FEA Analysis of LPG Pressure Vessel with SAS515 Grade 60 Material

Yedlapalli Yeshwanth[1], Dr.K. Hari Babu[2]
[1]Dept of Mechanical Engineering
[2]Principal, Dept of Mechanical Engineering
[1, 2] Chebrolu Engineering College , Chebrolu

Abstract- *architecture of the continuous stirred tank reactor (CSTR) based on its mathematical equivalent modeling of the physical system. The plant is formed analytically for the normal operating condition of CSTR. Then the transfer function model is obtained from the process. The analysis is made for the given process for the design of controller with Convectional PID (trial and error method), Ziegler Nichols method, Fuzzy logic method and Model Reference Adaptive method. The simulation is done using MATLAB software and the output of above four different methods was compared so that the Model Reference Adaptive Controller has given better result. This thesis also compares the various time domain specifications of different controllers.*

I. INTRODUCTION

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. They are used to store fluids under pressure. The pressure vessels are designed with great care because rupture of pressure vessels means an explosion which may cause loss of life and property. The material of pressure vessels may be brittle such that cast iron or ductile such as mild steel. And pressure vessels are classified mainly into two types, (a) According to Dimensions (b) According to end Construction.

The pressure vessels, according to the dimensions are classified as thin and thick shells. The ratio of internal diameter and wall thickness is the factor which differentiates between thin and thick shells. If the ratio d/t is more than 10, then it is called thin shell and if this ratio is less than 10 it is said to be thick shell. The examples of the thin shells are pipes, boilers and storage tanks while the thick shells are used in pressure cylinders, Gun barrels, etc.

The pressure vessels according to end construction are classified as open end and closed end. A simple cylinder with a piston is an example of closed end vessel. In case of open end vessels the circumferential stress is induced in addition to the circumferential stress.

And according to role of process vessels are mainly classified into four types:

(a) Reaction pressure vessel
(b) Heat exchanger pressure vessel
(c) Separation pressure vessel
(d) Storage pressure vessel

The objective of this project is to design a Vertical storage pressure vessel which can store LPG (liquid petroleum gases). In general storage pressure vessels are used to hold liquid or gaseous materials, storage media or container to balance the pressure from the buffering effect. In order to achieve better design results, ASME boiler codes were taken into consideration.

Fig: 1.1 Typical Vertical LPG Storage Vessel Assembly.

II. DETAILS AND DESIGN

Types of Loadings:

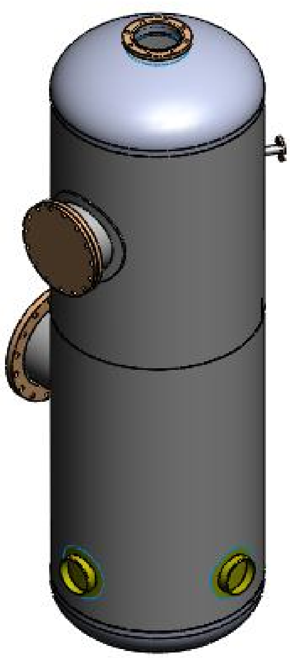
- Steady Loads: Long term duration, continuous.
-
    a) Internal/ external pressure
    b) Dead weight
    c) Vessel Contents

d) Loading due to attached piping and equipment
e) Loadings to and from vessel supports
f) Thermal loads
g) Wind loads

- Non-Steady Loads- Short term duration, Variable.
  a) Shop and field hydro-test
  b) Earthquake
  c) Erection
  d) Transportation
  e) Upset, emergency
  f) Thermal Loads
  g) Startup, Shut down

2.1 CAD Details:

Modelling is done using Solidworks



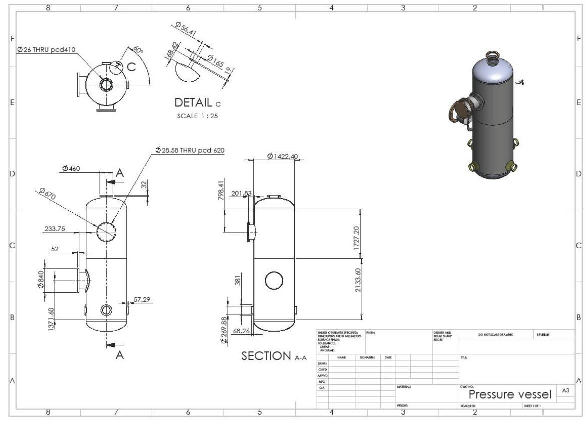


Fig: 2.6 Pressure Vessel ASME standard Design For LPG Details.

