A Study on Thermal Analysis of Butt Joint during Shielded Metal Arc Welding Process

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Abstract - The thermal analysis of shielded metal arc welding (SMAW) is measure the temperature of weld zone and thermal stress in heat affected zone in butt welded joint and investigate the effect of temperature on properties of material within heat affected zone. The main aim of this paper work are measure the peak temperature and thermal stress in heat effect zone using experimental work these peak temperature and thermal stress are verified by numerical simulation using ANSYSN model analysis software. The numerical simulation of SMAW process has been done by analysis tool ANSYS and response has been drawn based on experimental result and numerical result. All possible combinations of temperature difference generated with the help of ANSYS software. In this chapter compare the experimental work and numerical work. The outcome of this analysis work is the maximum temperature is at the middle of the weld zone.

Keywords: - SMAW HAZ ANSYS

I. INTRODUCTION

Welding is the fabrication technique used to weld or joint permanent of two different dissimilar or similar material like as metal, alloy, the heating the edge of metal by the application of heat or pressure and contact with each other, after solidification a permanent joint are achieved. During welding a filler material and flux may or may not be used, if filler material are used then chemical composition of filler material are approx same as base metal. The function of filler material is filling the extra gap between two metal pieces and it form strong bond after solidification of two metals. Welding is wildly used in all sectors of manufacturing industry. In recent years the different types welding technique has grownup. These processes differ greatly in the manner in which heat and pressure (when used) are applied, and in the type of equipment used. Many welding processes are accomplished by pressure with no external heat supplied, some type of welding processes are accomplished by combination of heat and pressure, and other by heat alone with no pressure applied. These heat analyzed [1] by the effect of thermal properties and weld efficiency on residual stress in butt weld joint. The estimate the thermal conductivity and residual stress by using FEM. Thermal conductivity if metal is effected temperature distribution of weld metal and it shows that thermal conductivity increase with decrease in temperature near the well-meant. The [2] angular distortion and thermal analysis of fillet weld saw have developed by numerical elastic plastic thermo mechanical analysis of SAW and compare the experimental result with 3d FEA. The maximum variation of angular distortion between 3d FEA and experimentally are 5-10%. The difficulties in residual stress and overall distortion have been formulated [3] for experimental study of this thesis SAW has been chosen, thermal effect of submerged arc are depend on the electric arc flux and temperature of work piece material. J.O Olawale et.all [4] established the correlation of SMAW and heat treatment on some mechanical properties of carbon steel. Properties of base metal are evaluated by [5], [6], [7] and [8] during SMAW, SAW processes the design parameters are perform experimentally to insure leak profile joint. Tensile stress [9], [12], [17] and [18] is occurring inside the cylinder, peak circumferential stress is outside the cylinder. The residual stress is influenced by the inside and outside weld FEM.

II. EXPERIMENTAL SETUP AND PROCEDURE

A. Experimental planning and procedure

Experimental work was done in two phase for this research work, first phase conduct the root gap butt weld joint by arc welding of carbon steel pipe of outer diameter 101.6mm and thickness 6.02mm, then in second phase butt welding of carbon pipe was done through shielded metal arc welding (SMAW).

Carbon steel pipe of 4 inch outer diameter 500mm length was selected as work piece material, pipe are cut in to two part of outer diameter 4 inch 250mm length with help of cutting machine and grinding done at the edge of work piece to smooth surface to be joined. After that the surface of pipe are polished with emery paper to remove any dust particle or external material, after sample preparation a root gap butt joint was conducted through arc welding as shown in fig. And then one end of pipe is fixed in the lathe after that set the welding parameter in welding machine (current, voltage), heating the electrode about 300 degree centigrade and welding done so that butt joint weld can be formed.

Shielded metal arc welding (SMAW) with alternating current (AC) used in experimental, as its deposited heat in weld area. AWS E 7018 carbon steel of diameter 2.4mm was taken as electrode at present experimental work. For experimental work the welding parameter has been selected as shown in table 1, for performing experimental work a number of trial experiment have been conducted to get appropriate welding parameters. During experimentation we are measure the temperature within heat affected zone with the help of thermocouple. The reading temperature of thermocouple is 200°c, 250°c, 300°c, 350°c, 400°c, and 450°c, etc. we take three temperature reading at a distance from weld 0mm, 20mm and 40mm at different time interval in four trial as shown in table 2.

