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Optimization of submerged arc welding process variables

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ABSTRACT

Submerged arc welding is widely used for welding thicker plates due to its various advantages and hence its bead strength should be high.This review paper presents various works done in optimizing welding process parameters which directly affect weld bead strength. This paper also reviews the effect of process variables,multi-wire & flux on bead–width quality, minimization of residual stresses.
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KEYWORDS

Submerged arc welding(SAW);
Taguchi method;
Residual stresses;
Response-surface methodology (RSM);
Particle swarm optimization (PSO);
Genetic algorithm(GA);
Acicular ferrite (AF);
Grain–boundary ferrite (GBF);
Heat-affected zone (HAZ).

INTRODUCTION

Submerged arc welding (SAW)[1] is a method in which the heat required to fuse the metal is generated by an arc formed by an electric current passing between the electrode and the workpiece. A layer of granulated mineral material known as submerged arc welding flux covers the tip of the welding wire, the arc, and the workpiece. There is no visible arc and no sparks, spatter or fume. The electrode may be a solid or cored wire or a strip .

Submerged arc welding offers various advantages in terms of excellent weld bead quality, minimum weld fume & radiation & high metal deposition rate. It can weld carbon, low & high alloy steels upto 60cm thickness. Apart from advantages it also has some limitations which are in the form of limitation of welding upto flat & horizontal positions only.

Submerged arc welding has various process parameters among which important ones are following

Arc Voltage[1]The voltage principally determines the shape of the fusion zone and reinforcement. High welding voltage prod- uces a wider,flatter, less deeply penetrated weld than low welding voltage.

Welding current[1] Welding current is the most influential variable. It controls the rate at which welding wire is burned off, the depth of fusion, and the amount of base metal fused. If the current is too high,the depth of fusion will be too great and the weld may melt through the backing. In addition to this, the higher heat developed may excessively extend the heat-affected zone of the adjacent plate. Too high a current also means a waste of power and a waste of welding wire in the form of excessive reinforcement. If the current is too low, there is insufficient penetration and not enough reinforcement.

Welding wire extension (Stick-out)[1]

The distance between the contact tip and workpiece is normally referred to as electrode extension or stick-out . Deposition rates can be increased with the use of longer extensions due to resistive heating of the wire. If the stick out is too long then the wire is preheated and can tend to wander leading to missalignment also penetration is reduced .

Travel speed[1]

If the welding speed is increased weld bead becomes smaller,penetration increases & in very high speed it may also result in undercuts & insufficient reinforcement while in slower welding speed heat input per unit length increases.

Wire feed rate

Increasing the wire feed rate increases the welding current so the deposition rate and penetration increase, reinforcement height increases marginally whereas bead width decreases[2]. It is further revealed that wire feed rate is the most significant factor which affects the dilution[3]. Murugun et al.[4] found that penetration, reinforcement and dilution and HAZ increase with increase in wire feed rate.

Filler wire diameter

Changing the electrode diameter in submerged arc welding will change the current density for given current. Miller[5] reported that at a given current setting, a small wire diameter electrode gives a higher current density and thus a higher deposition rate than a larger wire diameter electrode. Tueska[6] also found that melting rate decreases with the increase in filler wire diameter.

Flux

A flux protects weld pool from atmospheric contamination and also provides alloying elements brings about desirable chemical changes to the weld metal and control the shape of the deposited metal. Mechanical properties of the welds are improved for the fluxes containing TiO2 contents due to presence of acicular ferrite[7]. Figure 8 shows that with increases in titanium content hardness increases which results in better mechanical properties[8].

Welding polarity

Polarity is the direction of current flow. Harwig et al.[9]reported that polarity influences the amount of heat generated at the welding wire and work piece in the welding process which depends on direct current electrode positive (DCEP or reverse) or direct current negative polarity (DCEN or straight). There is more arc spread in straight polarity than in reverse polarity resulting in a higher bead width and less penetration. The two third of the total heat is generated at the positive welding wire and the one third of the total heat is generated at the negative welding wire[9]. Robinson[10] observed that DCEN has more electrode melting rate as compared to DCEP.

