Design Upgradation and Three Dimensional Finite Element Fatigue Analysis on Composite Pressure Vessel

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Abstract- A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The ever increasing demands for axisymmetric pressure vessels have high applications in chemical and nuclear industries, fluid transmitting plant, power plants and other hand in the military equipment's. An existing Pressure vessel designed with ASME section VIII, edition 2004 - addenda 2005, is proposed to modify with ASME section VIII, with edition 2010 - addenda 2011to increase its life time by reducing corrosion at inner surface of the vessel. In our project work the strength analysis of the vessel is calculated by using PASSAT software.

***Keywords* – Weld Over lay, ASME, Composite pressure vessel, Passat software....**

I. INTRODUCTION

This widespread need for the pressure vessel has turned the attention of design engineers to this particular area of engineering researches. We come to know about design up gradation requirement in industry for pressure vessel through in inter alloy industrial solutions Pvt. Ltd. This project works elaborates the design up gradation and weld overlay details of an existing pressure vessel to reduce corrosion level. Three dimensional finite element analysis is carried out in the pressure vessel CAD model before fabrication calculation of vertical steel tanks, designed oil product storage, is performed via module "PASSAT- Reservuary" ("PASSAT-Tanks")

1.1 DESIGN UPGRADATION OF PRESSURE VESSEL

All the pressure vessels are manufactured under ASME Boiler and Pressure Vessel Codes and standards. The pressure vessels are manufactured to operate at desired conditions for its life time. Some times in order to obtain the maximum life time the client may decide to upgrade the pressure vessel instead of fabricating new one. Pressure vessel of ASME section VIII, edition 2004 - addenda 2005, is proposed to modify with ASME section VIII, with edition 2010 - addenda 2011.

1.2 DESIGN &ANALYSIS

1.2.1. Pressure Vessel Design using Passat

PASSAT is strength analysis software for vessels and their elements designed for estimating load-carrying capacity in operation, test and assembly states. PASSAT is the basic module, which analyzes strength and stability of horizontal and vertical vessels using Russian& Americanstandards. PASSAT-Columns module analyzes strength and stability of columns considering wind and seismic loads. PASSAT-Heat Exchangers module analyzes tube and casing heat exchangers (HE), including analysis of tube plates, tubes, pass partitions, casing, expansion joints, expansion vessel, floating head.[8]PASSAT-Nozzle module analyzes strength of nozzles, dished heads and flange joints under pressure and external loads using ASME and WRC standards.[9]

1.2.2 Basic components

a) Input data

Component	Material	Diameter(mm)	Wall thickness(mm)	Length (height)(mm)	TotalAllowance (mm)	Weld strength ratio
Ellipsoidal head No.1	SA-516 Gr.70	1500	24	541	3.5	1
Cylindrical shell No.1	SA-516 Gr.70	1500	28	2575	3.5	1
Ellipsoidal head No.2	SA-516 Gr.70	1500	24	541	3.5	1

1.2.3 Calculation results

a) Operating conditions

Component	Calculation temperature(°C)	Calculation pressure (MPa)	Allowable stresses (MPa)	Effective thickness including allowances(mm)	Allowable pressure (MPa)	Strength Condition
Ellipsoidal head No.1	60	3.821	166.1	19.1	5.011	Fulfilled
Cylindrical shell No.1	60	3.821	166.1	20.95	5.34	Fulfilled
Ellipsoidal head No.2	60	3.82	166.1	19.1	5.011	Fulfilled

b) Test conditions

Component	Calculation pressure (MPa)	Allowable stresses (MPa)	Effective thickness including allowances (mm)	Allowable pressure (MPa)	Strength Condition
Ellipsoidal head No.1	5.012	238.2	17.77	7.185	Fulfilled
Cylindrical shell No.1	5.007	238.2	19.43	7.656	Fulfilled
Ellipsoidal head No.2	4.982	238.2	17.68	7.185	Fulfilled

1.2.4 Nozzles

a)Input data

Component	Label	Type	Material	Diameter (mm)	Wall thickness (mm)	Length (height) (mm)	Total allowance (mm)

Nozzle No.2	Nozzle No.2	Without additional reinforcement	SA-105	652	30	300	1.5
Nozzle No.1	Nozzle No.1	With pad	SA-105	562	24	411	1.5
Nozzle No.3	Nozzle No.3	Without additional reinforcement	SA-105	652	30	300	1.5

