Analysis of different types of weld joint used for fabrication of pressure vessel considering design aspects with operating conditions

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Abstract - **Pressure vessels are the containers or pipelines used for storing, receiving or carrying the fluid under pressure. Various type of pressure vessels like horizontal, vertical, spherical are used in industry. For Design and fabrication of pressure vessel various parameter are studied. Various parameters such as weld techniques types of weld grooves & groove angle are most considerable. Even due to experimental visit observed that at the nozzle to bottom dish weld joint crack is initiated by die penetration and expand due to hydrotest. In this project a design data is selected for that model and parametric software used for modelling. Then FEA tool is used for analysis and compare the result with analytical method. Various parametric variation through FEA tool V groove having 30° with pad to nozzle and 30° with nozzle to dish joint is found better than others joint.**

Index Terms –**Pressure vessel, Analysis of weld joint, changing weld grooves and angles of weld joint.**

I. INTRODUCTION

Pressure vessels are the containers or pipelines used for storing, receiving or carrying the fluid under pressure. The pressure vessels are designed with great care because the failure of vessel in service may cause loss of life and properties. The material of pressure vessels may be brittle such as cast iron or ductile as plain carbon steel and alloy steel. The main component of pressure vessel are (1) Shell, (2) Head, (3) Nozzle, (4) Support and the type of pressure vessel A) Horizontal Pressure Vessels, B) Vertical Pressure Vessels, C) Spherical Pressure vessels as shown in figure 1.1.

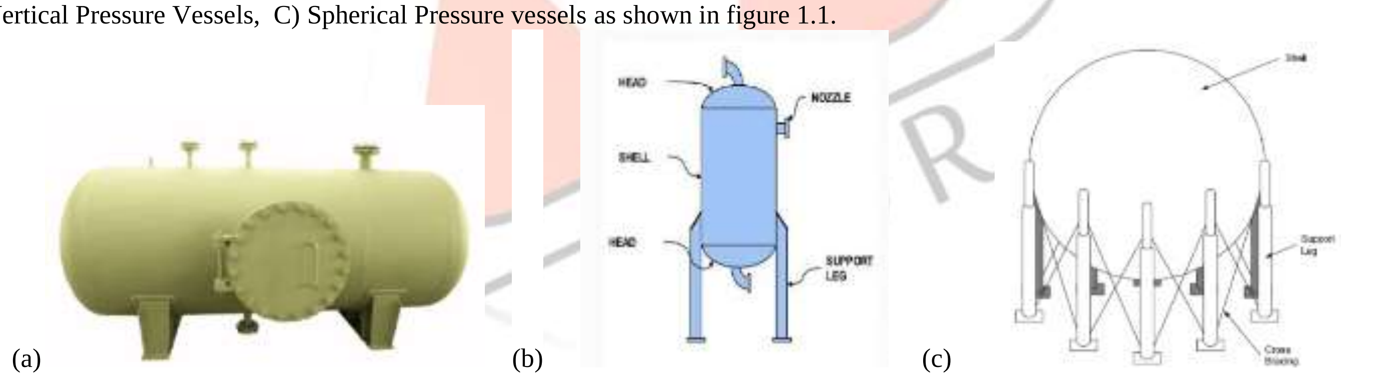


Figure 1.1- (a) Horizontal PV [1], (b) Vertical PV, (c) Spherical PV [2]

1.1 Different Types of grooves & welded joints

The various type of grooves used for fabrication of pressure vessel which is listed as below shown in figure 1.2 and work piece thickness limit per joint type describe in below table1.1

1.2 Material Related Failures

1. Elastic deformation- Elastic instability or elastic buckling, vessel geometry, and stiffness as well as property of materials are protection against buckling.
2. **Brittle fracture** – Fracture can occur at low or intermediate temperatures. Brittle fractures have occurred in vessel made of low carbon steel in the 40°-50° F range during hydro test where minor flaws exist.
3. **Stress rupture** – Creep deformation as a result fatigue or cyclic loading.
4. **Excessive plastic deformation** – The primary and secondary stress limit as in ASME section VIII, division 2 are intended to prevent excessive plastic deformation.
5. **High stain**- Low cycle fatigue is strain governed and occurred mainly in lower strength/high ductile material.
6. Stress corrosion – Chlorides cause stress corrosion cracking in stainless steel.
7. Corrosion fatigue- Corrosion can reduce the fatigue life by pitting the surface and propagating crack. Material selection and fatigue properties are the major consideration.

Table 1- Work piece Thickness Limit per Joint Type [4]

Work piece Thickness Limit Per Joint Type	
Joint type	**Thickness**
Square joint	Up to ¼ in (6.35 mm)
Single-bevel joint	3/16–⅜ in (4.76–9.53 mm)
Double-bevel joint	Over ⅜ in (9.53 mm)
Single-V joint	Up to ¾ in (19.05 mm)
Double-V joint	Over ¾ in (19.05 mm)
Single-J joint	½–¾ in (12.70–19.05 mm)
Double-J joint	Over ¾ in (19.05 mm)
Single-U joint	Up to ¾ in (19.05 mm)
Double-U joint	Over ¾ in (19.05 mm)
Flange (edge of corner)	Sheet metals less than 12 gauge (0.1046 in or 2.657 mm)
Flare groove	All thickness

(a)

(b)

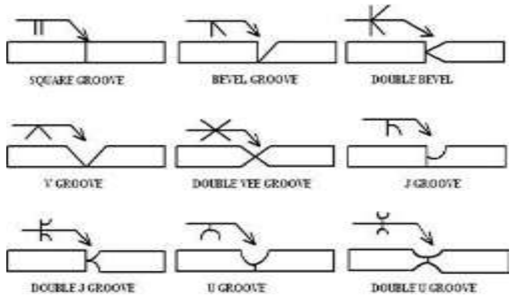


Figure1.2 (a, b) - Weld defects & Weld grooves

The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal. It can simply be defined as: “Defects introduced during welding beyond the acceptance limit that can cause a weld to fail”.

CHAPTER 2 - LITERATURE SURVEY

- Hessamoddin moshayedi 2015[1] in this paper 3-D finite element (FE) used for model FE analysis using ABAQUS 6.14 software and studied an internal circumferential crack is generated at the weld line. Residual stresses (RS) can be generated in a component due to fabrication process like welding, manufacturing, processing or assembly. A533B material steel pipe 130 mm diameter and 6.25 mm wall thickness which is weld by Welding technique manual GTAW (gas tungsten arc welding process). The distributions of stress on the speciment with and without welding residual stresses showed that welding process can cause very high tensile opening mode stresses.

