

C. Topological Features of Grains in the Heat-Affected Zone of Gas Tungsten Arc Welds in Ti-6Al-4V Alloy

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Introduction

In the heat-affected zone (HAZ) of Ti-6Al-4V gas tungsten arc welds, large beta grains significantly lower weldment strength. Understanding grain structure evolution requires analysis of both the size and topological features of grains because topology plays an important role in grain growth. No previous study of grain topology is available for the Ti-6Al-4V alloy HAZ under the unique non-isothermal conditions characterized by steep temperature gradients and strong thermal cycles. Both experimental determination of grain topology and theoretical calculations of topology using Monte Carlo technique will be discussed.

Approach

A well tested three-dimensional (3D) thermo-fluid model is used to calculate the thermal cycles in the Ti-6Al-4V weldment. The calculated thermal cycles at each site are used in a 3D Monte Carlo (MC) model to calculate grain structure map around the weld pool. Various topological features are extracted from two-dimensional cross-sections of the grain structure map and compared with the corresponding experimental results. The topological class distributions in commercially pure titanium welds are compared with those in Ti-6Al-4V welds. X-Ray Diffraction is conducted to examine the texture development in the HAZ under steep temperature gradients.

Results/Discussion

The fusion zone geometry calculated from the thermo-fluid model agreed well with the corresponding experimental result for four heat inputs. The spatial variation of average grain size in the HAZ, calculated by the Monte Carlo model, agreed well with the corresponding experimental results.

The 2θ locations and the intensities of the lines in the XRD patterns for the base metal and the region of HAZ close to the fusion zone, matched well with the standard XRD patterns available for titanium and its alloys. All major peaks could be accounted for indicating no significant texture development in the HAZ.

The topological class distributions were identical for different locations in the HAZ and for different heat inputs. The nature of the distributions was similar to those obtained for isothermal heating of materials. The topological class distributions in the HAZ of the Ti-6Al-4V alloy agreed well with those for commercially pure titanium. A linear relation was observed between average grain size for each edge class and the edge class number, at different locations in the HAZ.

The calculated results showed a linear relation between the average number of sides of neighbors and the number of sides of grains, at various locations in the HAZ. Locations with similar linear relations indicated the presence of similar local topological environment and hence possibility of similar grain sizes which was confirmed by the similarity of experimentally obtained average grain size versus side plots at these locations.

The average perimeter per grain decreased with distance from the fusion plane owing to the smaller average grain size due to weaker thermal cycles.

In all the cases, the calculated results for topological features of grains agreed well with the corresponding experimental measurements.

Conclusions

Monte Carlo model accurately predicted both size and topological features of grains in the HAZ.

Steep temperature gradients did not introduce any significant texture in the grains.

The topological class distributions were unaffected by the variation of thermal cycles and the welded material.

The average grain size for each edge class varied linearly with the edge class number, in HAZ.

The average number of sides of neighbors varied linearly with the number of sides of grains. Locations with similar local topological environment showed similar grain growth.

The average perimeter per grain decreased with distance from the fusion plane.