Table 1 welding parameter for experiment

Parameter	Unit	Range
Welding current	Amperange	70 – 100
Welding voltage	Volt	20 – 30
Welding speed	mm/s	3 – 6
Distance of tip from weld center	mm	2 – 3
Current type		AC, DC
Dimention	Mm	Dia.- 4 inch

Table 2 process parameter value

Distance (mm)	Voltage (V)	Current (A)	Temperature (°C)
0	24	90	400
20	24	90	350
40	24	90	300

B. Finite Element Analysis (FEA)

The finite element analysis (FEA) is a numerical method for solving integral or differential equation to obtain approximate solution. In this method all the complex problem are governed by partial differential equation. Such types of problem are called value problem as they are consist of boundary condition, partial differential equation, varying shape and load are maintain but approximate solution are obtain. The finite element method (FEM) converts the partial differential equation into a set of algebraic equation which is easy to solve. The initial value problem that are consist hyperbolic or parabolic differential equation and initial value condition cannot be solved completely by FEM. Analysis was done using ANSYS. ANSYS is general purpose Mechanical software is a complete FEA analysis tool for all discipline of structural analysis, vibration analysis, fluid dynamics including linear, nonlinear and dynamic readings for engineers. The engineering simulation product delivers a complete set of elements behaviour, material models and comparison solvers for a varied range of mechanical design problems. In addition, ANSYS workbench proposed thermal analysis and coupled-physics capabilities relating acoustic, piezoelectric, thermal–structural and thermo-electric analysis.

C. Typical FEA procedure

D. Evaluation of analysis work

Finite element analysis is done on electrode and work piece material through Shielded metal arc welding by using ANSYS. There we are using the work piece material of carbon steel pipe and tool material is different. For this analysis we have consider electrode as straight cylindrical tool. We will perform the thermal analysis of the tool geometry's are-

- Welding electrode
- Straight hallow pipe

[1] Pre-processing

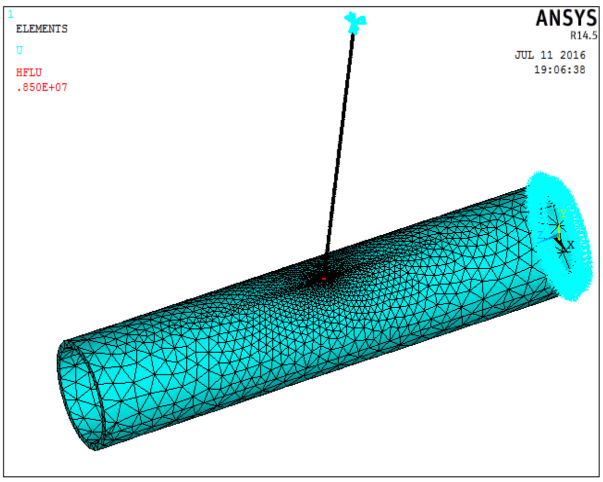
- Welding electrode
  Diameter of welding electrode (mm) = 2.4
  Length (mm) = 350
  Tool angle with vertical = 60 degree
  Electrode material = as per AWS E 7018 carbon steel
- Work piece dimension

Outer diameter (mm) = 101.6
Inner diameter (mm) = 89.56
Thickness (mm) = 6.02
Length (mm) = 500
Work piece material = ASTM A106 grade B carbon steel

- Model of tool and pipe

Types of welding electrode	Straight cylinder
Welding electrode code	AWS E7018 carbon steel
Welding speed (mm/s)	5
Welding voltage (volt)	24
Welding current (A)	90
Heat input (j/mm)	19440