- Kamal H. Dhandha et al 2015[2] in this paper Grade 91 steels are structural material. TIG (Tungsten Inert Gas) welding process was applied on P91 steel plate on which oxide powders CaO, Fe2O3, TiO2, ZnO, MnO2 and CrO3 were applied to produce a bead on plate welds. Present work was to investigate the effect of oxide fluxes on weld. Heat input increase with the use of activated fluxes. The increase in weld penetration and the decrease in bead width are significant with the use of the activating fluxes Fe2O3, ZnO, MnO2 and CrO3. Maximum depth to width ratio of flux ZnO, MnO2 and CrO3 is 0.95, 0.85 and 0.83 respectively and in case of normal TIG (tungsten inert gas) it was 0.29 so increase in aspect ratio with the flux ZnO by 320% as compared to conventional TIG welding process.

- Xiao-Tao Zheng et al 2015[3] in this paper observed that butt welded joints are usually the main failure parts under plastic deformation. Authors have done Analysis of different groove butt weld joint with Finite Element Modelling of various circumferential welded joints with UV-groove, Double U-groove, X-groove, U-groove, V-groove, and single-side weld. For smaller thickness U, V, X groove and for larger thickness UV- and Double U-groove are used for welding.

- Jingqiang Yang et al 2014[4] in this paper studied Failure analyses of weld joint between the nozzle and the head of the reactor after 1 year of operation. It is made of 2205 duplex stainless steel material. It was analysed by optical microscopy (OM) and scanning electron microscopy (SEM). Cracks were found in HAZ of the weld. The nozzles of reactor are located at the head of reactor and were welded SMAW with K groove penetration. Cracks are introduced during hydrotesting of pressure vessel but crack didn’t penetrate the nozzle so vessel put into operation but after some time it leakage at the crack. The crack repair by changing the welding techniques to GTAW by ER2209 with 2.0 mm diameter will be used as filler material.

- M.Clyde Zondi 2014[5] in this paper observed that safety is mainly considered when pressure vessels operates under pressure and may contain hazardous fluid/toxic substance. Residual stresses are generates while welding process which can affect the fatigue life of pressure vessel. In the study three categories of influential factors are studied. Factors are pre-welding conditions, in-process parameters, and post welding conditions. They conclude Heat input (arc voltage, welding current, and travel speed) is the most influential in-process parameter of residual stress generation during welding. Automatic arc welding processes (e.g., SAW) may decreased fatigue life of the weld bead due to larger stress regions.

- Shugen XuWeiqiang Wang et al 2014 [6] in this paper Layered cylindrical vessels of material austenitic stainless steel 1Cr18Ni9 & low alloy steel Q345R which is widely used in industries. During the girth welding of layered-to layered sections the structure integrity influenced by residual stress. In this paper, the Finite Element Method (FEM) is used to predict the residual stresses in a layered-to-layered joint and observed that discontinuous stress distribution at the location where the material miss-match. Larger amount of residual stresses are generated in the weld and HAZ. The residual stresses decreasing gradually away from the weld and HAZ. Stress distributions in layers were not continuous in layered vessel.

- Ravi Prakash et al in 2013 [7] in this paper in vacuum vessel fabrication of chamber with high thickness up to 60 mm or more which is made of special grade steel. Vacuum vessel of ITER has “D” shaped profile and is toroidal double walled huge steel cage having 6 m width and 19 m diameter, and the Cryostat of 30 m height and width. The pressure vessel fabricated by various section welded by number of joint. The weld joint will use various welding processes like NG-TIG, TIG, MIG, MAG and EBW. The analysis was carried out by taking into account the welding technique, welding sequence of the components, welding direction, fixture location, with and without clamps during welding. They do welding simulation of 60 mm thick stainless steel plate and optimized weld parameters and shrinkage to minimize the distortion.

- B. Arivazhagan et al 2015[8] in this study 2015 in this study they welding 2.25Cr-1Mo (P22) steel plate by TIG welding. 12 mm thick double side square butt joint is use for welding. Effect of post weld heat treatment (PWHT) on the impact toughness was studied. An activated flux in the form of paste is applied on the joint of weld area to achieve depth of more penetration up to 300 % and weld was found to be free from cracks after welding.

- C.R. Das et al 2013[9] in this paper the fatigue failure of fillet weld nozzle joint was studied. AISI 304L stainless steel Material and joint Failed during transportation. In this crack area at near fusion line. SEM (scanning electron microscope) observation of fracture-surface on surface ratchet and notches found which saws the fatigue failure of nozzle. The fillet weld joint and filler material ER 308 L austenitic stainless steel used for Welding & TIG welding technique used. Result is sensitization occurred in SS and crack generated due to external load, lake of penetration and due to attack of chemical.

- Han-sang Lee et al 2005[10] in this paper the cracks in the failed tube started from inner surface of the heat affected joint .Tube outer diameter 63.5 mm and thickness 4.3 mm. Welding technique used TIG welding. Found Formation of course Cr carbide in the heat affected zone of failed tube. Induced martensite on inner side of heat affected zone. Nb carbide Dissolution of at the HAZ and increase in the hardness at the inner side of the as welded specimen.

- Nausheen Naz et al 2009[11] Steel nozzle cracking observed after circumferential welding process. Nozzle –material is C-Cr MoV alloy steel. Butt weld joint used and TIG welding technique used for welding. Cracks on the surface in the area adjacent to weld bead (HAZ). Failure was occurred by the presence of course untempered martensite in heat affected zone due to localize heating. High heat input and low welding speed result in high transformation stresses. Transformation stresses combine with the thermal stresses and the constraint condition to cause intergranular brittle structure.

- H.M. Shalaby et al 2015[12] in this paper duplex stainless steel grade 2205 DSS material used for structure. Nozzle is subjected to fatigue failure due to vibration in piping system. Poor welding can cause failure of duct nozzle. The nozzle was subjected to repeated welding thermal cycle; heat input was relatively high % of austenite in the weld region above 70% and Poor welding practice make brittle cracking.

- Shugen Xu et al 2014[13] in this paper the material is austenitic stainless steel 1Cr18Ni9 is used, the stress distribution occurred discontinuous due to inter layer gap between two layer of head. Stress concentration occurred because of discontinuous structure model. With increased preheating temperature, the peak residual stresses decrease in the structure. The welding heat input cause effect on the residual stresses.

- Sattari-Far et al 2009[14] the structural, material factors and welding parameters impact on residual stress Then, effects of the weld groove shape on magnitude and distributions of residual stresses are studied. The most common weld groove shapes of, V-groove; X-groove and U-groove types are studied here. In addition, effects of weld pass number on welding residual stresses are studied by models considering three different pass numbers.