Residual stress[11]

When steel structures are welded, a localized fusion zone is generated in the welding joint because of high heat input from the arc and then non uniform temperature distribution is induced due to the heat conduction. Therefore, non uniform heat deformation and thermal stresses are included in the as welded parts. As a result, plastic deformation retained within the weldment and nonlinear plastic eformation and residual stresses exist after cooling of the welded joint . The principal factors determining residual stresses in a welded structure are Residual stresses present in the parts induced during its manufacturing & fabrication process, material properties of the weld and parent materials, including composition, microstructure, thermal properties and mechanical properties, geometry of the parts being joined, restraints applied to the parts being welded in the form of jigs & fixtures, welding procedure, including the weld preparation, the welding conditions and the pass sequence in multi-pass welds, residual stresses generated or relaxed by manufacturing operations after welding or by thermal or mechanical loading during service life.

STUDIES ON EFFECT OF BEAD GEOMETRY ON THE QUALITY OF WELD

L.J.Yang, R.S. Chandel,M.J. Bibby[12] while investigating the effects of process variables on low carbon steel weld bead width in submerged-arc welding concluded that bead width is affected by the electrode polarity,electrode diameter,electrode exten- sion, welding current, welding voltage and welding speed. A positive electrode polarity, a large electrode diameter, a small electrode extension and a high welding voltage encourages a large bead width in most cases. The bead width is not affected significantly by the power source, constant voltage or constant current, when an acidic fused flux is used. However, when a basic fused flux is used,constant-current operation gives some what larger bead widths.

N. Murugan,R.S. Parmar,S.K. Sud[13],while discussing the effect of submerged arc process variables on dilution and bead geometry in single wire surfacing said that the control parameters are required to be fed to the system according to some mathematical formulation to achieve the desired end results. The responses, namely,penetration, reinforcement, width and dilution as affected by open-circuit voltage, wire feed-rate, welding speed and nozzle-to-plate distance, have been investigated. The main and interaction effects of the control factors is shown in graphical form, which is more useful in selecting the process parameters to achieve the desired quality of the overlay. The results showed that penetration is not affected significantly by voltage and nozzle-to-plate distance and width is not affected by the latter.

B. Chan,R.S. Chandel,L.J. Yang,M.J. Bibby[14],described a software system which is under the Microsoft DOS operating system with either EGA or VGA graphics adaptors. This software was used in anticipating the size and shape of submerged arc welds told that the system consists of a specially designed interface for welding /materials /design/ fabrication engineers, auto mated plotting for parametric studies, a simplified data base for storing / editing /retrieving frequently used welding para meters and pictorial graphics for displaying weld size and shape.

Serdar Karaoğlu and Abdullah Seçgin[15] focuses on the sensitivity analysis of parameters and fine tuning requirements of the parameters for optimum weld bead geometry. Changeable process parameters such as welding current, welding voltage and welding speed are used as design variables. Effects of all three design parameters on the bead width and bead height show that even small changes in these parameters play an important role in the quality of welding operation. The results also reveal that the penetration is almost non-sensitive to the variations in voltage,speed & is highly sensitive to current.

Abhay Sharma, Navneet Arora, Bhanu K. Mishra[16] while doing the analysis of Flux Consumption in Twin-Wire Submerged Arc Welding Process with unequal wire diameters concluded that flux accomplishes different functions including covering the arc, elimination of spatter and smoke, control of arc stability, governing the bead shape and influencing weld chemistry. Therefore, the flux consumption remains a function of process parameters and directly influences the productivity of the process. Unequal wire diameters lead to more stable magnetic file with less deflection,thus, results in lesser flux consumption.

V. Gunaraj,N. Murugan[17] highlighted the use of RSM in optimization of input process variables for attainment of required weld quality by designing a four-factor ûve-level central composite rotatable design matrix. They also stated that these models are useful not only for predicting the weld bead quality but also for selection of optimum process parameters for achieving the desired quality.

STUDIES ON EFFECT OF HAZ ON THE QUALITY OF WELD

Viano, D.M.;Ahmed, N.U.; Schumann, G.O.[18], while discussing the influence of heat input and travel speed on microstructure and mechanical properties of double tandem submerged arc high strength low alloy steel concluded that increase in heat input results in a decrease in cooling rate and the widths of the different zones of the HAZ increase steadily with the increase in heat input.