Boundary condition applied on electrode and pipe



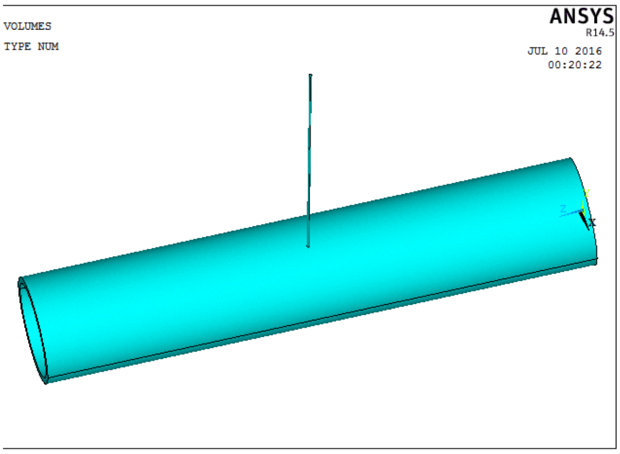


Fig.3 model of tool and pipe interface

E. Meshing of welding electrode and pipe

No. of element = 30006, No. of nodes = 54457

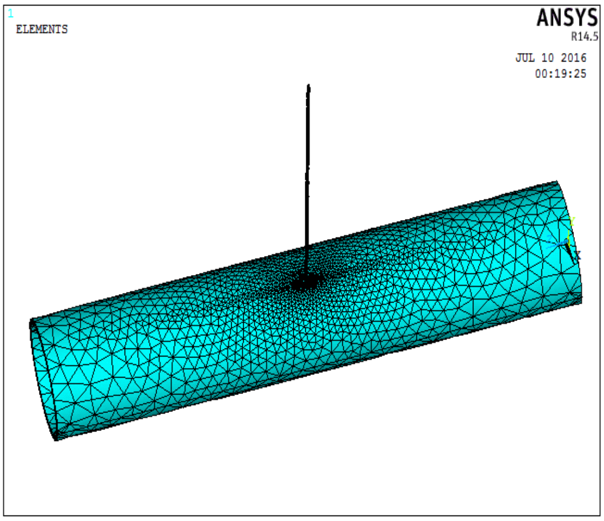


Fig.4 meshing of tool and pipe.

Fig.5 boundary conditions on electrode

III. EXPERIMENTAL RESULT

On the basis of experimental work and analysis work performance measure i.e. thermal and structural analysis is calculated, measure the temperature of HAZ and calculate thermal stress. All the works are summarize in the form of table. Table 3 shows the experimental values of temperature and stress

Table 3 experimental result

Distance (mm)	0
Voltage (V)	24
Current (A)	90
Welding speed (mm/s)	5
Temperature (°C)	400
Heat input (j/mm)	25920
Thermal stress (Mpa)	832

Effect of temperature on thermal and mechanical properties of material

The effect of temperature on thermal and mechanical properties of material during experimental work, numerical analysis and testing of material in arc welding process to be done at various research papers. The effects of temperature are

Fig. 6 work piece after welding

- As temperature of weld zone increase decrease the thermal conductivity, reduce density, increase Poisson ratio, reduce the young's modulus, increase specific heat of material and there is no change in thermal expansion.
- Young's modulus of material reduce due to increase in temperature the thermal stress is reduce, residual stress are increase at peak point then after decreasing during cooling.

Effect of welding parameter on properties of material

- Hardness increases as the value of welding current (I) increases at optimum value and then decrease. Higher peak current, i.e. heat energy (i.e. heat input)is more, results in more fusion of work-piece and thus increases welded zone. It is also observed that hardness is high for a certain value of current and further increment in current does not affect hardness considerably.
- As welding voltage is increase the hardness of weld joint are decrease and cooling rate also decrease.
- Increase in welding speed hardness of weld metal increase and cooling rate are also increase. It can be concluded that the lower the speed is, the higher temperature got in the result.

Thermal analysis of the shielded metal arc welding

Thermal analysis is a branch of material science where the properties of material are studied of the change with temp. The study of material properties of metal and non-metal, thermal capacity, coefficient of thermal expansion, thermal conductive, enthalpy, mass change, and heat input with change in temperature and in solid state chemistry to study of solid state reaction, phase transformation during thermal analysis. Thermal method are commonly used these are distinguished from one another by the properties which measured. Determine permittivity and loss factor and temperature difference. The result of analysis work is given below