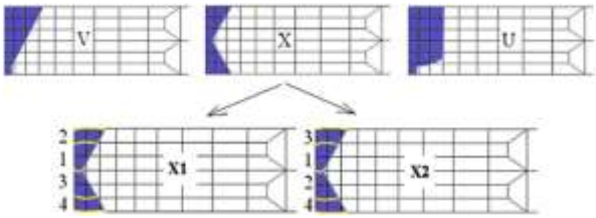


Figure 2.1- different grooves change

In thick pipes (10 mm thick) with X2-groove shape, significant increase in the axial tensile stress on the inner surface of the pipes are observed compared with U and V groove shapes.

- Akshaya T. Poojary et al 2012[15] in this paper author made modelled of ductile material of flat dish end pressure vessel and verified by maximum equivalent stress (von mises stress) which are induced by internal pressure. They design model in CATIA software and then simulate in FEA for determine the maximum von mises stress. Several size of mesh changes to achieve the actual desire stress value. compare the both analytical and FEA result of von mises stress which are nearer value and 2.4 % difference between this value and both are less then material yield strength.

- Sourabh Lawate 2015[16] in this paper the work on different head geometry of pressure vessel like torispherical, elliptical, and hemispherical head dish which are modelled and analysis in ANSYS APDL. Apply internal pressure hydrotest pressure and find stress (von mises) and deformation from Ansys and analytically also. Comparison made of three types of head by von mises stress and deformation. They conclude on the basis of forming cost of head geometry.

- Mulla Niyamat et al 2015[17] in this paper induced stresses are calculated using pressure vessel theory or ASME codes. In this project induced stresses are calculated using ANSYS and the results are then compared with analytical results. This work demonstrates usage of commercial FEA tool over analytical approach. Analytically as well as by FEA compare both and validate model with 15 % error.

- Jorge R. Miranda et al 2007 [18] the purpose of this paper is to evaluate the stress fields on the vessel/nozzle intersection of cylindrical pressure vessels using FEM (finite element models). Three models were developed using the vessel/nozzle intersection (I) unreinforced vessel/nozzle intersection, (ii) bonded pad reinforced vessel/nozzle intersection and (iii) partially welded pad. Results was negligible for the nozzle region, bonded and partially welded pad reinforced models, however, presented higher differences on stress levels for both tangential and radial stresses. The partially welded pad reinforced model contains stresses 20% higher and radial stresses were significantly higher than the bonded pad reinforced model.

- Brajesh Kumar Singh 2015[19] in the present study experimentations on welding were carried out and effect of the variations in welding joint designs on the properties of the weldment was studied. Mild steel plates, IS 2062: E250 were taken as sample for the study. The main objective was to compare the effects of variations in geometry of butt-joint welding on the mechanical properties of mild steel plate. Square butt-joint, single V-joint, double V-joint and single J-joint variation carried out while keeping all other process parameters like current, voltage, welding speed etc. as constant. High volume of the weld metal increases the weld width and so HAZ width, and thus increases the chance of weld defects. Double-V weld joint was the best choice to go for. The simulation results are solely dependent on the accuracy of finite element modelling. In the present study the model for each weld design was difficult to generate due to their unsymmetric nature of grooves.

- Kadhim Hussein Mukhirmesh et al 2015[20] In this paper, the pressure vessel is designed according to the weld efficiency and analyzed for its strength using Finite Element analysis with help of Ansys software. Mathematical calculation is considered for the design of pressure vessel whose design parameters are specified by a company according to the required weld efficiency. Modelling is done in Pro/E. Structural analysis is done in Ansys on the welded joint of pressure vessel for different weld efficiencies. Compare stresses of head, shell, and nozzle with different weld efficiency. Result is for E= 0.7 means no radiography thickness of component is more and E=1 means fully radio-graphed the thickness of components is low so effect of Stresses (Hoop stress & Longitudinal stress) and raises stresses can be studied well it as well which is cost dependent.

- Girish P. Kelkar [21] observe that there are a variety of physical defects such as undercut, insufficient fusion, excessive deformation, porosity, and cracks that can affect weld quality, Of those defects, cracks are considered to be one of the worst since even a small crack can grow and lead to failure. There are three requirements for cracks to form and grow: a stress raising defect, tensile stress, and material with low fracture toughness. Toughness is a measure of resistance to crack growth, Stresses can be reduced by changing the joint design to ensure that the weld is under very low tensile load, and preferably, have a compressive load at possible crack locations. Joint deigns & fillet shapes can be controlled to minimize stress concentrators which assist in initiation of cracks.

2.1 Finding from literature

- Pressure vessel is very important as the vessel, which comes in the shape of a closed container, is designed to hold gases or liquids at a pressure substantially different from the ambient pressure and temperature. Pressure vessel failure can cause loss of life and properties.
- There are many types of defects in weld joint cause failure of weld joint for e.g. Cracks, porosity, lake of penetration, etc. This defect can cause major problem at weld joint as well as failure of pressure vessel.
- The cracks also develop during hydrostatic pressure test due to internal pressure. Butt welded joints are usually the main failure parts resulting from the local accumulated plastic deformation. Analysis of different groove butt weld joint under certain condition & analyse different groove shape and conclude better option.
- In pressure vessel Due to geometric discontinuities, region presents high stress concentration levels and it is where failure is more likely to occur. Due to difficulties in manufacture, these intersections are more suitable to fabrication imperfections, such as lack of weld deposition and/or weld penetration, which consequently cause crack propagation.
- The simulation of weld residual stress by finite element method (FEM) can obtain the stress and deformation distribution in the total structure By using FEM and observed that changing the heat input, weld passes, groove shape, material properties and geometrical dimensions of the weld structure can decrease the residual stress.
- In many of the article author have done various experiment on various weld joints of pressure vessel and also used different FEA tool for analysis and validation purpose.
- Some authors have done work on various parameters of weld joints such as groove dimension and shape and observed that parametric variation also affect the residual stress at the weld joint.

CHAPTER 3 - TECHNICAL VISIT

- Technical visit is carried out to observe the fabrication techniques. Approach three of fabrication shop of pressure vessel. During visit observed many things at time of welding & testing. Three of the fabrication shops used Tungsten inert gas (TIG) welding techniques for stainless steel & Metal inert gas (MIG) welding techniques for mild steel and for testing the defects they used die penetration test & radiography. Surface & subsurface defects are observed during the die penetration test. Crack induced at the joint of bottom head to nozzle welded joint & further propagated crack is observed during hydrotest of pressure vessel which is shown in below figure

Figure 3.1- Crack location

CHAPTER 4 – OBJECTIVE

- Design of pressure vessel is required great care because the failure of vessel in service may cause loss of life and properties.
- Failure in pressure vessel is occurred with many ways. Weld related failure play significant role in the design of pressure vessel. So selection of weld techniques & their joints are also important for a safe design.
- Welding defects are also observed at nozzle joint due to testing of pressure vessel in industry. To overcome the defects & increase the strength of the pressure vessel at nozzle location a design data are selected form industry.
- Analytical calculation is carried out & compared the outcome of it with FE result also.
- For analysis various design parameters such as types of weld grooves & angle are considered.