1.2.5 Calculation results

a) Operating conditions

Component	Calculation temperature(°C)	Calculation pressure (MPa)	Diameter of the hole, which does not require any reinforcement (mm)	Allowable pressure(MPa)	Strength Condition
Nozzle No.2	60	3.821	241.7	3.858	Fulfilled
Nozzle No.1	60	3.82	231.6	4.725	Fulfilled
Nozzle No.3	60	3.82	241.9	3.858	Fulfilled

b) Test conditions

Component	Calculation pressure (MPa)	Diameter of the hole, which does not require any reinforcement (mm)	Allowable pressure (MPa)	Strength condition
Nozzle No.2	5.015	299.1	5.53	Fulfilled
Nozzle No.1	4.992	284.6	6.773	Fulfilled
Nozzle No.3	4.977	304.4	5.53	Fulfilled

1.2.6 Filling calculation

Component	Full volume (m^3)	Product volume (m^3)	Height of product column (mm)	Max. height of product column at 100% (mm)	ξ
Ellipsoidal head No.1	0.67	0.67	$3.6 \cdot 10^3$	$4.3 \cdot 10^3$	1
Nozzle No.2	0.10	0.10	$4 \cdot 10^3$	$4.6 \cdot 10^3$	1
Flange joint No.3	0.13	0.13	$4.4 \cdot 10^3$	$5 \cdot 10^3$	1
Cylindrical shell No.1	4.6	4.6	$3.1 \cdot 10^3$	$3.8 \cdot 10^3$	1
Nozzle No.1	0.10	0.10	$1.6 \cdot 10^3$	$2.3 \cdot 10^3$	1
Flange joint No.1	0.079	0.079	$1.6 \cdot 10^3$	$2.3 \cdot 10^3$	1
Ellipsoidal head No.2	0.67	0.67	550	$1.2 \cdot 10^3$	1
Nozzle No.3	0.10	0.0046	14	680	0.046
Flange joint No.2	0.13	0	0	380	0

1.3 Finite Element Analysis

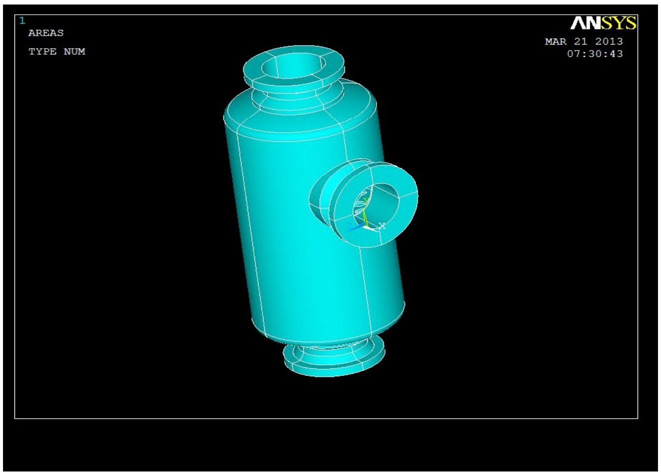
During the last three decades considerable advances have been made in the applications of numerical techniques to analyze the pressure vessel problem. Numerical solutions to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of Mechanics of Materials such as these modules should outline its principal features. It is estimated that 50-90% of structural failure is due to fatigue, thus there is a need for quality fatigue design tools.[4]

1.3.1 Structural Analysis of the Pressure Vessel

The structural analysis on the designed pressure vessel is performed by using the Ansys software. The following steps are followed to perform the finite element analysis.

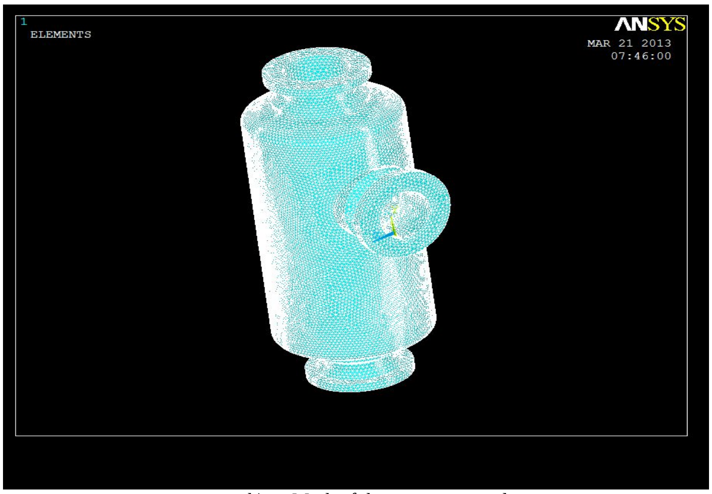
- Initially model of pressure vessel is created in ANSYS and mesh applied as per the requirement.
- All DOF at bottom end is arrested.
- Load applied at the top end in –Y direction with the specified value.
- The model is solved for the applied conditions as mentioned in the previous steps
- The final step is to find the value of deflection, maximum and minimum stress.