MODEL OF ELECTRODE AND PLATE

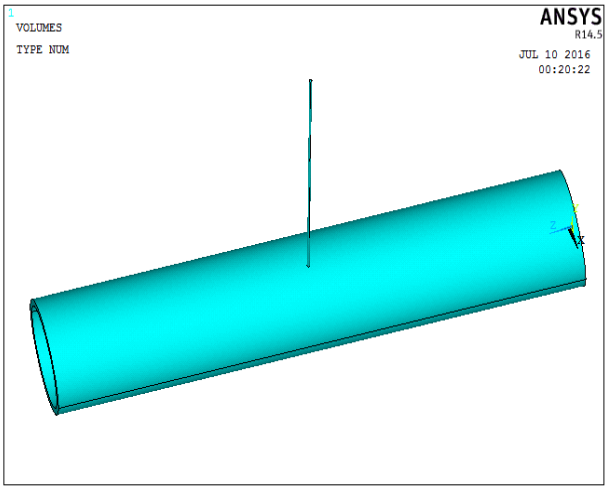


Fig.7 model of straight cylindrical electrode and pipe

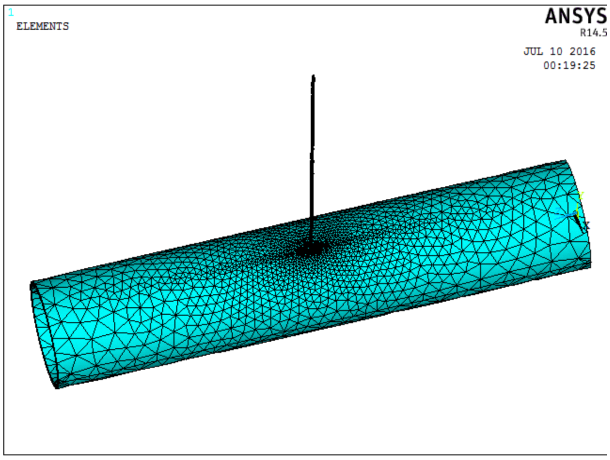


Fig. 8 meshing of the electrode and pipe

Tool material of = AWS E 7018 carbon steel

- Welding current = 90 A
- Welding speed = 5 mm/s
- Welding voltage =24 volt

Boundary conditions applied

- Convection at Free surface of tool and pipe i.e. outside weld zone (surface 2)
  H = 15 W/m^2k
  T = 27 ℃
  Maximum heat input = 2160 w or 25920 j/mm
  No. of element = 30006
  No. of nodes = 54457

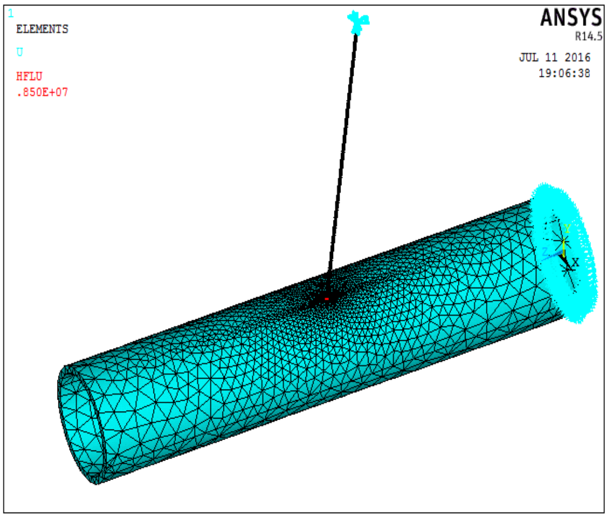


Fig. 9 boundary conditions on electrode and pipe

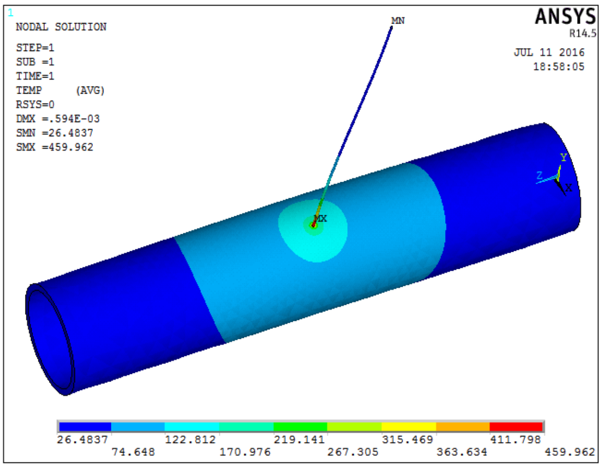


Fig. 10 welding speed = 5mm/s, welding current = 90 A, heat input =2160W

- In above fig. it is clearer that the maximum temperature at the middle of weld zone of work piece specimen is 460°C at the interface of tool and work piece material and acceptable maximum temperature for welding is about 412℃.
- The minimum temperature at the end of work piece as shown in fig. above and minimum temperature is about 27℃.