CHAPTER 5 -ANALYTICAL STUDY

5.1 DESIGN DATA [a]

Table 2-Design data of pressure vessel

No	Criteria	Detail
1	Design pressure	-1 to 6 kg/cm^2
2	Working pressure	-1 to 2 kg/cm^2
3	Working temperature	-20 to 150
4	Hydro test pressure	9 kg/cm^2
5	Joint efficiency	100 %
6	Radiography	Full
7	length	5666 mm
8	Width	2400 mm
9	Internal diameter	2400 mm
10	Cylinder thickness	10 mm
11	Head dish thickness	14 mm
12	Nozzle diameter	115 mm
13	Nozzle thickness	10 mm
14	Pad thickness	10 mm
15	Pad inner diameter	118 mm
16	Pad outer diameter	230 mm

5.2 Material property: - AISI 316

Table 3- material property

Material	SA240 grade 316(AISI 316)
Density	8000 kg/cm3
Yield strength	205 Mpa
Ultimate tensile strength	505 Mpa
Modulus of elasticity	193 Gpa

Table 4- Test report

Sr. No.	Sample	Material	Test	Result
1	Cut piece of 10 mm thick shell plate	AISI 316	Chemical analysis	Result is meeting material requirements
2	Cut piece for 14mm thick dish plate	AISI 316	Chemical analysis	Result is meeting material requirements
3	Pressure vessel	Water	Hydro test 9 kg/cm^2	leakage found
4	Weld joint	Cleaner, Penetrant, Developer	Die penetration	Surface Defects Crack, Porosity, Lack of penetration

5.3 Von-mises Stress Calculation for the pressure vessel

1) Stress in circumferential direction (hoop stress) in cylindrical shell (σ_t)= $\frac{pi(di+t)}{2t}$= $\frac{0.8825(2400+10)}{2*10}$= 106.35 Mpa

2) Stress in longitudinal direction in cylindrical direction (σ_l) = $\frac{pi(di+t)}{4t}$ = $\frac{0.8825*2410}{4*10}$= 53.17 Mpa

3) Equivalent stress

$\Sigma eq_{von\ mises} = (\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2)^1$

$= (106.35^2 + 53.17^2 - (106.35*53.17))^{1/2}$

$= 92.10$ Mpa

4) Stress at torispherical dish

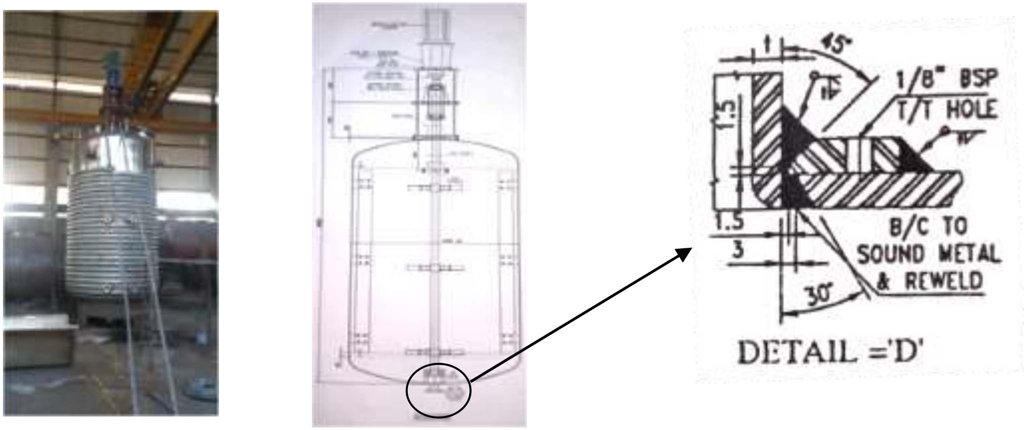
Hoop stress = $\frac{p(d+t)}{2t}$= 0.8825*(2414)/2*14 = 76.09 Mpa

5) **For dish von mises stress $\sigma_{eq\ von\ mises}$** =76.09 Mpa (both stress are same)

Total $\sigma_{eq\ von\ mises}$ = Shell von mises stress + Dish von mises stress = 92.10+76.09 **= <u>168.19 Mpa</u>** at 9 kg/cm2 pressure of hydrotest

CHAPTER 6 - MODELLING & FINITE ELEMENT ANALYSIS

6.1 *Experimental model*

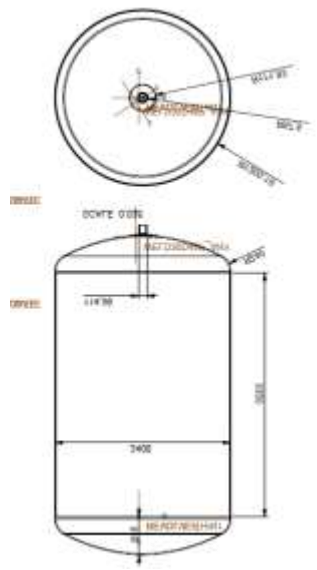


(a) (b) (c)

Figure 6.1 (a) Pressure vessel at fabrication shop, (b) Drawing of pressure vessel, (c) Weld joint detail D

- In the above figure (a) vertical pressure vessel at company is shown and in the second figure (b) is the 2D drawing of same vessel. The detail - D of weld joint is used at the nozzle to bottom dish of pressure vessel as shown in figure (c).

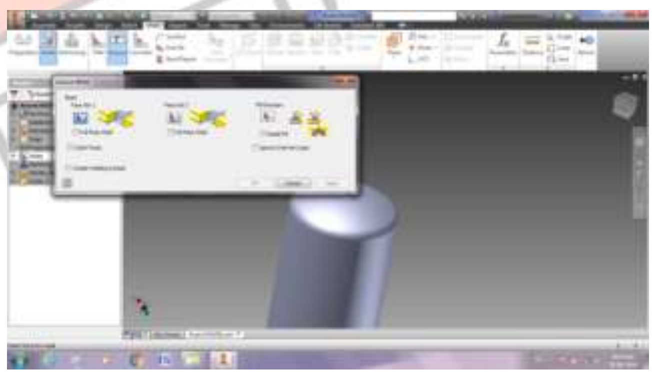
6.2 Steps of Modelling of pressure vessel from experimental data



