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FINITE – ELEMENT ANALYSIS FOR OPTIMIZATION OF SUBMERGED ARC WELDING (SAW) PROCESS

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ABSTRACT
Submerged Arc Welding (SAW) uses the arc struck between a continuously fed electrode and the workpiece to melt the metal in the joint area and provide additional filler metal under a blanket of granular flux. In this paper, the Submerged Arc Welding is studied and copper temperature field is gained in this process. The thermal effect of Submerged Arc that specially depends on the electrical arc, flux type and temperature field of it in workpiece, is the main key of analysis and optimization of this process, from which the main goal of this paper has been defined. Numerical simulation of welding process in SIMPELC method and by ANSYS software for gaining the temperature field of copper, the effect of parameter variation on temperature field and process optimization for different cases of Submerged Arc are done. The influence of the welding parameter for each mode on the dimensions and shape of the welds and on their ferrite contents is investigated.
Keywords: Finite-Element, Copper, Shielding gas, Argon, Helium, Flux, SAW

1. INTRODUCTION
SAW uses the arc struck between a continuously fed electrode and the work piece to melt the metal in the joint area and provide additional filler metal under a blanket of granular flux. This arc is completely submerged under the molten flux, which protects the molten metal from the atmosphere. There is no visible arc, spatter or fume during the welding operation.
The continuous electrode may be a solid or cored wire. The solid wires are normally copper coated. The cored wires may contain either metallic materials or a mixture of metallic and flux materials.
Flux cored wires affect the welding characteristics and metallurgical quality of the deposited weld metal. On surfacing applications, strip electrode can be used instead of a wire.

A wide range of flux compositions is used with submerged arc welding. Generally speaking, fluxes with the best welding characteristics give inferior weld metal mechanical properties. These fluxes are known as acid fluxes. Neutral fluxes generally give a good all round performance. While basic fluxes give the best metallurgical results, they possess inferior welding characteristics. The normal approach is to select the flux with the best running characteristics that will meet the metallurgical requirements comfortably.

SAW Process shows in Fig.1.

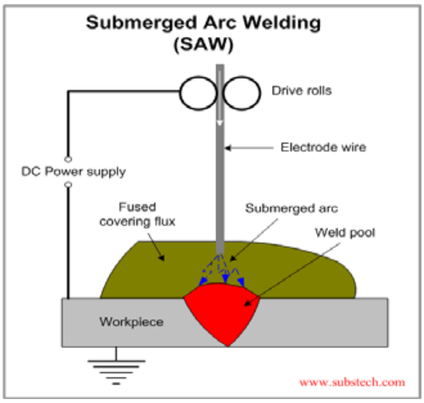


Figure 1. Submerged Arc Welding (SAW) Process

2. GOVERNING EQUATIONS

In the common direct current electrode positive (DCEP) connection, the electrode is the anode and the workpiece is the cathode. A plasma arc is struck between the electrode and the workpiece. The electrode is continuously fed downward and melts at the tip by the high temperature arc. Droplets are then detached from the electrode and transferred to the workpiece. The computational domain includes an anode zone (electrode), an arc zone, and a cathode zone (workpiece). The anode and cathode sheaths have been omitted and treated as special boundary conditions for computational simplifications. Assuming the arc is in local thermal equilibrium (LTE) and the plasma flow is laminar and incompressible, the differential equations governing the arc, the electrode, detached droplet, and the workpiece can be put into a single set.
The differential Equations (1) – (4) are solved iteratively by the SIMPLEC numerical procedure:

Mass continuity equation:

$$\frac{1}{r}\frac{\partial}{\partial r}(r\rho\upsilon_r)+\frac{\partial}{\partial z}(\rho\upsilon_z)=0 \qquad (1)$$

Radial momentum conservation equation:

$$\frac{1}{r}\frac{\partial}{\partial r}(r\rho\upsilon_r^2)+\frac{\partial}{\partial z}(\rho\upsilon_r\upsilon_z)=-\frac{\partial\rho}{\partial r}-j_zB_\theta+\frac{1}{r}\frac{\partial}{\partial r}(2r\eta\frac{\partial\upsilon_r}{\partial r})+\frac{\partial}{\partial z}(\eta\frac{\partial\upsilon_r}{\partial z}+\eta\frac{\partial\upsilon_z}{\partial r})-2\eta\frac{\upsilon_r}{r^2}$$
(2)

3. ELABORATION OF A MATHEMATICAL MODEL FOR MELTING RATE

Influences of welding parameters on melting rate in single wire and twin wire submerged arc welding were studied during numerous experiments. A study of the influence of current intensity on melting rate was carried out by means of practical experiments. The results obtained are shown in Figs. 2 and 3. Fig. 2 shows the influence of welding current on melting rate in welding with a single wire and a twin wire having a diameter of 3 mm. Welding was carried out also with wire diameters of 1.2, 1.6 and 2.0 mm. The results for the twin wire are shown in Fig. 2 (L is the wire extension length and b is the distance between the wires). Based on both diagrams (Figs. 2 and 3) similar conclusions may be drawn. In all cases the melting rate increases slightly exponentially with an increase in welding current intensity.