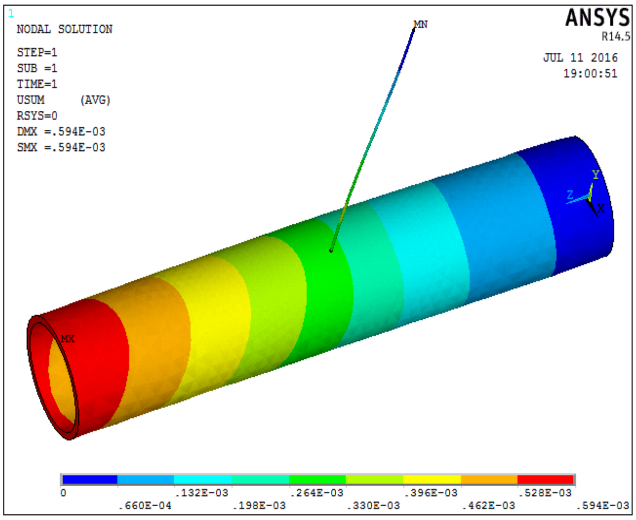


Fig.11 deformation of tool and work piece specimen.

- The minimum deformation at the fixed end of work piece is = 0
- The maximum deformation at the free end of work piece is = .528
- Deformation at middle of weld zone is = .264

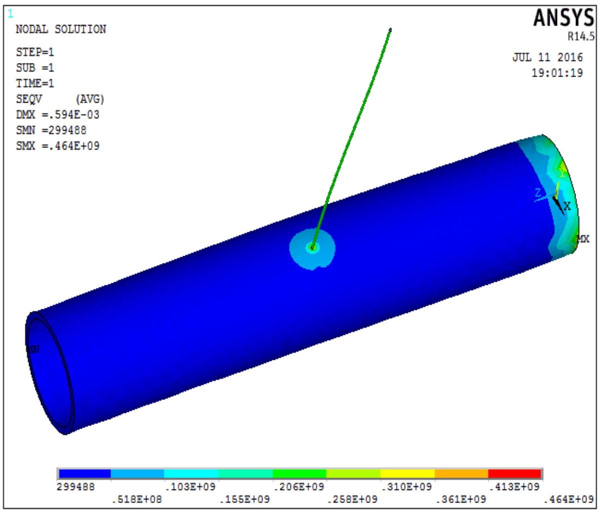


Fig. 12 vonmises stress distribution

Table 4 numerical result

Welding electrode code	Voltage (V)	Current (A)	Welding soeed (mm/s)	Maximum Temperature (°C)	Thermal stress (Mpa)	Maximum deformation at weld zone
AWS E 7018 carbon steel	24	90	5	460	464	.264

Comparisons of experimental result and numerical result

Table 5 comparisons of result

Welding electrode code	Welding voltage (V)	Welding current (A)	Welding speed (mm/s)	Maximum temperature (°C)	Thermal stress (MPa)
AWS E7018 Carbon steel	24	90	5	400	832
AWS E7018 Carbon steel	24	90	5	460	464

IV. CONCLUSION

Finite element method is used to obtain optimal solution. This overcomes the disadvantages of many multi-objective analysis techniques used in the field of shielded metal arc welding tool and work piece geometry thermal analysis. All possible combinations of temperature difference generated with the help of ANSYS software. The outcome of this analysis work is the maximum temperature is at the middle of the weld zone.

REFERENCES

[1] Munish Kainth, Deepak Gupta, Vivek Kumar Sharma "Experimental Investigation Of The Effect Of Vibration On Mechanical Properties of Aisi 1018 Mild/Low Carbon Steel Welded Joint Using Smaw" p-ISSN: 1694-2418, IJME, Vol. 2, Issue 2 (July, 2015).

[2] Nayab Singh, Karun, Sandeep Kumar and Dilbagh Singh "Investigating the Effect of Saw Parameters on Hardness of Weld Metal" International Journal of Advance Industrial Engineering, E-ISSN 2320 –5539, Vol.5, No.3 (June 2015).

[3] M. A. Bodude, I. Momohjimoh "Studies on Effects of Welding Parameters on the Mechanical Properties of Welded Low-Carbon Steel" Journal of Minerals and Materials Characterization and Engineering, 2015, 3, 142-153 Published Online.