a) CAD model of the pressure vessel



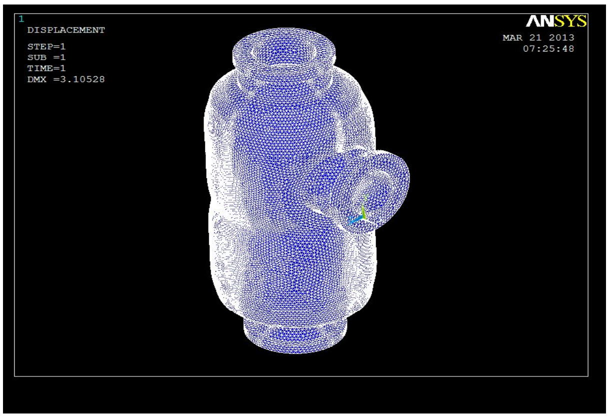
a) CAD Model of the pressure vessel

b) FINITE ELEMENT OF THE VESSEL



b) Mesh of the pressure vessel

DEFORMED SHAPE IN MESH



c) Deformed shape in mesh

1.5 COMPOSITE PRESSUREVESSEL

Material Details Of Pressure Vessel

SHELL	SA 516 GR. 70N
HEAD	SA 516 GR. 70N
NOZZLE NECK	SA 105N
INTERNAL / EXTERNAL SUPPORT	SA 516 GR. 70N
FORGINGS	SA 105N
NUT / STUDS	SA 193 B7 / SA 194 2H

1.5.1 Weld Overlay

Corrosion is an important issue to deal with in the operation and maintenance of processing equipment in petroleum refining.The corrosion level of the pressure vessel is controlled by making the weld overlay. The weld overlay is the process of joining one layer of metal to another layer. Weld overlay is an advanced welding technology that delivers permanent repair and upgrade solutions.[6]The material to be used for making of weld overlay is **NiCrMo-3**. It is a **nickel-chromium-molybdenum flux-coated electrode** designed for shielded metal-arc welding for high strength welds.Weld overlay had been used in the past as a temporary, “Band-Aid” type repair in the field until a somewhat permanent fix could be developed to address the corrosion problem. The present paper discusses briefly the status of the modern overlay technology for applying a corrosion-resistant alloy as an overlay in the field to the existing equipment for corrosion control.

1.5.2 CHEMICAL COMPOSITION:

(Ni Cr Mo3)

C	Si	Mn	Fe	Ni	Mo	Nb& Ta	Cr
0.06	0.44	0.73	5.07	60.18	8.75	3.50	21.5

1.5.3 MECHANICAL PROPERTIES:

(Ni CrMo3)

Yield Point N/mm2 (Ksi)	Tensile Strength N/mm2 (Ksi)	Elongation %
441 (64)	770 (112)	40

1.6 Result &Discussion

1.6.1 Comparison of Stress

Allowable bending stress= 0.9X yield stress

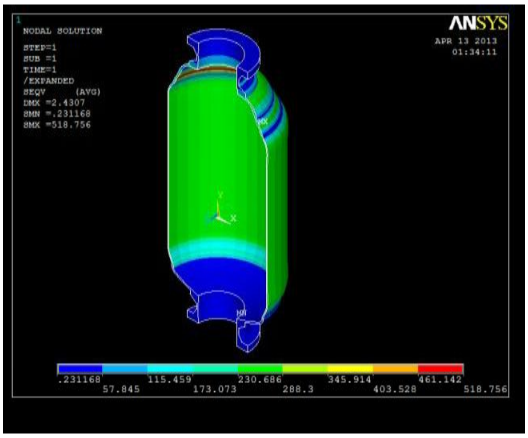
(Yield stress = 660 N/mm^2)

