

Influence of Submerged Arc Welding on Glass Lining Of Glass Lined Lined Reactor Vessel

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Abstract— Glass lined reactor vessel for mixing and storage has a unique advantage of higher corrosion resistance, retention of product flavour and purity, improved heat transfer and less frequent cleaning. Welding close to the glass-lined surface is at times the unavoidable need. However, such needs are to be dealt critically as the rise in the temperature of the glass-lined surface can lead to a failure of glass-lining. This failure results in considerable delay as rework in lining the glass takes 5-7 days and it involves considerable extra cost of reworking. The glass lined reactor vessels are provided with jacket for thermal insulation. The jacket is welded to main vessel by a closure ring. CO₂ welding in the root run and Sub-merged Arc Welding (SAW) process for subsequent passes. The cooling time of 15 to 20 minutes is provided between the successive SAW passes so that the shell surface cools down and temperature does not exceed the failure limit of glass-lining. The temperature measurements were initially measured with infrared pyrometer and Results are compared with thermal analysis by FEA. We see in the final pass of SAW process the temperature exceeds 100 °C though the cooling time of 15-20 minutes is provided between the successive passes and temperature does not exceeds the failure limit of 150 °C as well as the 3-4 °C/min temperature difference in heating and cooling rates.

Keywords— Glass Lined Reactor Vessel, SAW on Glass Lining, FEA, steady state Transient Analysis

I INTRODUCTION

In the present scenario, significant process in the field of Thermal Analysis of various component or mechanical part has been made and FEA is gradually becoming established as an efficient tool in comparing actual result obtained by experiment .Using FEA Analysis, Which is a general and systematic computational procedure for approximately solving problem in physics and engineering, many thermal problem from simple to complex, solved and compare its actual result with high accuracy. The FEM can be considered the approximate method to treat thermal problems..

II LITERATURE SURVEY OF GLASS LINED REACTOR VESSEL

David Frey et al. [2] carried out experiment in corrosion environment for Tantalum clad reactor vessel. David s. Dickey et al. [3] carried out experiments to understand the performance of glass lined reactor equipped with a retreat curved impeller and finger baffle. Based on engineering standard for lining original edition, August 2004,[4].Glass lining are used for protection of ferrous metals equipment such as reactors, storage tanks, pipes and valves in against corrosive environments. Based on catalogue of De-Dietrich DD3900 process system [5], Glass-lined steel is mandatory when service conditions of the process are particularly difficult. The large majority of equipment is designed with a system that enables the heating and cooling of their contents.

III PROBLEM FORMULATION

A determination and Finite Element Analysis of transient temperature field in and around the weld joint of jacket end and closure ring to prevent cracking / fusing / breaking of glass lining. The inner glass lining of jacket end shell is at about 75 mm away and 40 mm above the weld joint the joint angle is the 55°, root face is 1.5 to 2 mm, and root gap is 3 to 5 mm. The selected specification of the welding at joint as: In the root-pass CO₂ welding current is kept in range of 180 to 210 amperes with 35 volts. The current and voltage for SAW welding process for subsequent passes is between the range of 300 to 350 amperes and 30 to 35 volts respectively. Polarity in both the welding process is kept DCEP produces deeper penetration. The welding position is 1G for welding of jacket and closure ring.

- 1) **Material Specification:** Material for Jacket, sealer and shell is SA516Gr380 and for Backing strip is M.S. and Ultimate Tensile Strength: 380-515 Mpa and Yield Strength: 250 Mpa[1]