(A) Modeling of PV by parametric software

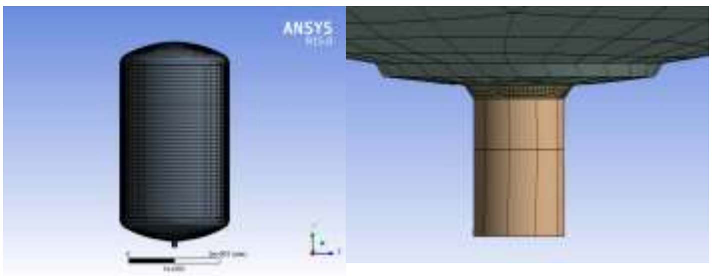
(B) 3D modeling of pressure vessel

(C) Create groove at nozzle joint



(D) Groove weld in inventor

(E) Weld joint at nozzle to head dish



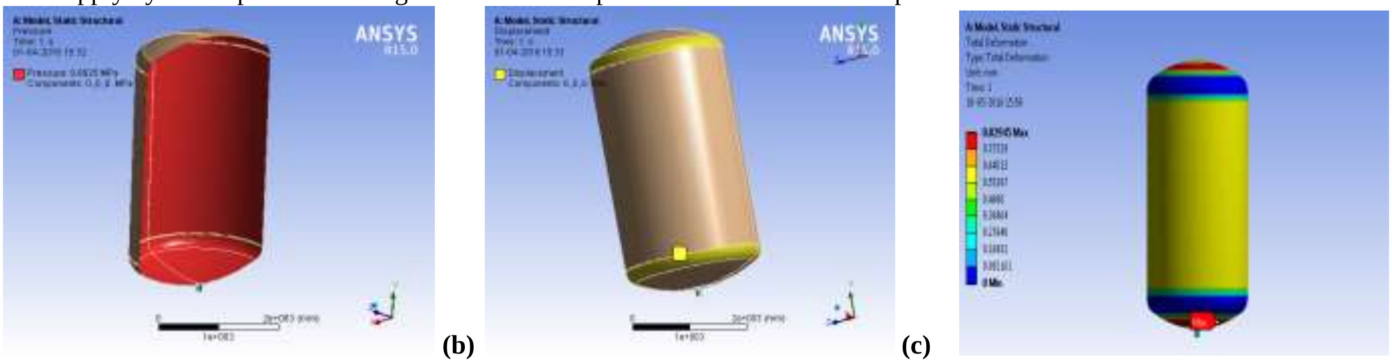
(F) Mesh size at pressure vessel and weld joint

Figure 6.2 steps of modeling to welding

In above figures A, B, C, D, E, F are the step from modeling to welding at joint at nozzle location now apply boundary condition.

6.3 Apply boundary conditions (pressure, force, fixed support etc.)

Apply hydrotest pressure of 9 kg/ cm^2 = 0.8825 Mpa in the internal surface of pressure vessel.



(A) (b) (c)

Figure 6.3 – (A) Apply internal pressure in internal surface, (b) Apply Displacement constraints, (c) Total Deformation

6.4 Run solver for result

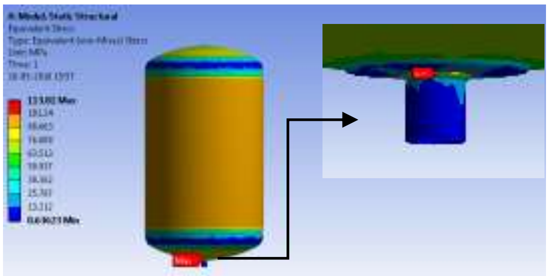


Figure 6.4 - Von mises stress result

- The maximum von mises stress is 113.81 Mpa and total deformation of the pressure vessel is 0.82 mm. Now for validation of model changes in the mesh size is carried out and achieved the stress near calculated stress for validation purpose.

6.5 Variation in Mesh size

Table 5– Different mesh size results

No.	Element types	Mesh size at pressure vessel (mm)	Mesh size at weld joint (mm)	Von-mises stress at weld joint(Mpa)	Total deformation (mm)
1	Tetrahedral	90	6	113.81	0.82
2	Tetrahedral	80	6	128.6	0.82
3	Tetrahedral	80	7	123	0.80
4	Tetrahedral	100	5	140.89	0.84
5	Tetrahedral	120	5	160.66	0.85
6	Tetrahedral	130	5	164.05	0.87
7	Tetrahedral	130	4	168.86	0.87
8	Tetrahedral	130	3	147.51	0.87
9	Tetrahedral	130	4.5	154.46	0.87
10	Tetrahedral	120	4	166.93	0.87
11	Tetrahedral	110	4	163.81	0.86
12	Tetrahedral	115	4	155.68	0.85
13	Hexahedral	80	6	218.65	0.80
14	Hexahedral	80	7	204.51	0.80
15	Hexahedral	90	7	135	0.80
16	**Hexahedral**	**90**	**6**	**174.8**	**0.80**
17	Hexahedral	90	5	193	0.80

- By changes of various mesh size and meshing element for validating the model to desire result of von mises stress and deformation. Mesh sizes are also major considerable for meshing a 3D model.
- For validation of model selection of hexahedral element types at mesh size of shell dish and nozzle is 90 mm and 6 mm mesh size choose for the weld joint.

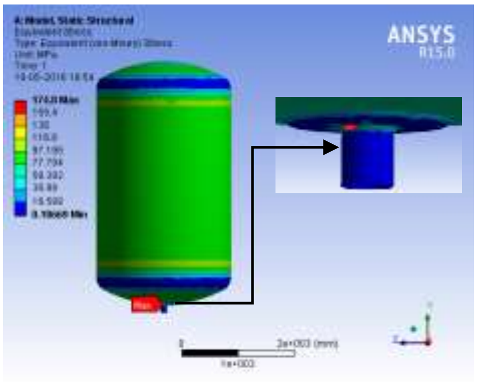


Figure 6.5 -Von mises stress result

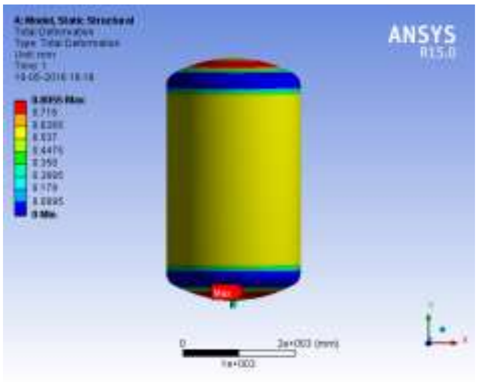


Figure 6.6 -Total deformation of structure

- The maximum von mises stress is 174.8 Mpa and total deformation of the pressure vessel is 0.80 mm.
- Stress is achieved by simulation is nearer to calculated stress. Deformation of pressure vessel is 0.80 mm so it is negligible deformation.

6.6 Validation of model by comparing von mises stress

Table 6- comparison table

Analytical von mises stress	By analysis in Ansys von mises stress
168.19 Mpa	**174.8 Mpa**

From above comparison the model validates by both stress result from analytical and by Ansys simulation result at 9 kg/cm2 internal pressure the difference is 6.61 Mpa so model validated by 4 % error. So we can take this model as same behaviour as experimental model for further changes at weld joint.

