where, t' = Minimum corroded thickness
t' = (P X d_o) / [(2 X S X E) – (0.2 X P)]
t' = (0.4908 X 1) / [(2 X 80 X 1) – (0.2 X 0.4908)]
t' = 0.003 m
(t) = t'/E = 0.003/1 = 0.003 m
t = 0.003 m
Also, as per the criteria of Minimum required thickness, it should be greater than (3/32 inches).
So, $(t)_{min}$ > 0.002381 m
Now the thickness of head must be greater from 0.003 m, and 0.002381 m

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So, it can be selected as 0.003 m
Now, (t) = Head thickness + Allowance for Corrosion
t = 0.003 + 0 = 0.003 m
t = 0.003m = 3 mm

Again the provided thickness for VLS is 5 mm and it is greater than the required thickness of head against internal working pressure so, it is safe against it.

As the ASME code provides the safe thickness of VLS as 0.005 m. Now calculate the maximum allowable working pressure for operating conditions and corresponding thickness.
Therefore, MAWP ($P_{all.}$) calculated as,
($P_{all.}$) = (2 X S X E X t) / (d + 0.2 X t)
($P_{all.}$) = (2 X 80 X 1 X 0.005) / (0.991 + 0.2 X 0.005)
P = 0.8064 MPa

M. Required thickness according to SF

t = (P X R) / [(S X E) – (0.6 X P)] + $C_{all.}$
t = (0.4908 X 0.445) / [(80 X 1) – (0.6 X 0.4908)] + 0
t = 0.00274 m
t = 2.74 mm

Check for the Requirement of Heat Treatment of cylindrical Shell: Fabrication Material is SA 240 TP 304
ASME Code suggested Shell Thickness (t) = 0.005 m
Inner Diameter of Shell (d_i) = 0.99 m
Provided Centerline Radius of Shell (r_o) = ∞
Due to the flat plate, the original centerline radius is infinity and after Fabrication the Mean (R_f) = 0.4975 m.

Now % Forming Strain = [(50 X t) / R_f] X [1 – (R_f / R_o)]
= [(50 X 0.005) / 0.49750] X [1 – (0.49750/ ∞)]
Therefore, % Forming Strain = 0.5025

As the Forming strain is remains below than 5% hence it is not necessary to check following conditions.

1. Is the VLS will have Lethal Substances Either Liquid or Gases as a working fluid – Not Applicable
2. Is the Material Requires the Impact Testing – Not Applicable
3. Is the thickness of component exceeds 5/8 Inch (15.875mm) Before Cold Forming – Not Applicable
4. Check for the reduction by Cold Forming from the rolled thickness is More than 10% - Not Applicable
5. Is the Fabrication Temperature range in between of 2120 ^{0}C to 4820 ^{0}C = Not Applicable

Hence Heat Treatment process is not required for the Shell of VLS.

Check for the Requirement of Heat Treatment of Dished End: Fabrication Material is SA 240 TP 304
ASME Code suggested Shell Thickness (t) = 0.005 m
Inner Diameter of Shell (d_i) = 0.99 m
% of Elongation Can be calculated as,
% Elongation = [(75 X t) / 101.5] X [1 – (101.5 / R_o)]
% Elongation = [(75 X 0.005) / 101.5] X [1 – (101.5 / 287)]
% Elongation = 2.387

As the Forming strain is remains below than 5% hence it is not necessary to check following conditions.

1. Is the VLS will have Lethal Substances Either Liquid or Gases as a working fluid – Not Applicable
2. Is the Material Requires the Impact Testing – Not Applicable
3. Is the thickness of component exceeds 5/8 Inch (15.875mm) Before Cold Forming – Not Applicable
4. Check for the reduction by Cold Forming from the rolled thickness is More than 10% - Not Applicable
5. Is the Fabrication Temperature range in between of 2120 ^{0}C to 4820 ^{0}C = Not Applicable

Hence Heat Treatment process is not required for the dished end of VLS.

IV. Results And Discussion

As the VLS used for the waste water up to 10 to 20 % of wash during operation. The VLS is totally designed by using ASME Section VIII Division I code and the material is selected by using ASME section II. Also the requirement of Distillery Plant is considered. Though the mathematical solution suggests the thickness of VLS less than 0.005 m but for more safety purpose the thickness selected as 0.005 m. Also the VLS is fully proof against the maximum allowable stress value at the suggested thickness. Though the mathematical solution and ANSYS results slightly differ but the stresses value are also remains within allowable stress values. Hence the provided thickness of VLS is proved effective.

V. Conclusion

By using ASME codes and the ANSYS software the appropriate thickness of VLS is reduced up to 0.005 m. The failure of VLS mainly occurred in the dishes and it can be reduced by the modification in the shape of dished end. The mathematical and analysis results provide the appropriate validation which proved reliable. The VLS system provides the economically cost saving operation in distillery plant than conventional system.

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REFERENCES

[1] H. Darijani, M.H. Kargarnovin, R. Naghdabadi, "Design of spherical vessels under steady-state thermal loading using thermo-elasto–plastic concept", International Journal of Pressure Vessels and Piping, 2009.

[2] M. Maleki, G.H. Farrahi, B. Haghpanah Jahromi, E. Hosseinian, "Residual stress analysis of autofrettage thick-walled spherical pressure vessel", International Journal of Pressure Vessels and Piping, 2010.

[3] L.M. Alves , P. Santana , H. Moreira , P.A.F. Martins , "Fabrication of metallic liners for composite overwrapped pressure vessels by tube forming", International Journal of Pressure Vessel and Piping, 2013.

[4] Jack Besse & Danielle Dechaine, "Distillery Design: Producing Vodka and other spirits" A Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfilment of the requirement for a bachelor of Science Degree in the field of Chemical Engineering, 2014

[5] E.S. Barboza Neto, M. Chludzinski, P.B. Roese, J.S.O. Fonseca, S.C. Amico, C.A. Ferreira, "Experimental and numerical analysis of a LLDPE/HD PE liner for a composite pressure vessel", Polymer Testing, 2011.

[6] Lei Zu , Sotiris Koussios, Adriaan Beukers , "Shape optimization of filament wound articulated pressure vessels based on non-geodesic trajectories", International Journal of Pressure Vessel and Piping, 2009.

[7] H. Darijani, M.H. Kargarnovin, R. Naghdabadi, "Design of thick-walled cylindrical vessels under internal pressure based on elasto-plastic approach", International Journal of Materials and Design, 2009.

[8] Ching-Yu Hsua, Cho-Chung Liangb, Sheau-Wen Shiahc, Chan-Yung Jend, " A study of stress concentration effect around penetrations on curved shell and failure modes for deep-diving submersible vehicle", International Journal of Ocean Engineering, 2005.

[9] Jaroslav Mackerle, "Finite elements in the analysis of pressure vessels and piping, an addendum", International Journal of Pressure Vessels and Piping, 2004.

[10] Lei Zu, Jihui Wang, Shuxin Lu, "Analysis of multi-layered thick-walled filament-wound hydrogen storage vessels", International Journal of Hydrogen Energy, 2014.

[11] M.H. Kargarnovin*, A. Rezai Zarei, H. Darijani, "Wall thickness optimization of thick-walled spherical vessel using thermo-elasto-plastic concept", International Journal of Pressure Vessels and Piping, 2004.