Figure. 1 Weld junctions of closure ring and jacket

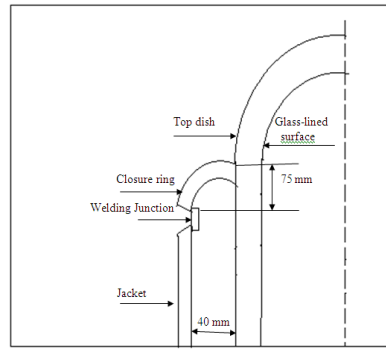


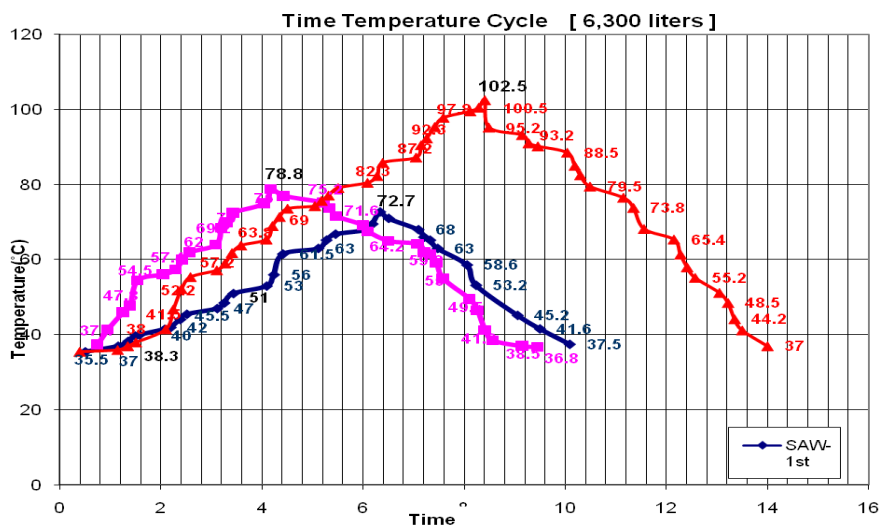
Figure. 2. Location of Welding Junction (NTS)

IV PROCESS SEQUENCE AND SOLUTION METHODOLOGY

The root pass is carried out manually with CO2 welding process for 3 to 5 mm root gap and 1.5 to 2 mm root face. The glass would crack / fuse / break above 150 ° C.(1)The cooling time after the root pass is given for 15 to 20 minutes as continuous welding might result in rise of temperature above 150 ° C.(2)Submerged Arc Welding process is then carried out for the subsequent passes as deposition rate is to be kept higher and to minimize welding time.(3)The cooling time of 15 to 20 minutes is also given between two successive passes of SAW welding process.(4)The welding speed in the final pass is maintained at 3-5 mm/sec to ensure weld of higher width.(5)Prepare a quarter section of 10,000 liters capacity vessel to determine the transient temperature field in an area (120 mm × 120 mm) located at junction of closure ring end and shell on glass-lined surface (6) Measure the temperature at pre-defined point on glass coated surface with time through optical pyrometer for different capacity of vessels.(7) find critical temperature and compare the results of temperature which taken by pyrometer with thermal analysis by ANSYS(APDL) and determine the conditions for failure of the glass.

Table1: The maximum temperature recorded for different capacity reactor vessels at each pass

Reactor vessel (litres)	Maximum Temperature recorded in °C		
	SAW-First Pass	SAW- Second Pass	SAW- Final Pass
2,000	63.3	73.4	105.5
3,000	67.5	73.4	101.4
5,000	70.3	91.5	104.6
6,300	72.7	78.8	102.5



Graph 1. Time Temperature cycle for 6,300 liters Reactor vessel

V THERMAL ANALYSIS

A thermal analysis calculates the temperature distribution and related thermal quantities in Glass lined reactor vessel. Typical thermal quantities are: 1. The temperature distribution, 2. The amount of heat lost or gained, 3. Thermal fluxes .Here we consider both steady state and transient Analysis.

1) Finite Element Formulation for Heat Conduction and convection:

The first law of thermodynamics states that thermal energy is conserved. Specializing this to a differential control volume:

$$\rho c \left(\frac{\partial T}{\partial t} + \{v\}^T \{L\} T \right) + \{L\}^T \{q\} = \ddot{q} \quad [13],[14] \text{Equation.-1}$$

Where:

ρ = density (input as DENS on MP command)

c = specific heat (input as C on MP command)

T = temperature (=T(x,y,z,t))

t = time

$$\{L\} = \begin{Bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \\ \frac{\partial}{\partial z} \end{Bmatrix} = \text{vector operator}$$

$$\{v\} = \begin{Bmatrix} v_x \\ v_y \\ v_z \end{Bmatrix} = \begin{matrix} \text{velocity vector for mass transport of heat} \\ \text{(input as VX, VY, VZ on R command,} \\ \text{PLANE55 and SOLID70 only).} \end{matrix}$$