Keshav Prasad;D.K. Dwivedi[19], describe ing the Microstructure and Tensile Proper ties of Submerged Arc Welded 1.25Cr-0.5Mo Steel Joints concluded that the increase in the heat input affects the proportions of different micro constituents both in the weld metal and heat affected zone (HAZ). It is observed that the tensile strength(UTS,YS) decreases with increase in heat input

STUDIES ON EFFECT OF PROCESS VARIABLES

P. Kanjilal,T.K. Pal, S.K. Majumdar[20] studied combined effect of flux and welding parameters on weld metal chemical composition and mechanical properties in SAW process using rotatable design model in statistical experiments with mixture. Based on their study they concluded that among the welding parameters, polarity has a profound influence on weld metal chemical composition. Welding speed infl- uences weld metal carbon content through oxidation reaction whereas weld metal sulphur and phosphorous content are affected by dilution of weld deposit. Welding current influences weld metal manganese content through slag–metal reaction. Transfer of nickel from flux to weld, is found to be impeded by oxides formed during slag–metal reaction. Weld metal yield strength and hardness are mainly determined by welding parameters; whereas the impact toughness is determined by flux mixtures variables.

Kishor P. Kolhe, C.K. Datta[21] carried out detailed study on the microstructure, phase analysis and mechanical properties, HAZ width of SAW weld metal multipass joint and heat-affected zone of 16mm thick mild steel plate. They investigated and correlated the relationship between the various parameters; mechanical properties and microstructure of single “V” butt joint of mild steel plate, performed the phase analysis of the multipass welded joint to get defect free welded structures.

Ravinder Pal Singh[22] review paper revealed that process variables strongly influence the weld bead geometry and microstructure of the welded joints in submerged arc welding. In his review he revealed that apart from the welding current, arc voltage, travel speed, electrode stickout and flux which strongly affects the weld bead geometry, addition of metal powder also increases the deposition rate and improves the welding arc efficiency and reduces the shielding flux consumption. Longer electrode extension can be used to increase the melting rate. The presence of acicular ferrite in submerged arc welds optimizes the toughness in the weld metal which was strongly affected by inclusion of titanium. So,fluxes apart from main ingred- ients having contents of titanium oxide improve the mechanical properties.

M.O.H. Amuda, A.M. Oladoye, K. Ojemeni, J. Agunsoye, W. Subair[23] investigated the microstructural induced hardness variation in multirun welded plain carbon steel at different interpass time. They welded Bevelled 16mm thick mild steel samples in 2 and 4 passes at interpass time of 90, 120 and 240s respectively via manual metal arc. The result showed that the differences in hardness values of the fusion zone and heat affected zone reduce as interpass time increases for both 2 and 4 runs. The effect was however quite distinct in the 4 runs welding cycle. In the 2 run cycle, the fusion zone and heat affected zone merge at 100 seconds; while in the 4 runs cycle, the merging occurred at 25 seconds; indicating that the higher the multipass, the shorter the time required to produce uniformity in hardness and structural homogeneity. There by increasing the resistance of the weld to crack susceptibility and failure.

N.D. Pandey, A. Bharti & S.R. Gupta[24] investigated the influence of submerged arc welding (SAW) parameters and flux basicity index on the weld chemistry and transfer of elements manganese, silicon, carbon and sulphur using five fluxes and different values of the welding parameters. The welds were produced as a bead on a mild-steel plate. The weld-metal composition showed gain of silicon and loss of carbon, manganese and sulphur elements. The results showed that welding current and voltage had an appreciable influence on element transfer, as well as on weld composition. Apart from this, except for weld-metal silicon, the basicity index of the fluxes has only a minor influence. Weldments properties such as strength,toughness & solidification cracking behaviour are affected by chemical composition.

P. Yongyutph,K. Ghosh, C. Gupta, K. Patwardha,Satya Prakash[25] while studying the Influence of Macro/Microstructure on the Toughness of' all Weld Multipass Submerged Arc Welded C-Mn steel deposits found that the variation in welding para meters alter the macrostructure primarily by influencing its co-axial dendrite content. The chemical composition and hardness of the dendritic and the heat affected regions were affected little by the welding parameters. A dendrite content up to 37%,has no significant effect on the tensile properties. However an increase in it beyond 37% was found to enhance the UTS and YS and reduce percent elongation. The use of post-weld heat treatment (PWHT) at 873 K caused spheroidization of cementite there by somewhat reducing the hardness and strength.

