ANALELE UNIVERSITĂȚII
“EFTIMIE MURGU” REȘIȚA
ANUL XIII, NR. 1, 2006, ISSN 1453 - 7397

Lenuţa Suciu, Iancu Tătucu

Uncoupled Thermo - Mechanical for the Determination of Welding Deformations

Simulation of the welding process for butt and tee joints using finite element analyses are presented. The simulation are performed with the commercial software Ansys, which includes mathematical model, temperature dependent material properties, transfer and mechanical analyses. One way thermo – mechanical coupling is assumed.

1. Introduction

Welding is a very involved manufacturing process where complex termal, matallurgical, mechanical and electrical phenomena. Two types of welding sequences are usually used in practice; multi – layer which is normally used in thick plates joining, and multi – block which is always applied into the long strip welds.

In 1989, Anand[1] presented an empirical relation to predict the viscoplastic behavior of metals at elevated temperatures. The Anand viscoplastic model is frequently used for modeling many manufacturing processes including welding. Welding is affected by various mechanical and metallurgical phenomena which have different levels of importance in the formation of final residual stresses and distortion in welded parts. Due to the small effect of metallurgical phenomena (phase change, chemical change, etc) in comparison to the thermo – mechanical ones, these effects were ignored in the present work an only the uncoupled thermo – mechanical aspects of welding are considered.

2. Geometrical model

To analyze the thermo – mechanical response of thick plates under the piese welding, two 300x700x10mm steel plates were assumed to be joined by a single pas of welds. The temperature of welding pool was assumed to be 1500^0C (melting point) and the ambient temperature was taken as 20^0C. Heat convection into surrounding would also take place from all external surfaces an assumed constant coefficient of 10 W/m^{2}K.

3. Mathematical model

Joining of parts by welding always occurs at high temperatures. High temperatures also cause great values of nonlinear thermal loads in the welded region and these unevenly distributed loads produce undesired stresses and deformations in welded parts. Kinematics of a body for this kinds of thermo – mechanical problems is normally formulated by the use of Lagrangian description.

In reality, welding is a coupled thermo – mechanical process wich is mathematical modeling consists of two principles expressing thermal an mechanical equilibrium, the balance of internal energy and balance of momentum as well as the initial and boundary conditions.

The equilibrium condition for welded parts can be expressed by the following equations:

$$\left(T_{KI} + T_{KJ} \cdot u_{I,J}\right),_{K} - \left(b_I + r_I\right) = 0 \quad \text{for particle, } \mathrm{X} \in \Omega$$

$$\left(T_{KI} + T_{KJ} \cdot u_{I,J}\right) N_K = T_I \quad \text{for particle, } \mathrm{X} \in \partial\Omega$$

where the indices I, J, K refer to the reference configuration, and comma is the usual abbreviated notation for a gradient component. The balance of internal energy for the weldwe materials can be expressed in the form of:

$$p \cdot \dot{e} + div q = T \cdot \dot{L} + q_{ext} \cdot N + p\Re$$

where let e be considered as the energy density per unit mass of the plates, let q is the vector of heat flux transferred through the parts $\mathrm{X} \in \Omega$, q_{ext} ist heat flux supplied to the welded body through the outer surface, $\Re$, is the energetic radiation from weldments.

4. Material properties

The magnitudes of thermal load are highly varied in the welded parts. Therefore, the variation of thermal and mechanical properties of welded materials with respect to temperature would be significant and should be considered in welding analysis. The variation of thermal and mechanical properties of the selected material that is shown in Table 1.

Table1.Thermal and mechanical properties of a material function of temperature

T (^{0}C)	Thermal Conductivity k (W/m.K)	Specific Heat C_p(J/Kg.K)	Coeff.of thermal expansion α (10^{-6}1/C)	Young's Modulus E(GPa)

0	51,9	450	10	200
75	-	486	-	-
100	51,1	-	11	200
175	-	519	-	-
200	49	-	11,5	200
225	-	532	-	-
275	-	557	-	-
300	46,1	-	12	200
325	-	574	-	-
375	-	599	-	-
400	42,7	-	-	-
450	-	-	13	150
475	-	662	-	-
500	39,4	-	-	-
550	-	-	14	110
575	-	749	-	-
600	35,6	-	14	88
675	-	846	-	-
700	31,8	-	-	-
725	-	1432	14	20
775	-	950	-	-
800	26	-	14	20
1000	27,2	-	14,5	11
1200	-	-	15	2
1500	29,7	400	15	0,2

5. Mesched model. Finite element aproximation

Because of rate dependent plastic deformation in welding, the mechanical stiffness matrix in structural analysis is changing with respect to time and it should be re-calculated in each time step.

Based on Galerkin's method, the finite element form of the equation of motion can be expressed as:

$$K_u \cdot u = R_u - F_u ,$$

where: $K_u, u, R_u,$ and F_u are the mechanical stiffnes matrix, displacement vector, vector of externally applied loads and vector of nodal point forces.