2.2 General Notes:

a) All Dimensions are in MM unless otherwise specified.
b) All flange bolt holes to straddle vessel principal centre lines unless otherwise specified.
c) Protect all machined surfaces and threaded connections with rust preventive immediately after machining.
d) Install wood or steel protectors for fittings immediately after testing.
e) No welding is to be done on the vessel after PW heat treatement/SR unless otherwise permitted by CODE/Specification
f) Assembly Instruction: orientation angles 0, 90, 180, 270 of all components shall match with that of assly.
g) All pressure resistant butt welds are full peneration welds with backchipping and welding. wherever backchiping is not possible, root run shall be carried by GTAW.
h) All sharp corners/ edges are to be rounded off
i) The vessel shall have a slope of 1:200 between the ends with respective to true Vertical, however manway/ nozzle falnge faces except the liquid receipt nozzle N1 shall be perpendicular to Vertical.
j) Centerline of all nozzles, manholes and dome shells shall coinside with true vertical axis and shall be chekced with plumb
k) The out of roundness of the cylinder sections i.e, the difference between max & min internal diameters measuered at any cross section shall not exceed 0.5% of nominal diameter.
l) For circumferential joints, the misalignment of center lines of plates shall not exceed 10% of thickness of thinner plate or 3mm. Whichever is smaller.
m) Prior of hydrotest, all weld spatter, metal dust etc. shall bee removed from the tank during hydrotest, tank is to be supported on sand bed.
n) During hydro test settlement monitoring of the equipment supported on its foundation should be per-formed. The

settlement should be monitored at 0,25,75, & 100 % filling and after 48 hrs with the vessel completely fillet. The settlement rate during the testing period must dimnish with the time. Otherwise the vessel must be partially emptied and corrective action on the foundation shall be taken.

o) Radiography shall be carried out before and after post weld heat treatement and wet fluorescent magnetic particle testing of weld shall be carried out after post weld heat treatment.

p) All forgings aand nozzle flanges shall be MP/DP tested. After machining.

q) Nozzle necks fabricated from plate to be fully radiographed

r) Hydrotest of vessel shall be carried out only once after stress relieving.

s) NDT of weld joint after hydrotest is as follows:

  a) 100% UT exam of all the T joints from inside of the vessel followed by DP Test.

  b) MP of 1/3rd length of fillet of inner shell to stiffener web as 0,90,180,270deg

  c) after final inspection, before gassing up and commissioning of LPG bullet an ultrasonic shell thickness testing shall be carriedout on the internal walls of bullet at the points designated for 5 years.

t) Gasket seating surface of all flanges shall have smooth finishing to 125 AARH.

u) surface preparation & painting:

  a) all external surfaces steel structure painting council: surface preparation specification SSPC - SP10, painting: polyurethane protective coating as per techincal specification.

v) Flange dimensions for nozzles shall be as per ANSI B16.5 upt 24 size/ANSI B16.47 series-A above 24 size.

w) All nozzles shall be provided with insulating gasket, insulating bolts and insulating washer under backup washers and nuts.

x) Bullet is to be stress relievedand hardness controlled at 200 BHN after PWHT.

y) bullet is to be designed for the following foundation settlement values

  a) immedciate settlement value 5mm

  b) longterm settlement value 15mm

  c) maximum settlement value between center and end of the bullet (at empty, operation, testcase) 10mm

z) RF pads shall be pnematicallytestedfor tightness to 1.0KG/sq.cm(g) with soap solution on all attachmetn welds.

aa) RF pad is to be welded to shell such that one tell tale hole will be at the bottom of the pad in the erected position of the vessel.

bb) Tell tale/Vent holes shall not be plugged and shall be filled with hard grease after PWHT.

cc) wherever RF pad crosses the weld seam the weld seam is to be ground flush.

dd) calibration: volumetric capacity calibration shall be done for the LPG bulletby statutory authorities

ee) Work at site:

  a) each bullet will be fabricated in 4 sections in vertical position, stiffener rings shall be welded in this position, These modules will be turned Vertical dn each module placed on temporary saddles maintaing slope as per drawing assembly and welding of all nozzles, doems and D'ends shall be completed on the individual modules.

  b) after completion of welding of all attachments,the modules shall be individually stress relieved.

  c) all external surfaces of modulesshall be blast cleaned and painted. the modules will be placedon foundation bed maintaining slope and C-Seams between modules shall be completed. local SR will be carried out for these C-Seams followed by Hydrotest of bullet.

  d) the PH of fresh water used for hydrotestshall be between 6 &7.The vessel shall be completely drained, cleaned and dried with hot air after Hydrotest.

  e) Internal surfaces of bottom 90 section of bullet shall be properly cleaned and painted with amine cured epoxy paint. Frames shall be used for lifting/handling the shell courses over the foundation during different stage of fabrication, inspection and testing.