S. W. Wen,P. Hilton,D. C. J. Farrugia[26], while doing Finite element modeling of a submerged arc welding process concluded that the geometrical distortion and residual stresses and strains caused by welding can be minimized through process optimization. It is therefore demonstrated that finite element analysis can be applied to better understand the SAW process and hence be a useful tool for future process development and control with the view of optimizing product properties.

De-liang Ren, Fu-ren Xiao, Peng Tian, Xu Wang, Bo Liao[27], investigate the effects of welding wire composition and welding process on the weld metal toughness of submerged arc welded pipeline steel and concluded that the contents of alloying elements need to vary along with the welding heat input. The microstructures mainly consisting of acicular ferrite can be obtained in weld metals using the wires with a low carbon content and appropriate contents of Mn,Mo, Ti-B, Cu & Ni, resulting in the high low-temperature impact toughness of weld metals.

A Sharma, N Arora, B K Mishra[28] during study of statistical modeling of deposition rate in twin-wire submerged arc welding concluded that a significant amount of material loss may occur in the case of single- wire SAW. Material losses also depend on the polarity. In the case of Direct current electrode positive (DCEP), the loss is, on average, about 4 percent, whereas in the case of DCEN, the same is about 8 per cent.

D.V. Kirana,B. Basub,A. Dea[29] presented a detailed experimental study on the inûuence of leading wire current,trailing wire current pulses,and welding speed on the weld bead dimensions and mechanical properties in single pass tandem submerged welding of a typical HSLA steel. They found that the weld bead penetration is primarily inûuenced by the leading wire current while the weld bead width and the reinforcement are sensitive to the trailing wire current pulses. Greater magnitude of trailing wire current pulses and shorter negative pulse duration increase the weld pool volume leading to reduced cooling rate and poor mechanical properties as the formation of the strengthening phases like acicular ferrite is inhibited. In contrast, increase in welding speed reduces the rate of heat input thereby enhancing the cooling rate and the weld bead mechanical properties. They also developed a set of empirical relations to estimate the weld bead dimensions and mechanical properties as function of the welding conditions & the predictions from the empirical relations and the corresponding measured results were observed to be in fair agreement.

PROCESS VARIABLES OPTIMIZATION STUDIES

As welding involves various process variables each of which has it's own effect on weld bead, so in order to get maximum bead strength these parameters need to be optimized. There are various optimization methods,some of which are factorial design method, artificial neural network, response surface methodology,taguchi method. In this review paper among various methods literature work on taguchi has been discussed. The Taguchi method is one of the powerful optimization techniques which characterize with improving the product quality and reliability at low cost. The optimization algorithm works by calculating signal-to-noise (SN) ratios for each combination and then the combination having a maximum SN ratio is defined as the optimal setting. However, Taguchi's analysis approach of SN may lead to non-optimal solutions, less flexibility and the conduction of needless experiments[30]

L.Manihar singh & Abhijit Saha[31] per formed SAW welding on two mild steel plates of size 200mm(length) X 50mm (width) X 12mm (thickness) with a V angle of 30°to 45°,4mm root height & 0.75 mm root gap in 8 different cases with 2 levels for every parameters.After completion of the welding process the weld bead width was measured with the help of a measuring scale. Similarly S/N ratio for weld bead width has been found separately and recorded in the table. From observation table corresponding to higher signal-to- noise ratio the values of arc current, arc voltage, welding speed & electrode stick-out were obtained(optimum level). Multiple regression analysis using Minitab 15 software was also performed to determine the relationship between the dependent variables of bead width with welding current, arc voltage, welding speed, and electrode stick out From the equations obtained,predicted values of weld bead width was calculated and tabul- ated with the measured value in the table. In order to conform for weld bead width a test sample,having same size and dimension as per earlier specification was taken and performed welding at the optimum predicted process parameter and the weld bead width was measured & was found within 95% confidence level.

S. Kumanan, J Edwin Raja Dhas & K Gowthaman[32] performed welding on two mild steel plates of size 500 mm(length) × 50 mm(width) × 6 mm (height) & with the help of TAGUCHI and regression analysis optimized welding process parameters. The percentage contribution of each factor was also validated by analysis of variance (ANOVA) software.

Saurav Datta,Asish Bandyopadhyay & Pradip Kumar Pal[33] performed Taguchi optimization technique evaluating optimal parametric combinations to achieve accept- able features of weld bead geometry and HAZ in submerged arc welding. Apart from process optimization they also introduced a new concept of slag consumption during subsequent runs of the SAW process. They showed that 10% slag-mix can be used to obtain optimum bead width and depth of HAZ, whereas 15% and 20% would yield optimal reinforcement and depth of penetration respectively.