$\{q\}$ = heat flux vector (output as TFX, TFY, and TFZ)

\ddot{q} = heat generation rate per unit volume (input on BF or BFE commands).It should be realized that the terms $\{L\}T$ and $\{L\}^T \{q\}$ may also be interpreted as ∇T and $\nabla \cdot \{q\}$, respectively, where ∇ represents the grad operator and $\nabla \cdot$ and ∇ represents the divergence operator. Next, Fourier's law is used to relate the heat flux vector to the thermal gradients:

$$\{q\} = -[D]\{L\}T \quad [13],[14] \text{Equation.-2}$$

Where:

$$[D] = \begin{bmatrix} K_{xx} & 0 & 0 \\ 0 & K_{yy} & 0 \\ 0 & 0 & K_{zz} \end{bmatrix} = \text{conductivity matrix}$$

K_{xx} , K_{yy} , K_{zz} = conductivity in the element x, y, and z directions, respectively (input as KXX, KYY, KZZ on MP command), Combining Equation.- 1 and Equation .-2

$$\rho c \left(\frac{\partial T}{\partial t} + \{v\}^T \{L\} T \right) = \{L\}^T ([D]\{L\} T) + \ddot{q} \quad [13],[14] \text{Equation.-3}$$

Expanding Equation .3 to its more familiar form

$$\rho c \left(\frac{\partial T}{\partial t} + v_x \frac{\partial T}{\partial x} + v_y \frac{\partial T}{\partial y} + v_z \frac{\partial T}{\partial z} \right) = \ddot{q} + \frac{\partial}{\partial x} \left(K_x \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_y \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_z \frac{\partial T}{\partial z} \right) \quad \text{Equation.-4}$$

It will be assumed that all effects are in the global Cartesian system.Three types of boundary conditions are considered. It is presumed that these cover the entire element.

(1) Specified temperatures acting over surface S1: $T = T^*$ [Where T^* is the specified temperature (input on D command)]

(2) Specified heat flows acting over surface S2:

$$\{q\}^T \{\eta\} = -q^* \quad \text{Equation.-5}$$

where:

$\{\eta\}$ = unit outward normal vector

q^* = specified heat flow (input on SF or SFE commands)

(3) Specified convection surfaces acting over surface S_3 (Newton's law of cooling):

$$\{q\}^T \{\eta\} = h_f(T_S - T_B) \quad \text{Equation.-6}$$

Where:

h_f =film coefficient (input on SF or SFE commands) Evaluated at $(T_B + T_S)/2$ unless otherwise specified for the element

T_B =bulk temperature of the adjacent fluid (input on SF or SFE comd.)

T_S = temperature at the surface of the model

Note that positive specified heat flow is into the boundary (i.e., in the direction opposite of $\{\eta\}$), which accounts for the negative signs in Equation .-5 and Equation.-6

Combining Equation-2 with Equation-5 and Equation.-6

$$\{\eta\}^T [D] \{L\} T = q^* \quad \text{Equation.-7}$$

$$\{\eta\}^T [D] \{L\} T = h_f(T_B - T) \quad \text{Equation.-8}$$

Pre-multiplying Equation.-3 by a virtual change in temperature, integrating over the volume of the element, and combining with Equation.-7 and Equation.-8 with some manipulation yields:

$$\int_{vol} \left(\rho c \delta T \left(\frac{\partial T}{\partial t} + \{v\}^T \{L\} T \right) + \{L\}^T (\delta T) ([D] \{L\} T) \right) d(vol) = \int_{S_2} \delta T q^* d(S_2) + \int_{S_3} \delta T h_f (T_B - T) d(S_3) + \int_{vol} \delta T \ddot{q} d(vol)$$

where:

vol = volume of the element

δT = an allowable virtual temperature (= $\delta T(x,y,z,t)$)

2) STEP FOR ANALYSIS [ANSYS 12.0 (APDL)]