6.7 Parametric variation related to weld joint

V - joint

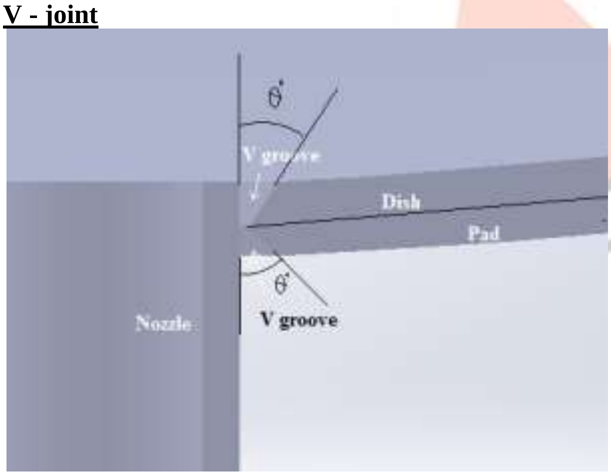


Figure 6.7 - V joint preparation

Table 7 – Changes of V- joint angle

No.	Change joint angle (θ)	Von-mises stress Mpa.	Deformation (mm)
1	**N/P 30° – N/D 30 °**	**129.17**	**0.91**
2	N/P 30° – N/D 45°	172.01	0.82
3	N/P 45° – N/D 45°	166.44	0.83
4	N/P 60° – N/D 30°	204.14	0.80
5	N/P 60° – N/D 45°	305.45	0.80
6	N/P 60° – N/D 60°	152.02	0.80
7	N/P 45° – N/D 60°	161.03	0.80
8	N/P 30° – N/D 60°	143.68	0.80

Where, N/D - Nozzle to bottom head dish joint, N/P – Nozzle to pad joint

- N/P 30° – N/D 30 °   N/P 30° – N/D 45°

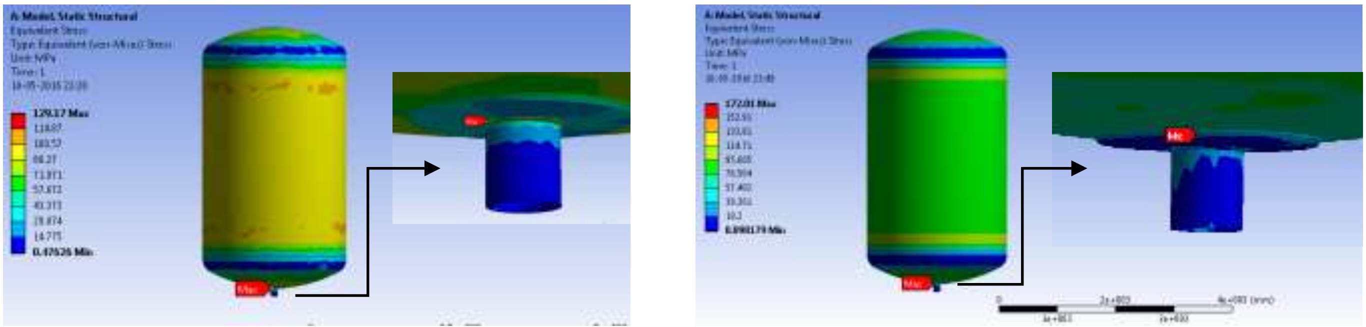
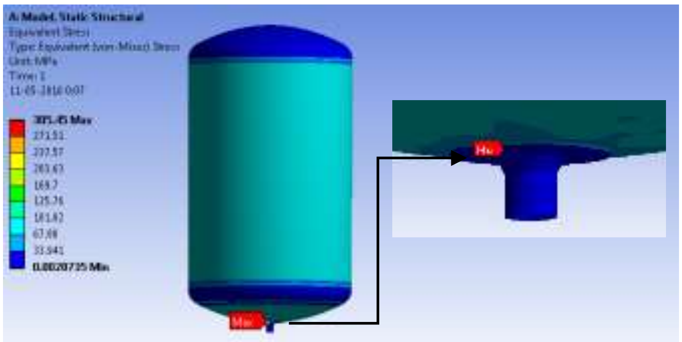


Figure 6.8 – Von mises stress

- N/P 60° – N/D 45°



N/P 60° – N/D 60°

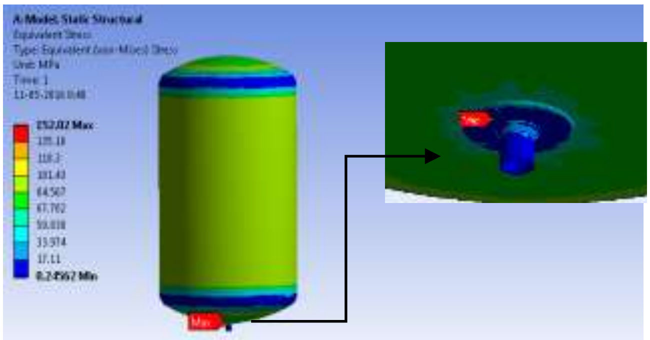


Figure 6.9 – Von mises stress

Some of von mises stress results V-Joints are shown in above figure. The lowest von mises stress is taking from the table as N/P 30° – N/D 30 ° Joint is 129.17 Mpa.

6.8 U – Joint

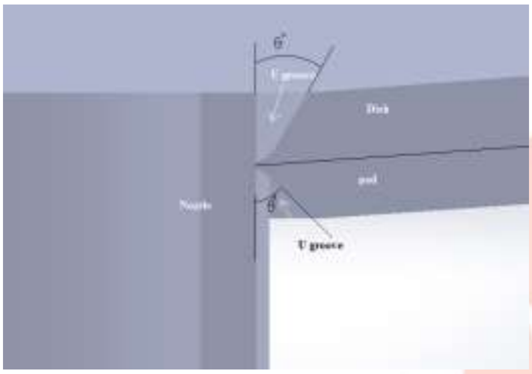
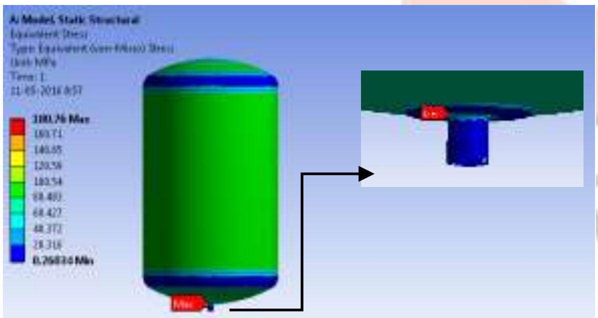