GK Purohit, Digamber[34] performed Tag- uchi optimization technique coupled with Grey relational analysis for evaluating parametric combination to achieve accept- able depth of penetration, height of rein- forcement, bead width and HAZ of the hardfaced weldments obtained by using submerged arc welding. The criteria selected for a weldment was to provide lower penetration and increased height of reinforcement, bead width and lower HAZ. It was concluded in order to minimize the HAZ (minimum width and depth of HAZ) drastic microstructural changes between the weld metal and HAZ should be avoided.

Saurav Datta, Siba Sankar Mahapatra[35] obtained weld bead characteristics using four process control parameters viz. voltage,wire feed rate, traverse speed and electrode stick-out. The selected weld quality characteristics related to features of bead geometry are depth of penetration, reinforcement and bead width. Quadratic Response Surface Methodology (RSM) was applied to establish a mathematical model representing overall desirability as a function involving linear, quadratic and inter action effect of process control parameters . The model was optimized finally within the experimental domain using PSO (Particle Swarm Optimization) algorithm. & confir- matory test showed a satisfactory result.

Y. S. Tarng and W. H. Yang[36] applied Taguch imethod in optimizing the sub- merged arc welding process parameters. The Taguchi method was used to formulate the experimental layout, to analyze the effect of each welding parameter on welding performance, & to predict the optimal setting for each welding parameter. They also performed experiments to confirm the effectiveness of Taguchi approach.

G.Mahendramani,N.Lakshmana Swamy[37] performed an experimental analysis of transverse and longitudinal shrinkage in single and double v-groove butt joints in submerged arc welding by varying included angle and keeping process parameters constant and found that maximum shrinkage was at the centre of the plate and minimum at the ends. They also found that transverse and longitudinal shrinkage increase with increase in the included angle and there is a significant increase in the transverse shrinkage and small variation in longitudinal shrinkage.

J.Edwin Raja Dhasa,S. Kumanan[38] stated the weakness of trial & error method in caluculation of optimized welding para meters. In order to overcome the weak ness of trial & error method they suggested non-traditional methods. By per forming bead-on-plate welds on mild steel plates using semi automatic SAW machine. All the data were collected as per Taguchi's Design of Experiments and regression analysis was carried to establish input–output relation ships of the process. By this relationship, they tried to minimize weld bead width, using optimization procedures based on the genetic algorithm (GA) and particle swarm optimization(PSO) algorithm. Finally the optimized values obtained from these techniques were compared with experi -mental results.

Y.S. Tarng,S.C. Juang, C.H. Chang[39] applied grey-based Taguchi methods for the optimization of the submerged arc welding process parameters in hardfacing with considerations of multiple weld qualities. In their new approach,the grey relational analysis is adopted to solve the saw process with multiple weld qualities. A grey relational grade obtained from the grey relational analysis is used as the per formance characteristic in the Taguchi method. Then,optimal process parameters are determined by using the parameter design proposed by the Taguchi method. Experimental results obtained showed that optimal SAW process parameters in hardfacing can be determined effectively so as to improve multiple weld qualities using this new approach.

STUDIES ON CHANGE IN WELD METAL PROPERTIES DUE TO METAL POWDER ADDITION

Ana Ma. Paniagua-Mercado, Victor M. Lopez-Hirata, Hector J. Dorantes-Rosales, Paulino Estrada Diaz, Elvia Diaz Valdez[40]studied the effect of TiO2 additions in fluxes on the mechanical properties and microstructure of the weld metal formed during Submerged-Arc Welding on ASTM A-36 steel plates. Four fluxes with about 9, 12, 15 and 18% Ti were used with a low-carbon electrode. The welding conditions were kept constant. The microstructure of the weld metal for each flux consisted mainly of equiaxed ferrite and acicular ferrite. The increase in the percentage of acicular ferrite and a decrease in its length were observed with an increase in titanium content. The increase in titanium content in fluxes also improved the toughness and ductility of the weld.

J.Tuseka, M. Suban[41] dealt with multiple-wire submerged-arc welding and cladding with metal-powder addition. They described three different ways of supplying the metal powder to the welding area. They also found that the use of metal powder will increase the deposition rate, and the welding-arc efficiency and reduce the shielding-flux consumption.