(a)Modelling -Geometry: create model in ANSYS or create model in Pro-E and import in ANSYS for 15 degree due to vessel is symmetry around the axis.(2)Preprocessor-modeling –create-key point-in active co-ordinate.(3)Define element type: Preprocessor-element type –add element (solid-70)(4)Define material properties of steel and Glass: Pre-processor-material properties –material models-material Models -1–enter values [thermal conductivity (k), specific heat (c),density of material(ρ)] and for Model-2.(5)Meshing: Pre-processor-meshing-mesh tool –set-1-hex -sweep-mesh.(6)Create component:(a) Utility menu-select-entities-volume -By number/pick-from full-ok- select volume-ok-replot.(b)Utility menu-select-entities-element-attached to-volume-from full-ok-Utility menu-plot-element.(c)select- entities-element- By number/pick-reselect-tick box-ok-replot and select- component/assembly-create component–select element and give name–ok.

(b)Apply Load: (1)**For Body load:**(1)Select first weld component of co2 pass: select-component manager select component–ok(2)Plot nodes: select entities–nodes-attached to element–from full- ok-utility menu-plot-nodes.(3)Apply body force : solution-define load-apply-thermal -Heat Generation-on nodes-pick all-enter value. Heat input (Q) = 727/3600 kJ/sec.-ok.(2)**For surface load:** (1)Un select the other weld component: select everything- plot element Select–component/assembly-select component./assembly.-by component name-ok-select kill component-unselect–ok-replot- again Select–component/assembly-select component/assembly- create component-type name–ok.(a)Select nodes related to exterior surface:–select entities –node-exterior-reselect –ok. (b)Unselect side nodes:- select entities –component manager-select component–component of side node –un select-ok-replot(c)Apply Surface Loads (Only air convection):solution-define loads-Apply–thermal –convection -on nodes-pick all-enter Values of air film Co- efficient $h=50W/m^2k$ and $T=30^0C$ (atmosphere)(d)Select all element live & kill for analysis. & use N-R Method

(c)Solution (1)Define analysis type: solution-Analysis type-new analysis :first steady state and then transient analysis.(2)solution-load step opt-time/freq-time-time step-enter value of time step.(3)Same process follow for other pass: SAW-first pass and SAW second pass(4)Plot results:General post processor-plot results-nodal solution.-temperature

Table.-2 Details of Material Properties

Material Properties	Structural steel	Glass line material (Vitreous Enamel)
Thermal conductivity K (w/m k)	60.5	0.84
Density, (kg/m ³)	7850	2400
Specific heat , C (J/Kg k)	0.24	0.84

3) Results of Steady State Thermal Analysis:

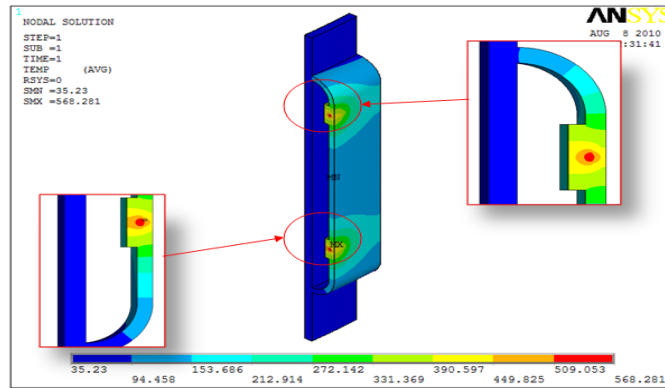


Figure 3: Temperature distribution in the reactor vessel

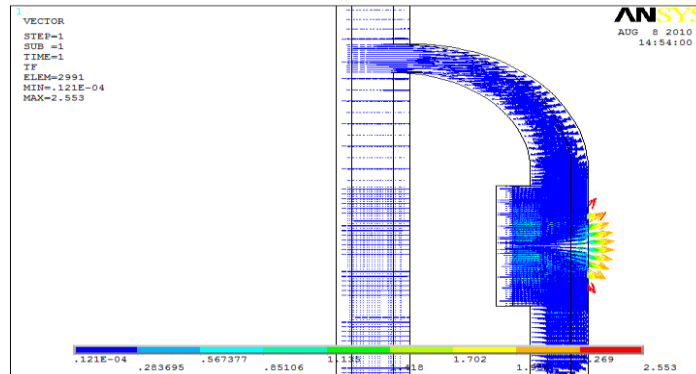


Figure 4: Heat Flux distribution in the reactor vessel

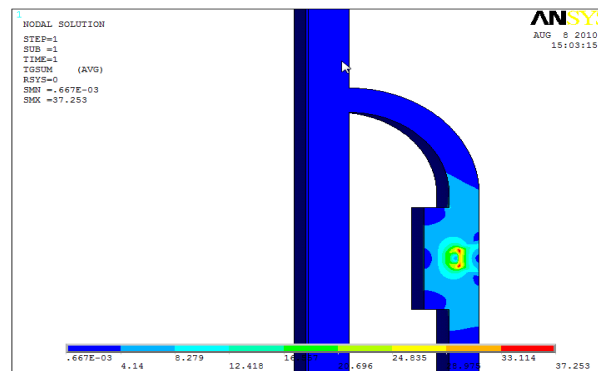
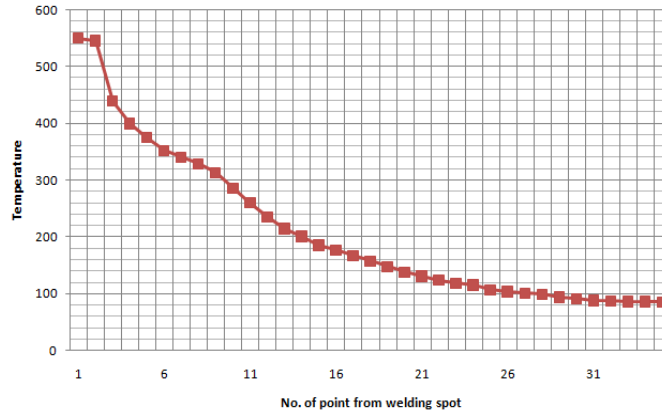


Figure 5: Average thermal gradient in the reactor vessel



Graph 1. Temperature Distribution along 75 mm closure ring

4) Results of Transient Thermal Analysis:

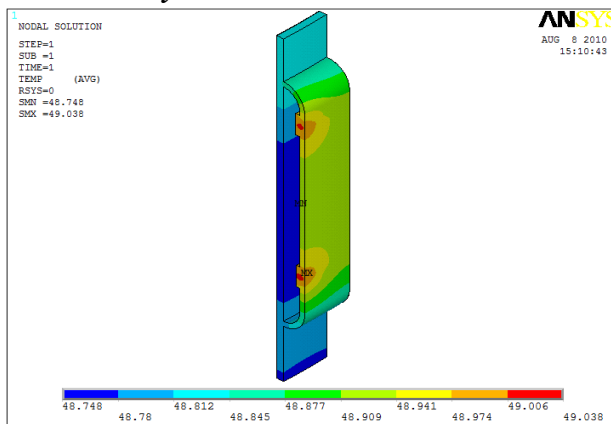


Figure 5 Temperature distributions at 1 second in the reactor vessel

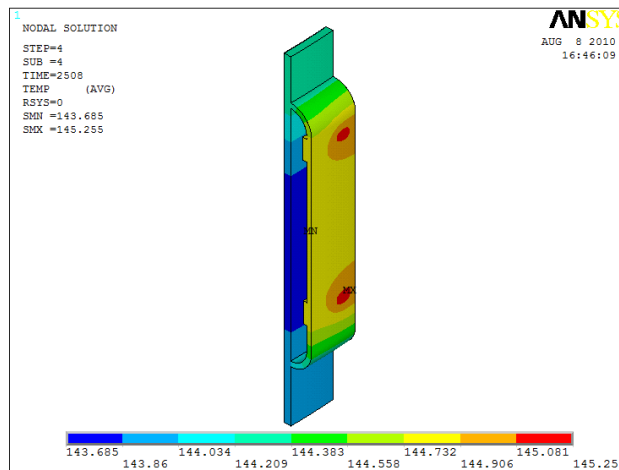


Figure 6 Temperature distributions at 2508 second in the reactor vessel

VI CONCLUSIONS

(1) We can see from the steady state thermal analysis that the temperature in and around the weld joint the glass lined with reactor vessel for the both closure rings, 75 mm closure ring and 125 mm closure ring is under the limiting value of 150°C. The observed maximum temperature at the glass lined wall is approximate 94°C (at x axis point no: 36 and y axis 94°C) for 75 mm closure ring shown in Graph.1 (2) We can see from the transient thermal analysis the temperature distribution at every time near the glass lined connection with reactor vessel steel material wall for the both closure rings, 75 mm closure ring and 125 mm closure ring is under the limiting value of 150°C . The observed maximum temperature at the glass lined wall is approximate 143°C lower than fusion temperature of glass. i.e. 150°C.

