VIII International Conference on Computational Plasticity
COMPLAS VIII
E. Oñate and D.R.J. Owen (Eds)

MACRO-MICRO TRANSITION TO MODEL CRACKING PHENOMENAS DURING MULTIPASSES WELDING PROCESSES

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Key words: Welding process, Material Behaviour, microstructure, local fracture

Summary. *The nucleation of cracks during welding process is of main importance in order to assess the lifetime prediction of the component that is made. Due to the complexity of the loading of the material during the process, a two scale numerical model is developped. The two scales are (i) the structural level and (ii) the microstructural level. A macroscopic criteria is developped and a simultion is performed to look at the influence of the process parameters (initial temperature, input energy, thermal boundary conditions,...). Then a microstructural finite element model is developped.*

1 Introduction

Some tools damage due to thermal fatigue during forming cycle. These surface damages could be repaired. The repairing is decomposed in two phases: (i) Chamfer creation in place of the cracks, (ii) Recharging with a filler material [1]. Multipasses are necessary to fill the chamfer.

In order to assess weldability, some experiments were performed on a massive block repaired using shielded metal arc welding process. Some micrographic analysis of the transverse part of the repair have shown cracks in the vicinity of the interface base/filler metal.

The level of stresses, strains and temperature during welding are the main variables to predict nucleation of cracks in the base metal.

In order to investigate the most critical place for the nucleation of cracks, a criteria must be developed. A simple stress criteria is developped. In the zone where the criteria is overlapped, a particular microstructure is stretched with the loading at the particular points (node). An image or a macrography must be digitized to analyse the stress distributions with the loading to have a numerical model. This will give particular access to the critical phase heating or cooling.

In this zone, stresses, strains, temperature and temperature gradient are extracted to load the microstructure. This type of simulation gives us important informations to know the evolution of the carbide network along the welding process.

2 The material

2.1 The microstructure

The material under study is a austenitic steel which keep good material properties at high temperature. Due to the manufacturing of this steel (solidification process), the material has a complex microstructure. Coarse austenit dendrites and chrome carbides in the interdendritic zone.

2.2 Mechanical behaviour

In the range of temperature from 20 to 900 degrees, a classical model of isotropic plasticity can model the behaviour. We assume that the inelastic behaviour that occurs beyond 1000 °C is not relevant to low temperature and we decide to use a cut-off temperature to annihilate the plastic accumulated strain and that will deserve us for numerical convergence (see next part). Plastic hardening combined with elasticity is probably the most important parameter for cold cracking. In this way, the behaviour of the material must be appreciated during the whole processes.

As outlined earlier, the rupture of the base material will dictated by the local stresses in microstructure. In general, microcracks are nucleated by three phenomenas: *(i)* Rupture of the chrome carbide during strain, *(ii)* Interfaces can not sustain the high level of stress and *(iii)* cracks in the matrix if it has poor mechanical properties.

3 Modelling Multipass Welding

The main purpose is to predict or prevent from the nucleation of cracks during multipass welding. The problem induced weak thermomechanical coupling in the sense that it is the thermal history that mainly induced the mechanical loading.

The parameter involves in the process that can be modified to decrease the high level of stress could be the initial temperature and the order of sequences.

In the first simulations of repairing [2], some passes were gathered in order to decrease computational cost. Nowadays, each bead could be modelled indepedently in the geometric model. We decide to cut a fill by straight line such that the delimited surface is equal to the one of the bead observed experimentally.

The material for the base material the one that constitutes the metal forming tool, and for the filler material are almost of the same composition. As said earlier, the base material is modelled by *isotropic elastoplasticity* (at the macroscopic scale) with isotropic hardening and the filler material is modelled by elastic-rigid plastic material.