N.bailey[42] provided data showing how metal powder additions to submerged arc welds can be used safely to give increased productivity and hence reduce fabrication costs. The aims of their program were to improve the balance between properties and productivity, either by improving heat affected zone (HAZ) and weld metal toughness levels while increasing product- ivity or, at least, to improve productivity without impairing toughness.

R. S. Chandel, H. P. Seow, F. L. Cheong[43] performed submerged arc welding on 25 mm thick low carbon mild steel plate corresponding to ASTM A283 & alloyed it with metal powder containing elements such asC±0.17,Si±0.19,Mn±0.51,S±0.020 and P±0.040. Plate samples measuring 350x 220x25 mm were flame-cut from a single large plate,and surfaces were cleaned to remove dirt and oxides. The included angles for V-groove welds were flame-cut to 35° and 25° on each plate to obtain groove angles of 70° and 50°, respectively. All welds were made using a welding current of 650 A(corresponding to a wire feed speed of 42.33 mm=s),an arc voltage of 32V,an electrode extension of 25.4 mm and an electrode wire 3.00 mm in diameter. As due to the limited number of experimental samples, they found it very dificult to draw any conclusion on the effect of powder addition and groove angle on the weld-metal toughness;but they found sufficient evidence to suggest that the weld metal is stronger and tougher than the base metal.

S.D. Bhole,J.B. Nemadeb, L. Collins, Cheng Liua[44] investigate the effects of nickel (Ni), molybdenum (Mo), and Ni and Mo together on the impact toughness of an API HSLA-70 steel using submerged arc welding . In their study they discussed the micro-structural factors which affect the impact toughness of welded joints. Ni additions resulted in a low impact toughness and an increased fracture appearance transition temperature (FATT) in weld metal (WM). The above inûuences of Ni were discussed to be attributed due to the suppression of formation of acicular ferrite on increasing the Ni content. Moreover, the combined presence of Ni and Mo in the WM decreased the volume fractions of grain-boundary ferrite (GBF) and promoted formation of high toughness of AF. The increase amount of Mo content created an acicular ferrite predominant weld metal microstructure with impressively improved toughness.

STUDIES ON MINIMIZATION OF RESIDUAL STRESSES

R.H. Leggatt[45] discussed the nature of residual stresses in welded structures in terms of their magnitude, directionality, spatial distribution, range and variability. They studied the effect of materrial properties,material manufacture & structural geometry,fabrication procedure, welding procedure,post-weld treatments and service conditions on residual stresses. They discussed the factors for variation in the prediction of residual stresses in the form of factors such as experimental error in measured data, erroneous assumptions in analytical modelling,pre-existing residual stresses, inadequately documented welding, fabrication procedures or unrecorded local repairs.

N. Murugan, R. Narayanan[46] performed three-dimensional transient thermo-mech anical simulation on a welded Tee-joint using the finite element method, to predict longitudinal residual stresses.

Tso-Liang Teng, Chih-Cheng Lin[47] pred-icted the residual stresses during one-pass arc welding in a steel plate using ANSYS finite element techniques. From the analysis they found that higher welding speed reduces the amount of adjacent material affected by heat which decreases the residual stresses. They found that the magnitude of the residual stresses with a restrained joint is larger than that estimated with an unrestrained joint and with pre- heating treatment, the residual stresses reduces significantly.

Ergun Nart,Yuksel Celik[48] proposed a new practical approach using double ellipsoid model & with some modiûcations in modeling in it to catch the correct shape of the weld pool. The need to modify the double ellipsoidal model arises when weld pool's shape diverges from the shape of simple ellipsoid, as observed in one pass SAW welds creating a crater-ûnger,then it is not right to use the power density distribution function for accurately computation of the temperature ûeld. In the present revised model the corresponding ûnite element temperature distributions and residual stresses are predicted for a plate using user subroutines available in Abaqus CAE software and the analysis results are compared with experimental results & both the results were in quite agreement.