REFERENCES

- [1] Swiss Glass Coat Equipment Limited, 18th annual report 2008-2009.
- [2] David Frey, (December 1997) Astor Cosmos Metallurgical Co. and John G. Banker, V.P., DMC Clad Metal Div *Zirconium Clad Pressure Vessels Offer Cost saving in highly corrosive HCL service.*, www.twca.com/pdf/2k1ConfProc/2001019.pdf
- [3] David s.Dickey, 2004, MIXTECH,INC, *Understand Flow pattern in Glass Lined Reactor* ,Applied Process Technology Group, www.acusim.com/papers/Glass-110421.pdf , <http://www.robbinsmyers.com/process-solutions-group/tycon-technoglass>
- [4] Engineering Standard For Linings Original Edition, property of Iranian Ministry of Petroleum, IPS-E-TP-350 (updated by August 2004) <http://217.174.18.60/ips/tp/e-tp-350.pdf>
- [5] Chateau de Reichshoffen, *DE DIETRICH SAS*, Paper from sustainably managed forests ,001-04/09, endstock-Fotolia.com, http://www.diedrichddz.com/documents /Email_GB.pdf
- [6] Y. Kwon and D. C. Weckman, 2008, *Analytical thermal model of conduction mode double sided arc welding*, MAsc thesis, University of Waterloo ,Canada ,Science and Technology of Welding andJoining ,,13,(6), 485-495 , [http://www.me.uwaterloo.ca/~camj/pdf/Weckman%20Papers/\(2008\)%20Analytical%20Thermal%20Model%20of%20Conduction-mode%20Double-Sided%20Arc%20Welding.pdf](http://www.me.uwaterloo.ca/~camj/pdf/Weckman%20Papers/(2008)%20Analytical%20Thermal%20Model%20of%20Conduction-mode%20Double-Sided%20Arc%20Welding.pdf)
- [7] Sindo. Kou, 1987 ,‘Welding metallurgy’; second edition ,Library of congress catalogue, Department of material Science and Engineering , University of Wisconsin ,Toronto, John Wiley & Sons, Inc Publication ,ISBN 0-471-43491-4 http://uqu.edu.sa/files2/_tiny_mce/plugins/filemanager/files/4220115/Welding_Metallurgy_Second_Edition_-_Wiley_.pdf
- [8] C.S. Krishnamoorthy, *Finite Element Analysis , Theory and Programming* , second edition ,seventh reprint , Tata McGraw- Hill Publishing Company Limited, ISBN0-07-462210-2, <http://books.google.co.in/books?id=M0cK4Tocx9MC&pg=PR13&lpg=PP1>
- [9] Rosenthal, D., 1946,“The Theory of Moving Source of Heat and Its Application to Metal Treatments,” *Trans. ASME*, 43, (11), 849 – 866, <http://www.scribd.com/doc/30169627/>
- [10] Ansys Axis symmetric Cylinder , MENG 421 Assignment 4 , lecture notes, <http://infohost.nmt.edu/~es421/ansys/assign4.html>.
- [11] Example of Finite Element Analysis , *Thermal Stress of a Cylinder Using Axis- Symmetric Element*, <http://infohost.nmt.edu/~es421/ansys/assign4.htm> and
- [12] Ansys Thermal Guide, ANSYS release 12.0 ,ANSYS, Inc and , PA15317 , registered in ISO 9001-2000,<http://www.ansys.com>
- [13] David Roy lance, February 2001, *Finite Element Analysis* ,Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-58782003000300013
- [14] M. Necati Ozisik, *Heat Conduction* second edition, printed in acid free paper, Library of congress cataloguing in Publication Data December 1992, North Carilona , U.S.A,