[4] Vijayesh Rathi, Hunny "Analyzing the Effect of Parameters on SMAW Process" International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-4, Issue-6).

[5] J. Dutta, P. Pranith Kumar Reddy "Thermo mechanical and Metallurgical Analysis of SMA and GTA Welded Low Carbon Steel Butt Joints" World Academy of Science, Engineering and Technology International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering Vol: 9, No: 7, 2015.

[6] Abhijit Sarkar, Aparesh Datta, Prasenjit Dey, R.N.Rai, S. C Sasha "Numerical Approach For Modeling Thermal Profiles And Effects Of Process Parameters On It In Submerged Arc Welding Of Asia 1518 Grade Steel" Journal of Thermal Engineering Yiddish Technical University Press, Istanbul, Turkey Vol. 1, Special Issue 3, No. 6, pp. 505-516, May, 2015.

[7] Abhishek B P, Anil kumar G ,Madhusudhan.T "Experimental And Finite Element Analysis Of Thermally Induced Residual Stresses For Stainless Steel 303grade Using GMAW Process" International Research Journal of Engineering and Technology (IRJET), ISSN: 2395 -0056Volume: 02 Issue: 02 | May-2015.

[8] Swapnil R. Deogade, Prof. Sachin P. Ambade, Dr. Awanikumar Patil "Finite Element Analysis of Residual Stresses on Ferritic Stainless Steel using Shield Metal Arc Welding" International Journal of Engineering Research and General Science Volume 3, Issue 2, March-April, 2015 ISSN 2091-2730.

[9] Harmeet Singh, Som Kumar, Nimo Singh Khundrakpam, Amandeep singh "Thermal Stress Analysis in Butt Welded Thick Wall Cylinder" ISO 9001:2008 Certified International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 10, April 2014.

[10] J. Dutta, Narendranath S. "A Parametric Study of Temperature Dependent Properties Influenced due to Transient Temperature Field Developed in Arc Welded Steel Butt Joints" International Journal of Advances in Engineering Sciences Vol.4, Issue 3, April, 2014.

[11] Rohit Jha, A. K. Jha "Investigating the Effect of Welding Current on the Tensile Properties of SMAW Welded Mild Steel Joints" International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181 Vol. 3 Issue 4, April – 2014.

[12] Osman Culha "Finite Element Modelling Of Submerged Arc Welding Process For A Symmetric T-Beam" ISSN 1580-2949 Original scientific article/Izvirni znanstveni ~lanek MTAEC9, 48(2)243(2014).

[13] Prof. Rohit Jha, Dr. A.K. Jha "Influence of Welding Current and Joint Design on the Tensile Properties of SMAW Welded Mild Steel Joints" Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 6(Version 4), June 2014, pp.106-111.

[14] Y. Kachaou, Nader haddar, Gilbert Henaff, Khaled Elleuch "Micro structural, compositional and mechanical investigation of Shielded Metal Arc Welding (SMAW) welded super austenitic UNS N08028 (Alloy 28) stainless steel" Article in Materials and Design · November 2014 Impact Factor: 3.5 · DOI: 10.1016/j.matdes.2014.06.014.

[15] G.I. Mahiskar, R.B. Chadge, S.P. Ambade, A.P. Patil "thermo-mechanical analysis of multi- pass bead- on-plate welding" ISSN 2211-8128, AMME 2014.

[16] Apurv Choubey, Vijaykumar S. Jatti "Influence of Heat Input on Mechanical Properties and Microstructure of Austenitic 202 grade Stainless Steel Weldments" Seas Transactions On Applied And Theoretical Mechanics, E-ISSN: 2224-3429, Volume 9, 2014

[17] Dae-Won Cho, Woo-Hyun Song, Min-Hyun Cho, Suck-Joo Na "Analysis of submerged arc welding process by three-dimensional computational fluid dynamics simulations" Journal of Materials Processing Technology, ScienceDirect 213 (2013) pp-2278– 2291.

[18] Devinder Pal Singh, Mithlesh Sharma, Jaspal Singh Gill "Effect of Post Weld Heat Treatment on the Impact Toughness and Micro structural Property of P-91 Steel Weldment" IJRMET Vol. 3, Issue 2, ISSN : 2249-5770 (Print) May - Oct 2013.