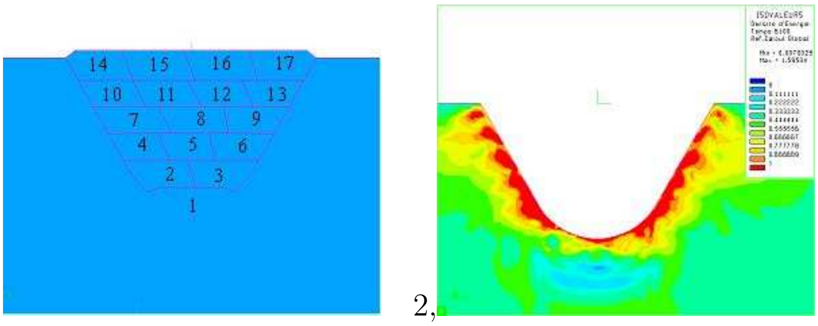
We are interest into the cracks nucleation during the processes. The material show brittle behaviour, so that we establised a simple stress criteria in order to see the best place for the nucleation of cracks.

$$g = \max_{t \geq t_0}\left(\frac{max(\sigma_i)}{\sigma_f(T)}\right) \tag{1}$$

where σ_i is a principal stress and $\sigma_f(T)$ is simply the fracture stress identifies by uniaxial test.

A plane strain analysis will be done. The Goldak gaussian heat source [3] is chosen. The heat input is calibrated to have the complete melting of the bead.

An other important point is the initial temperature of the base material. In this analysis, the base material is of 20 degrees. The order of the pass chosen for the analysis is shown on figure 1.



2,

Figure 1: Model and results of the criteria

The thermomechanical analysis will tell us at which pass the higher level of stress will be reached. This map of figure 1 tells us the most critical point. Now, we are able to know the whole strain-temperature history at this point.

4 Microstructure study

4.1 The finite element model

One cell as those of the figure **??** is taken. Using a digital filter, points of the intertendritic zone are identified by their coordinate and then injected in a preprocessor for finite element modelling. The two phases are modelled them with two different properties.

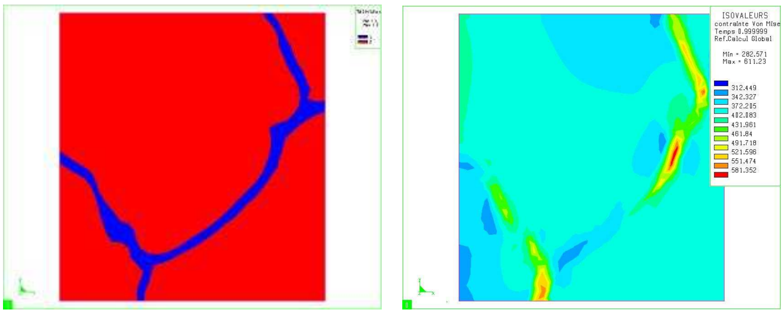


Figure 2: Model of the microstructure, in blue the interdendritic zone, in red the austenitic matrix

Mechanical material parameters are : for Carbide Young's modulus 317GPa, for Austenit Young's Modulus 210GPa and for Austenit yield limit 350Mpa.

We apply a classical boundary conditions for tensile test. The displacement on the face are given by:

$$\mathbf{u} = \mathbf{E}.\mathbf{x} \tag{2}$$

$$\mathbf{T} = \bar{\mathbf{T}} + \mathbf{q}.\mathbf{x} \tag{3}$$

where $\mathbf{E}$,$\bar{\mathbf{T}}$ and $\mathbf{q}$ are the macroscopic strain tensor, mean temperature and the flux obtained from the simulation of the process. Some studies of this type was done to find the behaviour of polycrystal [4].

4.2 Cold cracking

We see that because of the incompatibilty of straining i.e the austenitic phase deform plastically $\nu = 0.5$ and the carbide network can not $\nu = 0.3$, so that the carbide network tends to be stretched. We can appreciate the high level of stresses in the carbides network which will induce cracks due to the brittleness of this component. We can appreciate that the maximum stress in the carbides is much more higher than the average stress.

5 Conclusion

For cold cracking a study based on tensile test will allow us to extract the stress at rupture for the nucleation of cracks. On real micro test, we will be able to know the critical sites in the matrix and then knowing the macroscopic force at rupture, the stress in the interdendritic zone will be approximated.

For further studies, several cells will be digitized and tested with the same loading in order to appreciate the influence of the topology for the onset of cracks.

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