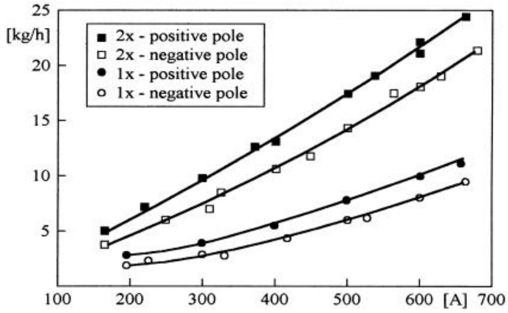


Figure 2. Melting rate depending on welding current intensity per wire and on polarity of a wire having a diameter of 3 mm; L.30 mm, b.8 mm

4. NUMERICAL CONSIDERATIONS

For the metal domain, the method developed by Torrey et al. was used to solve p, u, v, and T. This method is Eulerian and allows for an arbitrary number of segments of free surface with any reasonable shape. The basic procedure for advancing the solution through one time step, Dt, consists of three steps. First, explicit approximations to the momentum Equations (2) – (4) are used to find provisional values of the new time velocities at the beginning of the time step. Second, an iterative procedure is used to solve for the advanced time pressure and velocity fields that satisfy Eq. (1) to within a convergence criterion at the new time. Third, the energy equation Eq. (5) is solved. Fig.3. shows A typical sequences of temperature, electrical potential, and pressure distributions on the symmetric plane for an axisymmetric stationary arc.

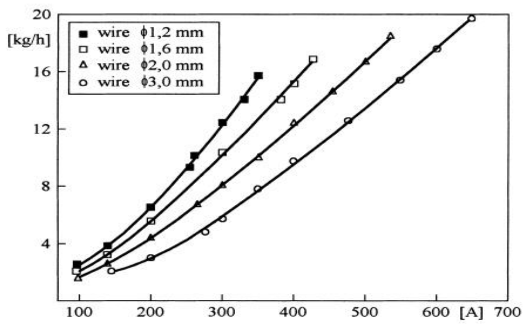


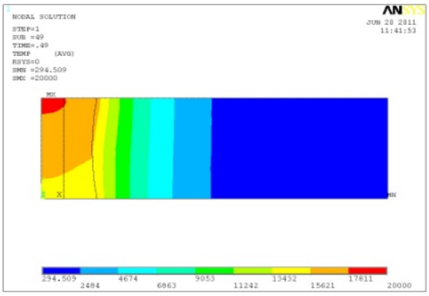
Figure 3. Influence of welding current intensity on the melting rate in twin electrode arc welding with the following wire diameters: 1.2, 1.6, 2.0 and 3.0 mm; L.25 mm, b.8 mm, U.30 V, electrode positive.

5. RESULTS AND DISCUSSION

Conclusions for fluid temperature field copper temperature field, completely shown in Fig.4.

A complete 3D mathematical model for the SAW process is developed, the complete solution for a 3D case can be obtained if the numerical solution procedures proposed by Hu and Tsai are followed. The biggest challenge for such a 3D solution lies in the cost of numerical computation. Normally, the plasma flow can be computed with a relatively large grid size, but the metal flow requires a much smaller grid size in order to resolve various body forces within the tiny droplet.

a)



b)

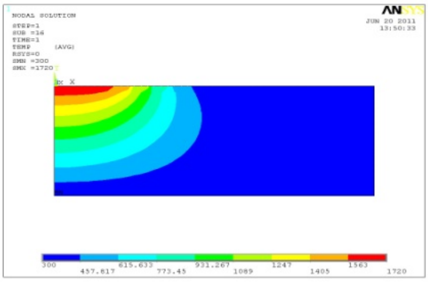


Figure 4. Conclusions for temperature field:
a) temperature field b)Copper temperature field

6. CONCLUSIONS

A more elaborate mathematical model than the one existing before was developed for calculation of melting rate in single-wire arc welding. Additionally a mathematical model for calculation of melting rate in twin-wire arc welding not known from the literature before was developed. On the basis of variation of validity of the mathematical models developed for single-wire and twin-wire arc welding it can be stated that the models are quite a true representation of the experimental results and that they are applicable to practical cases as well as to further research work.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] S. Tashiro, M. Tanak, L. Murph, and J. Lowke, "Prediction of energy source properties of free-burning arc" Welding Journal, March 2008, pp. 23-29.
[2] A. Moarrefzadeh, "Numerical simulation of temperature field by Plasma arc welding Process in stainless steel" IREMOS Journal, February 2010, pp.101-107.
[3] A.Moarrefzadeh, " Choosing Suitable shielding gas for thermal optimization of GTAW process, IREME Journal, Sep 2011