2.3 Design Data for CAD:

a) Process fluid : LPG (commerical grade)

b) Design pressure - internal : 14.5 Kg/cm2(g)

c) Design Pressure – External : 1.856 Kg/cm2(g)

d) Design Temperature : -27 to +55 C

e) Hydro Test Pressure : 19.75 Kg/cm2(g)

f) Operating temperature : Amb C

g) Water Capacity : 2165 Cu.m

h) Storage Capacity of LPG (working) : 1000 MT

i) Position : Vertical

j) Dished Ends : Hemispherical

k) Class of Hazard : Flammable

l) No. of bullets : 3

m) Liquid flow rate (feed) : 330 Cu.m/hr
n) Liquid flow rate (loading) : 200 Cu.m/hr
o) Boing Point : Range >-40 C
p) Density of liquid water : 1000 Kg/m3
q) Desnity of LPG : 550 Kg/m3
r) Physical Condition : liquid, Vapour
s) Vapour pressure : 8.5 Bar @ 20C
t) Flash Point : -104 C
u) COmposition : propane -60%, Butene-40%
v) Physical state : Gas at 15C at one ATM
w) Design Code : PD 5500
x) Radiography : 100 % Before and after PWHT
y) Weld joint efficiency : 1.0
z) Vapour Density :1.5
aa) Corrosion allowance : 1.5mm
bb) Length of Vessel : 44000mm
cc) Diameter of vessel : 7500mm
dd) Empty Weight : 319Tonnes
ee) Hydro Test Weight : 2505 Tonnes
ff) Operating Weight : 1379 Tonnes
gg) Painting -External : Polyurethane Coating
hh) Painting –Internal : Surface preparation specification SSPC SP10

2.4 Materials Used in Design:

ASME SA515 Steel Plate

SA515Gr60|SA515 Grade 60|SA515 Gr.60,SA515GR.60 PLATE

ASME SA515 standard specification for pressure vessel plates, carbon steel, for intermediate-and higher-temperature service

ASME SA515 grade 60 plates shall be normalized.
Supplementary Technology: HIC Test | NACE MR0175 | Z15 | Z25 | Z35 | S1 | S2 | S3 | S4.1 S5 | S6 | S7 | S8 | S9| S11 | S12 | S17
Thickness: 6MM to 300MM,
Width: 1500mm to 4050mm,
Length: 3000mm to 15000mm

Gangsteel is specialized in supplying ASME SA515 steel plate in SA515 grade 60. For more information of SA515 grade 60 steel plates, please check them in following:

SA515 grade 60 Chemical Composition					
Grade	The Element Max (%)				
	C	Mn	P	S	Si
SA515 grade 60	0.24-0.31	0.98	0.035	0.035	0.13-0.45

Carbon Equivalent: Ceq = 【C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15】 %

Grade	SA515 grade 60 Mechanical Property			
	Thickness	Yield	Tensile	Elongation
SA515 grade 60	mm	Min Mpa	Mpa	Min %
	200	220	415-550	21
	50			25

Inorder to meet the requirements of ASME Boiler and Pressure Vessel Codes, SA 537 CL- 1 is a grade of “Carbon Manganeses-Silicon Steel” is used in this design. Here are the compositions used in this material:

Pmax = 0.035
Smax = 0.040
Cu max = 0.035
Ni max = 0.25
Cr max = 0.25
Mo max = 0.08

Heat Treatment = normalized, ultrasonically tested, impact tested

Tensile Strength = 70 – 90 Ksi / 485 – 620 MPa
Yield Strength = 50 Ksi / 345 Mpa

Other Characteristics of this material:

- The plates shall be free of scales and rolled in the direction of length specification and shall be supplied in the normalized condition. Accelerated cooling by liquid quenching or other means is not permitted.

$$C_{eq} = C + \frac{MN}{6} = 0.42$$

- The plates shall be supplied with gas/sheared edges with tolerances as per SA 20 latest. Manual gas cutting is not acceptable. Tolerance on thickness shall be positive only.
- All the plates shall be supplied in normalized condition.
- The plates shall be free from injurious defects and shall have work-man like finish. Reconditioning/ repair of plates by welding is not permitted.
- The carbon content for plates shall not exceed 0.23%.
    - Additionally, one of the following requirements for carbon equivalent based on heat analysis, shall be also satisfied:

III. RESULTS

Pressure vessel Analysis Study Results

Name	Type	Min	Max
Stress1	INT: Stress Intensity(P1-P3)	0.0679248 psi Node: 35293	39350.4 psi Node: 50780

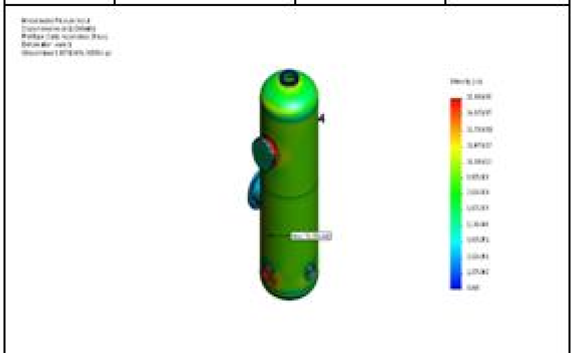


Fig 4.17: Pressure vessel-vessel 1-Stress-Stress1

Name	Type	Min	Max
Displacement 1	URES: Resultant Displacement	0.00107217 mm Node: 50678	6.52455 mm Node: 16179

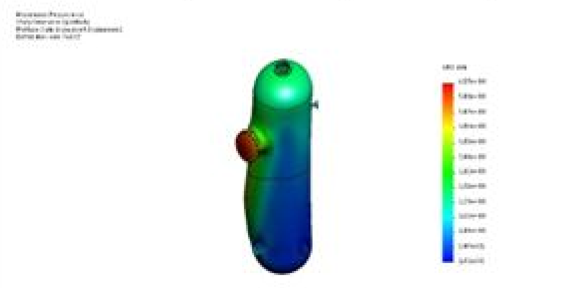


Fig 4.18: Pressure vessel-vessel 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.74624e-009 Element: 153985	0.00145684 Element: 225774

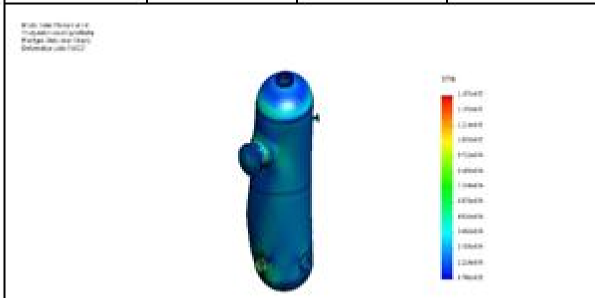


Fig 4.19: Pressure vessel-vessel 1-Strain-Strain1

Name	Type	Min	Max
Stress2	SZ: Z Normal Stress	-56729.2 psi Node: 51001	49432.4 psi Node: 50843

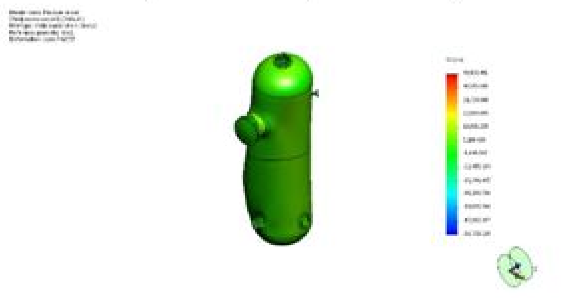


Fig 4.20: Pressure vessel-vessel 1-Stress-Stress2

Name	Type	Min	Max
Stress3	SZ: Z Normal Stress	-56729.2 psi Node: 51001	49432.4 psi Node: 50843

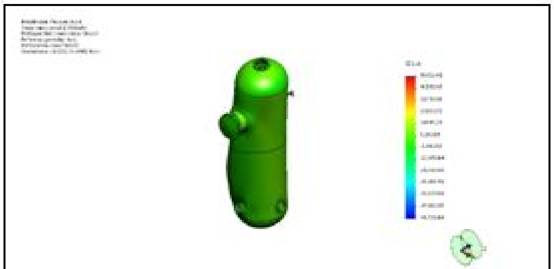


Fig 4.21: Pressure vessel-vessel 1-Stress-Stress3

Name	Type	Min	Max
Stress4	SX: X Normal Stress	-65688.9 psi Node: 50811	49493 psi Node: 50802