= 0.9X 660

Allowable bending stress = 594 N/mm^2

a)Pressure vessel without thickness

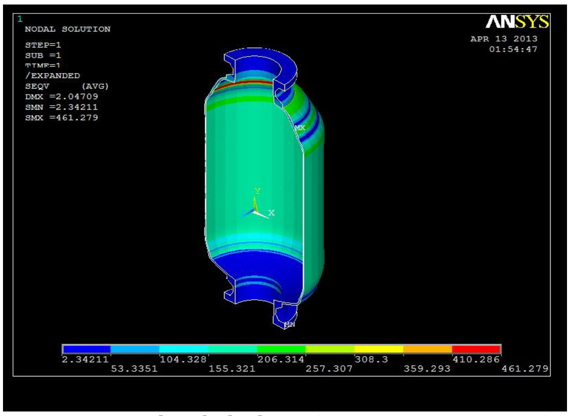
Smx = 518.756 < 594 N/mm^2



Pressure vessel without thickness(SA516 Gr70)

b)Pressure vessel with thickness

Smx = 461.279 < 594 N/mm^2

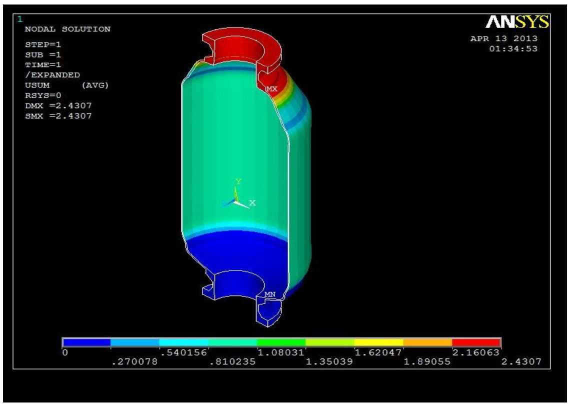


Pressure vessel with thickness(SA516 + Ni Cr Mo – 3)

1.6.2 Comparison of Deflection

a) Pressure vessel without thickness

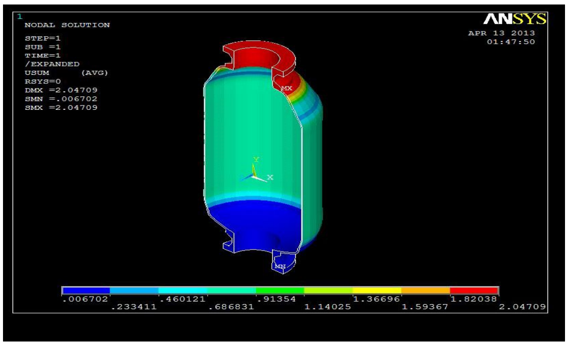
Dmx = 2.430 mm.



Pressure vessel without thickness(SA 516 Gr 70)

b) Pressure vessel with thickness

Dmx = 2.04mm



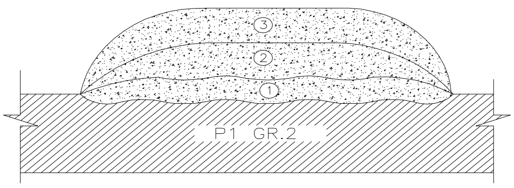
Pressure vessel with thickness(SA 516 Gr 70+ Ni Cr Mo-3)

WELDING PROCEDURE SPECIFICATION

WELDING PROCEDURE SPECIFICATION				**WPS # 073** REV. # 00 DATE: 01/02/2006
Welding Process(es) : SMAW Type(s) : Manual (Automatic, Manual, Machine or Semi Auto)				Supporting PQR # 073
CODES: ASME Section. IX Edition 2010 Addenda 2011				
BASE METALS (QW-403) Incoloy 825 weld overlay on Carbon steel base material				
F.No. 43	Group No. ----	on	P.No. 1	Group No. 2
OR				
Specification Type & Grade : SA 516 GR 70				
Specification Type & Grade : SA 105				
OR				
Chem. Analysis & Mech. Properties : ------				
TO				
Chem. Analysis & Mech. Properties : -------				

Thickness ranges qualified for :	
Base Metal :	20mm
Deposited filler metal :	3mm and above
DiameterRange Qualified : All	

JOINTS (QW- 402)



Overlap between the beads: Min ½ bead width
To max 2/3 bead width

FILLER METALS (QW- 404)	1st Layer	2nd& 3rd Layers
Spec. No. (SFA)	5.11	5.11
AWS No. (Class)	E Ni Cr Mo-3	E Ni Cr Mo-3
F. NO.	43	43
A- NO /Chem. Composition	--	--
Size of Filler Metals (mm)	3.2	3.2 & 4.0
Weld Metals ThicknessRange:	2mm (Min)	3mm (Min)
Electrode-Flux (Class)	NA	N/A
Flux Trade Name	NA	N/A
Consumable Insert	Not Required	N/A
Flux (404.50	N/A	-