M.R. Forouzana,S.M. Mirfalah Nasiri,A Mokhtari, A. Heidari, S.J. Golestaneh[49] performed three-dimensional ûnite element (FE) simulations of double SAW & hydro static test processes of spirally welded pipes in two simulation steps using the ANSYS software. In the ûrst step,i.e., welding,unfurl-mapping (UM) is introduced to overcome the geometrical difûculties of deûning the Goldak double ellipsoidal heat source of the welding process. UM virtually opens the pipe into a ûat surface, and therefore, the spiral seam is mapped to a straight line. To discretize the pipe, ûne brick elements are utilized for meshing the main computational zone. The rest of the model is meshed by coarse shell elements by applying the multi-point constraint tech nique. In the second step, the hydrostatic test is simulated by deûning a ramped internal pressure. The method was validated using hole drilling measurements performed before and after hydrostatic test for this research. It was observed that obtained results from the FE simulations are in good agreement with the experimental measurements.

Hugh D. Hibbitt, Pedro V. Marcal[50] developed numerical model for the welding and subsequent loading of a fabricated structure. The model treats the weld process as a thermo-mechanical problem. A finite element formulation derived from the uncoupled thermal and mechanical energy balances forms the basis of the model. During the development of the thermal model,two significant problems are dis- cussed. One is the material nonlinearity, which manifests itself in the temperature dependence of the thermal properties, and in the fusion problem, where the material phase change is accompanied by a latent heat effect. The second problem is that of boundary conditions:The deposition of molten bead on the base is modelled by using the intimate contact boundary condition, which is developed into a set of impulse type equations on the finite element model. During the second part of the work the mechanical model is described. This is an incremental finite element model in which the basic constitutive descriptions are time independent elastic-plastic behaviour with temperature dependent properties, and a creep rate formulation for the time dependent behaviour.

F.Vakili-Tahami and A.H.D sorkhabi[51] presented a numerical method to study the thickness effect on the residual stress in the 2.25 Cr-1Mo plate with the help of flow chart. Using finite element based software ANSYS, coupled thermal-mechanical three dimensional (3D) finite element models was developed. Based on the modeling they found that by increasing plate thickness, the residual stresses increase and the residual stress affected zone becomes larger. Moreover, the longitudinal residual stress in the weld axis, change from compressive to tensile stress by increasing plate thickness.

Pradeep Chaubey,S.Panwala, S.A channiwal,K N Srinivasan[52] presented the finite element analysis for transient temperature for single pass butt weld joint during welding. They developed code in FORTRAN 95 for analysing the thermal effect during welding process. The moving heat source was modelled by adopting 'Pavelic's two dimensional circular disc model' with Gaussian distribution. They also performed experiment for evaluation of residual stress which is generated due to welding. On comparison of numerical and published literature result both were in good qualitative agreement.

Lars-Erik Lindgren[53] focused on the some basic information regarding the welding simulation. In this paper he gives the information about thermo-mechanical analysis. He concluded that the welding simulation is the done by thermo-mechanical analysis which include the analysis of thermal as well as mechanical. It may be coupled to gather because due to thermal effect the residual stress is produce which causes the deformation.

Gurinder Singh Brar and Rakesh Kumar[54] presented three-dimensional finite element welding simulation for different types of welding.The finite element analysis results of the residual stress distributions of two butt welded plates in the axial directions was presented.Moreover, various geomet-rical constraints and material nonlinearities were included in the analysis. In order to obtain results using the finite element methods different mesh sizes were taken into consideration.It was concluded that residual stresses are lowest in case of GMAW,and highest in SAW. From all these it was concluded that the decreasing of heat input decreases the distribution of residual stresses in the material

S.Panwala,S.A channniwala, K.N Srinivasan[55] developed numerical method for the temperature profile in single pass and double pass of 45ÚV & 60Ú V weld geometry during welding process.These thermal analyses are validated by extensive investigation.In this second part of the study they developed thermo mechanical analysis of welding and simulated the residual stress induced during the welding. These numerical methods are validated by measuring residual stress in the weld based on hole-drill method.The stresses and temperature were in very good agreement with experiment result.

SUMMARY & FUTURE OUTLOOK

From the study of the various papers based on optimation of submerged arc welding processes parameters it can be concluded that among the various welding parameter arc voltage & arc current affects the microstructure and mechanical property the most & hence need to be optimized. The microstructure depends not only on chemical composition of base metal, flux and filler wire but also on the rate of heat input and heat dissipation which in turns depend on the thickness of plate and the angle of groove. In a multi pass welding, the study of microstructure and mechanical property is complex.Due to complexity and unavailability of the information regarding heat source, the detrimental effect like residual stresses are generated which affect the life of the product& need to be minimized.

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