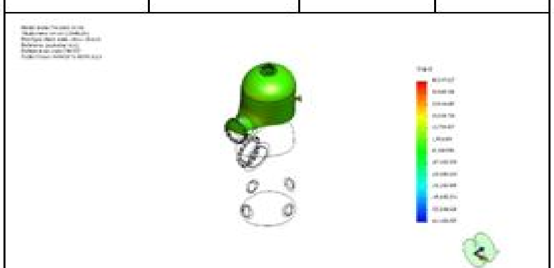


Fig 4.22: Pressure vessel-vessel 1-Stress-Stress4

Name	Type	Min	Max
Stress5	INT: Stress Intensity(P1-P3)	0.0679248 psi Node: 35293	68389.4 psi Node: 50811

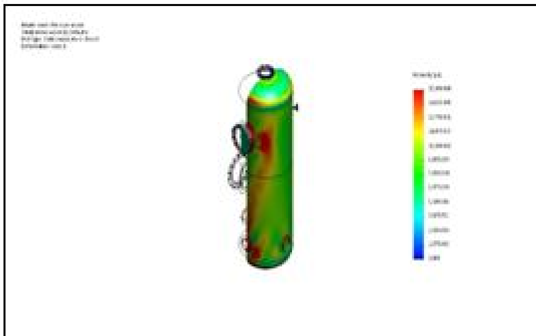


Fig 4.23: Pressure vessel-vessel 1-Stress-Stress5

Name	Type	Min	Max
Factor of Safety1	Automatic	0.936617 Node: 50780	505633 Node: 35293

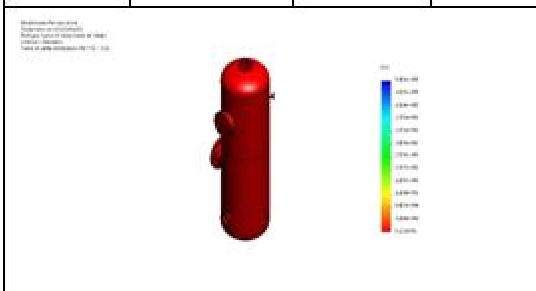


Fig 4.24: Pressure vessel-vessel 1-Factor of Safety-Factor of Safety1

IV. CONCLUSION

Throughout the analysis the loading conditions of different loads such as static loads , thermal loads Nozzle loads and the self load of the pressure vessel is taken at the maximum value though the performance of the pressure vessel is calculated using pressure vessel as a single event for all these conditions the design comes to have least effect of that therefore. The design of the Pressure vessels is safe. The Factor of safety that we consider is permissible and by which the design are considered safe. The bursting pressure is under the allowable stress so that the design does not fail. And the analysis are so close to the Analytical design hence the both data are validate and the design is considered as safe And there are no failure occurs in the pressure vessel.

REFERENCES

[1] Donald Mackenzie," Design by analysis of ductile failure and buckling in torispherical pressure vessel heads", Elsevier Thin-Walled Structures volume 46 PP 963–974

[2] Daniel Vasilikis, Spyros A. Karamanos,"Buckling Design of Confined Steel Cylinders Under External Pressure" Journal of Pressure Vessel Technology February 2011, Vol. 133 pp 011205-9

[3] You-Hong Liu, "Limit pressure and design criterion of cylindrical pressure vessels with nozzles", International Journal of Pressure Vessels and Piping volume 81 pp 619–624

[4] Y. BANGASH," Safe analysis for cooling pipes for prestressed concrete reactor vessels", Nuclear Engineering and Design", volume 55 (1979) pp 305-313

[5] A. Chaaba, "Plastic Collapse Assessment of Thick Vessels Under Internal Pressure According to Various Hardening Rules", Journal of Pressure Vessel Technology Copyright 2010 by ASME October 2010, Vol. 132 pp 051207-1

[6] SotiriaHouliara, Spyros A. Karamanos," Buckling of Thin-Walled Long Steel Cylinders Subjected to Bending", Journal of pressure vessel technology, Vol. 133, February 2011

[7] Vishal V. Saidpatil,"Design& Weight Optimization of Pressure Vessel Due to Thickness Using Finite Element Analysis", International Journal of Emerging Engineering Research and Technology Volume 2, Issue 3, June 2014, PP 1-8

[8] R.C. Carbonari," Design of pressure vessels using shape optimization: An integrated approach", International Journal of Pressure Vessels and Piping volume 88 pp 198-212

[9] M.H. Toorani, "Dynamics of the geometrically non-linear analysis of anisotropic laminated cylindrical shells", International Journal of Non-Linear Mechanics volume 38 pp 1315 –

[10] Kiran D. Parmar1, Kiran A. Patel, "Thermal analysis for skirt dished end joint of pressure vessel using finite element analysis approach", International Journal of Advanced Engineering Research and Studies,Vol. I/ Issue III/April-June, 2012 pp184-187