Figure 6.10 - U joint preparation

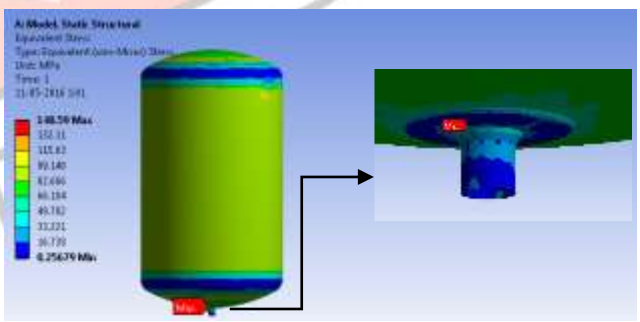
Table 8– Changes of U- joint angle

No.	Change joint angle (θ)	Von-mises stress Mpa.	Deformation (mm)
1	N/P 45° – N/D 30°	195.12	0.80
2	N/P 30° – N/D 45°	180.76	0.80
3	N/P 60° – N/D 30°	148.59	0.80
4	N/P 60° – N/D 45°	150.95	0.80
5	N/P 60° – N/D 60°	168.06	0.80
6	N/P 45° – N/D 60°	160.86	0.80
7	N/P 30° – N/D 60°	186.65	0.80
8	N/P 30° – N/D 30°	245.05	0.81
9	**N/P 45° – N/D 45°**	**148.48**	**0.80**

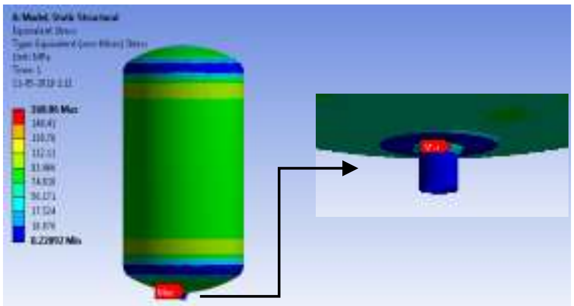
- P 30° – N/D 45 °



N/P 60° – N/D 30 °



- N/P 60° – N/D 60 °



N/P 45°- N/D 45°

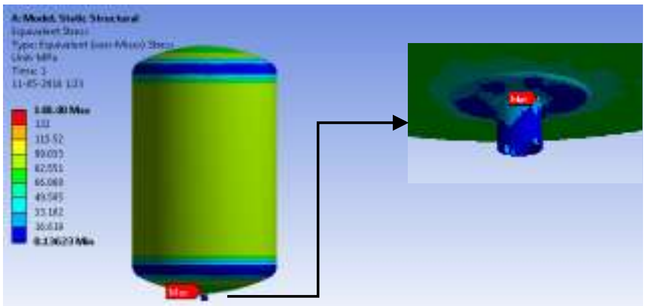


Figure 6.11 – Von mises stress result for U joint

Some of von mises stress results of U Joints are shown in above figure. The lowest von mises stress is taking from the table as **N/P 45° – N/D 45° joint** is 148.48 Mpa.

6.9 U-V joint

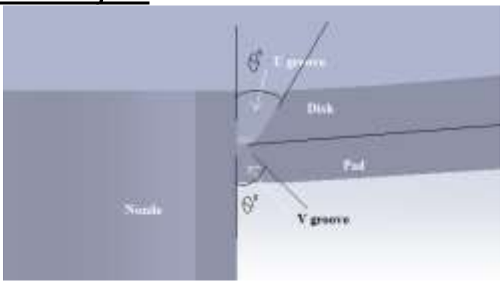


Figure 6.12- U-V joint preparation

Table 9– Changes of V-U - joint angle

No.	Change joint angle(θ)	Von-mises stress Mpa.	Deformation (mm)
1	V-N/P 45° & U-N/D 30°	209.62	0.81
2	**U-N/P 45° & V-N/D 30°**	**153.88**	**0.80**

Where, V- N/P - V joint with nozzle to pad, U- N/P - U joint with nozzle to pad
V- N/D – V joint with nozzle to bottom head dish, U- N/D – U joint with nozzle to bottom head dish

❖ U-N/P 45° & V-N/D 30°

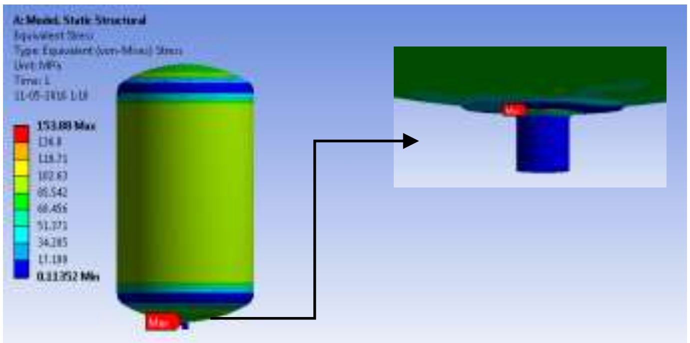


Figure 6.13 – Von mises stress

- For U V Joint lowest von-mises stress U-N/P 45° & V-N/D 30° is 153.88 and deformation 0.88 which is negligible.