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WPS # 073 Rev. 00

POSITIONS (QW-405)	POSTWELD HEAT TREATMENT (QW-407)			
Position(s) of Groove: N/A	TemperatureRange: 610° C			
Welding Progression: Forehand	TimeRange: 3 Hrs 30 Mins			
Position(s) of Fillet: NA	Heating Rate	100° C/Hr	Cooling Rate	100° C/Hr

PREHEAT (QW-406)	GAS (QW-408)			
Preheat Temp. (Min.): 16^0C		Percent Composition		
Interpass Temp (Below.): 175^0C		Gas(es)	(Mixture)	Flow Rate
Preheat Maintenance : Not Required	Shielding	NA	-	-
	Trailing	NA	-	-
(Continuous or Special heating where applicable should be recorded)	Backing	NA	-	-

TECHNIQUE (QW-410)	
String or Weave bead: Both	Oscillation: N/A
Max. Weave Width: 3 X electrode diameter	Contact tube to work distance: NA
Orifice/Gas cup size: N/A	Multiple/Single pass (per side):Multiple
Initial Cleaning: Wire Brush / Grinding -SS	Multiple/Single Electrode(s): Single
Interpass Cleaning: Wire Brush / Grinding-SS	Travel Speed (Range): Refer the table below
Method of back gouging: N/A	Peening: Not Required
Other: --	Time between R&H.pass: N/R

ELECTRICAL CHARACTERISTICS (QW-409)	
Current (A.C./D.C.): DC	Polarity: Reverse

Amps (Range) : Refer table below	Volts (Range): refer table below
Tungsten Electrode Size & Type: N/A	Mode of metal Transfer for GMAW: N/A (Spray arc, short circuting arc, etc.)

Electrode/Wire Feed Speed Range:

Weld Layer(s)	Process	Filler Mettal		Current		Volts (Range) (V)	Travel Speed (Range) mm/min	Other
		Class	Dia	Type & Polarity	Amp. Range (A)			
1	SMAW	E NiCrMo-3	4.0 mm	DCEP	110-120	24 – 30	25- 75	NA
Others	SMAW	E NiCrMo-3	3.2 mm	DCEP	90-110	24 -30	25-100	NA

REMARKS
- First layer to be deposited by 4mm diameter electrode only.
- No increase of 10% amperage used in 1st layer.
NR- Not Required
N/A – Not Applicable

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II. CONCLUSION

The modern weld overlay technology for applying a corrosion-resistant Ni Cr Mo-3 as an overlay in the existing equipment for corrosion control had been discussed. The WPS had been prepared for the fabrication of composite pressure vessel which includes Ni Cr Mo-3 weld overlay on SA 516 Gr 70.A focus of finite element fatigue analysis is to provide useful information to the design engineer when fatigue failure may be a concern. FE fatigue analysis is carried out and the results has to be included and discussed in this paper.

REFERENCES

[1] H.Darijani, M.H.Kargarnovin, R.Naghdabadi “Design of thick-walled cylindrical vessels under internal pressure based on electro-plastic approach” material and Designvol.30, pp.3537–3544, (2009).

[2] MaëlCOUCHAUX , Ivor RYAN , Mohammed HJIAJ “Stress concentration factors for the fatigue design of tubular flange connections” pp.255-262 (2009). [3] Dr NWM Bishop, MSC Firmley and Alan caserio.MSC Costa Mesa “finite elementbased fatigue analysis” pp.10-15 (1998).

[3] Dr NWM Bishop, MSC Firmley and Alan caserio.MSC Costa Mesa “finite elementbased fatigue analysis” pp.10-15 (1998).

[4] D. Alfred Hancq, Ansys inc. “Fatigue Analysis Using ANSYS” pp.8-20 (2004).

[5] JaroslavMackerle “Finite element in the analysis of pressure vessels and piping, an addendum: A bibliography (2001-2004)” international journal of pressure vessel and piping vol.82,pp.571-592(2005).

[6] George Lai and Philip Hulsizer Welding services Inc. “Corrosion control by modern weld overlay technology” pp.3-12 (2006).

[7] Dr.AndrejTrkov and Dr.IgorLengar“Influence of repair length on residual stress in the repair weld of a clad plate”Vol.246, pp.211–219(May 2012).

[8] GOST 52857.5-2007. Vessels and apparatuses.Norms and methods of strength calculation. Calculation of the shells and heads from influence of support loads.

[9] GOST 52857.2-2007. Vessels and apparatuses.Norms and methods of strength calculation. Calculation of cylindrical and conical shells, dished and flat bottoms and covers.