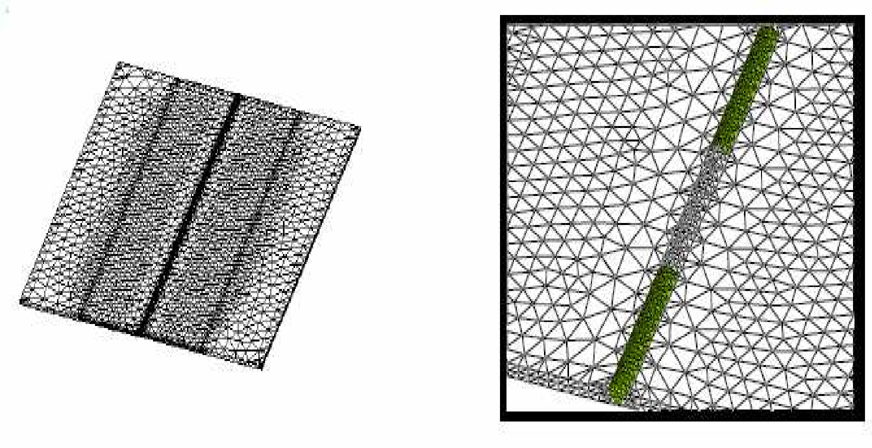


Figure 1. Meshed model of welded region

6. Solution

The applicability of the present model in welding of thick plates has been thoroughly verified, and measured the magnitude of residual stress on the surface of two thick multipass -welded plates by the method of X-ray diffraction.

a) Temperature distribution

The computed isothermal lines on the top surface of welded plates for two different welding sequences are shown in Figure 2. As the figure shows, the application of different welding sequences significantly changes the overall profile of isothermal (constant temperature) surfaces.

Sequence no.1 has produced a more uniform isothermal profile in weldments as compared to Sequence no.2, and the magnitudes of their maximum temperatures are also different. The differences and smoothness happened mainly due to the order of joining and the direction of arc movement in welding. In sequence no.1, the applied is guided toward the center of the welded strip (concentrated at mid-point) but in the second one the welded line. This localization of isothermal surfaces on a specific area causes a great deal of distortion and residual stresses in the welded region.

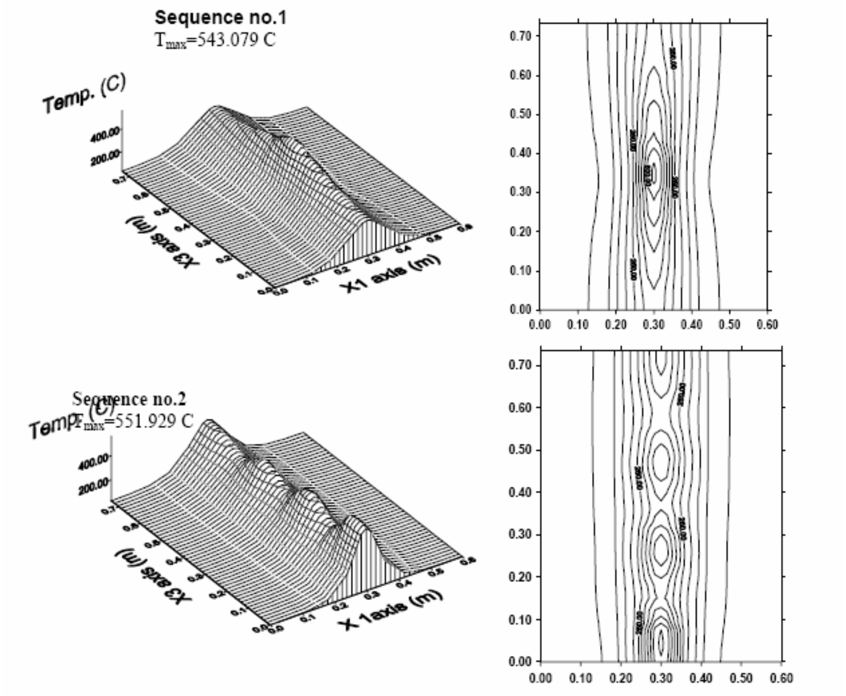
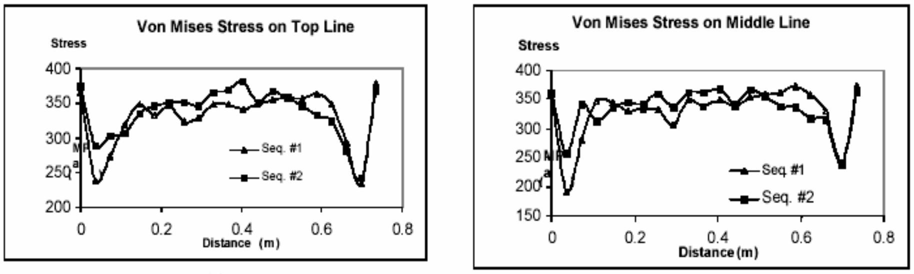


Figure 2. Isothermal lines and their magnitudes on top surface of multi – block welded plates, 120 seconds after the welding completed



(a) (b)

Figure 3. Variation of Von Misses stress on a section the weld

a) Von Mises stress on Top line
b) Von Mises stress on Middle line

5. Conclusion

The validation of results was thoroughly satisfied by comparing the model with two experimental and analytical works, and can optimize the sequences of welding which have been specified for practical solutions.

References

[1] Brown, S.B., Kim, H.K., Anand, L. (1989) *An internal variable constitutive model for hot working of metals.* International Journal of plasticity, 5, 95-130
[2] Tătucu, I. *Modelarea câmpului electromagnetic şi a câmpului termic* Editura ,, Eftimie Murgu" Reşiţa-2002, pag 59-93
[3] Suciu, L.*Teza doctorat- Referat nr.3, 2006*

Addresses:

- As. Drd.ing. Lenuţa Suciu, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, ilesuciu@yahoo.com
- Conf. Dr.ing. Iancu Tatucu, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, itatucu@ uem.ro