6.10 V- J Joint

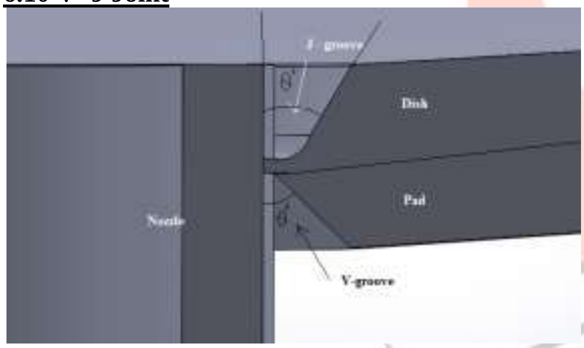


Figure 6.14 - V-J joint preparation

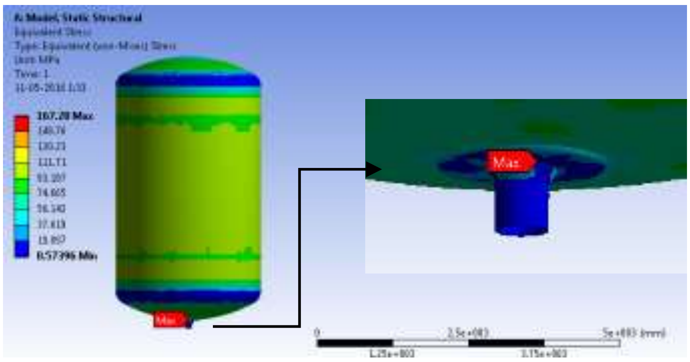
Table 10 – Changes of V-J joint angle

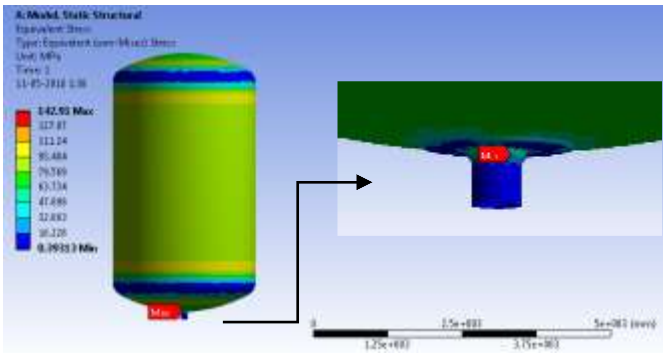
No.	Change joint angle(θ)	Von-mises stress Mpa.	Deformation (mm)
1	V- N/P 60° & J-N/D 30°	178.37	0.80
2	V- N/P 60° & J-N/D 45°	167.28	0.79
3	**V- N/P 60° & J-N/D 60°**	**142.91**	**0.80**
4	V- N/P 45° & J-N/D 30°	199.89	0.79
5	V- N/P 45° & J-N/D 45°	410.27	0.80
6	V- N/P 45° & J-N/D 60°	315.96	0.80
7	V- N/P 30° & J-N/D 30°	171.16	0.80
8	V- N/P 30° & J-N/D 45°	209.76	0.79
9	V- N/P 30° & J-N/D 60°	237.14	0.79

- J – Joint is use for the plate thickness between the 12.70 to 19.90 mm, so in this study J- groove is created only in the plate of dish of pressure vessel. R.F pad thickness is less than requirement of the J- joint so J-joint is not created at the pad. The various combinations also simulate and put the results of stress and deformation in the table.

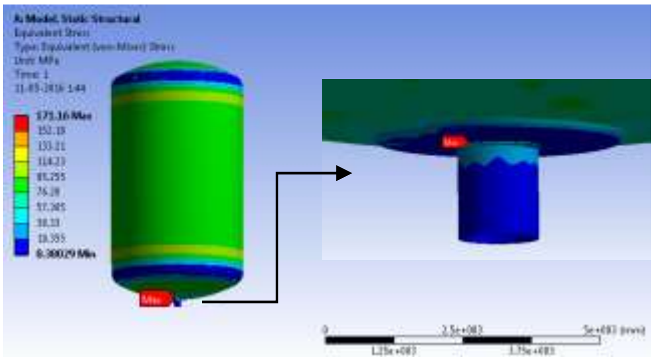
Where, V-N/P – V joint with nozzle to pad , J- N/D – J joint with nozzle to bottom head dish

❖ V- N/P 60° & J-N/D 45° V- N/P 60° & J-N/D 60°





- V- N/P 30° & J-N/D 30°



V- N/P 30° & J-N/D 60°

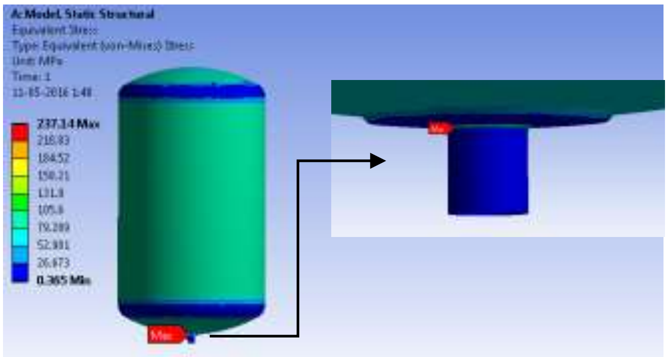


Figure 6.15 – Von mises stress

Some of von mises stress results of V-J Joints are shown in above figure. The lowest von mises stress is taking from the table as **V- N/P 60° & J-N/D 60° joint** is 142.91 Mpa.

CHAPTER 7 – RESULT AND DISCUSSION

Experimental test to check the leakage & strength of the reactor pressure vessel are done with hydrotest. Experimental result shows that there is leakage in reactor & it cannot sustain pressure as per defined design limit, also.

Selection of materials is also important consideration in case of design of pressure vessel reactor. Experimental model have been manufactured from AISI316 SS material. In such case chemical analysis of AISI316 SS material is done 10 mm thick shell & 14 mm thick head cap. Results shows that the chemical composition of tested material as per ASTM standard. Pressure vessel is manufactured with fabrication techniques. In fabrication different welded joints are used which are selected as per material thickness. Welded joints are also defined the strength of product. In such case NDT method die penetration have been done on fabricated model. From these test some of surface defects such as crack, porosity & lack of penetration have been obtained. These defects are improved with reweld the section. FEA is one of the best methods, which eliminate the expensive trial & error process in the development of the products. FEA tool have been choose & will be analyze the model.

From the industrial data of design of pressure vessel choose for analysis of weld joint at the nozzle location. The parameter of weld joint angle and grooves are changes for analyse the effect on weld joint.

Mesh size is also important for analysis of model because small mesh size generates more accurate result then larger size of mesh.

The stress level indicates the strength of the weld joint. Small amount of stress level at weld joint indicate the higher strength of weld joint and larger amount of stress level indicate lower the strength of weld joint.

From the four tables select one best joint combination form one table as from the 4 tables select 4 combinations is selected which is shown in below table. There are four combinations of different different types of grooves that are show less von mises stress at weld joint.

Table 11- Best combination table

No.	Joint	Von mises stress	Deformation
1	**V joint N/P 30° – N/D 30°**	**129.17**	**0.91**
2	**U** joint N/P 45° – N/D 45°	148.48	0.80
3	**U-V** joint N/P 45° – N/D 30°	153.88	0.80
4	**V-J** joint N/P 60° – N/D 60°	142.91	0.80

After the analysis of different-different types of weld joint at the location of nozzle to bottom dish of pressure vessel the **V joint at N/P 30° – N/D 30 °** joint configuration is shows lower amount of stress 129.17 at weld joint than another joint configuration.

CHAPTER 8- CONCLUSION

The analytical calculation and FEA result are carried out for validation point. Hydrotest pressure as internal pressure is used to validate the model. Weld joint at nozzle location is selected for the analysis by variation in angle and shape of grooves. There V, U & J grooves and 30, 45, 60 angles selected for the analysis. From the overall simulation process weld joint strength is increased by selecting the best weld joint configuration of angle with grooves.

From the analysis of 27 joint configurations "V joint N/P 30° – N/D 30°" combination of angles shows the minimum result at the weld joint location. V joint N/P 30° – N/D 30° shows less von mises stress then the experimental validated model's von mises stress, so the strength of weld joint V joint N/P 30° – N/D 30° is higher than the experimental validated model. Overall increase the strength of pressure vessel by using this joint configuration.

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