Predicting Stir Zone Grain Size in Friction Stir Welding and Processing

J. D. Robson[1], L. Campbell[1], J. dos Santos[2]
[1]LATEST2, School of Materials, The University of Manchester, UK
[2]Virtual Institute – IPSUS, Helmholtz-Zentrum Geesthacht (HZG), Germany

One advantage of friction stir welding over fusion welding methods is that the weld nugget (correctly referred to as the stir zone) usually shows much improved strength and ductility. Indeed, the properties of a FSW stir zone often exceed that of the parent material, and this is taken advantage of in friction stir process (FSP), where the same technology is used to refine the microstructure rather than produce a joint.

A key reason for the excellent properties of FSW stir zone is the grain refinement that occurs as a result of the local severe plastic deformation. However, the grain size obtained (and hence critical properties) is strongly dependent on both alloy and processing conditions. A model to predict grain size would therefore be of great utility in helping to optimize both alloy and processing conditions to acheive the required level of grain refinement to produce target properties.

In this work, the first physical model for grain size evolution in FSW/FSP has been developed. In this model, a prediction of the local strain rate and temperature history from a process model (e.g. Figure 1) is coupled to a microstructure model that calculates both the formation of new grains (recrystallization step) and the growth of those grains in the hot material trailing the tool. The model for grain refinement is coupled to a precipitate evolution model developed previously (LATEST1). This allows the interaction between precipitation and grain refinement to be predicted. Such coupling is critical to correctly simulate the microstructural evolution in aerospace aluminium alloys during FSP or FSW.

The model has been tested against experimental welds produced at HZG using their innovative FlexiStir system, a FSW machine that sits on a synchrotron X-ray beam line (DESY) allowing in-situ monitoring of the microstructure during welding. The model has been shown to give good predictions to experiement, providing a valuable tool for optimization of FSW and FSP.

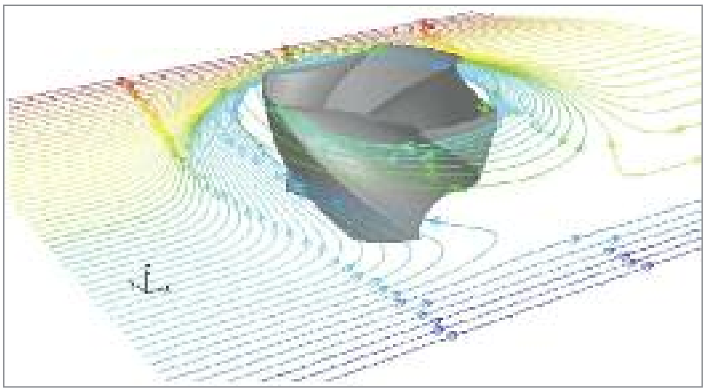

Fig. 1 Predicted flow of material around a friction stir welding tool from a process model. Temperature and strain rate data extracted from this model are used as inputs to microstructure prediction.

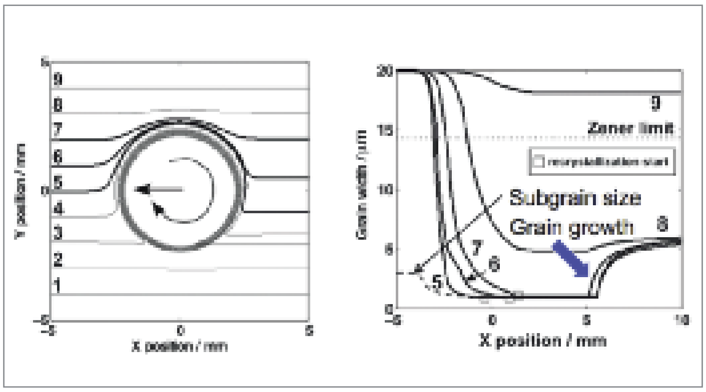

Fig. 2 Predicted material flow lines at increasing distance from the FSW tool (left) and the associated prediction of grain size evolution (right).

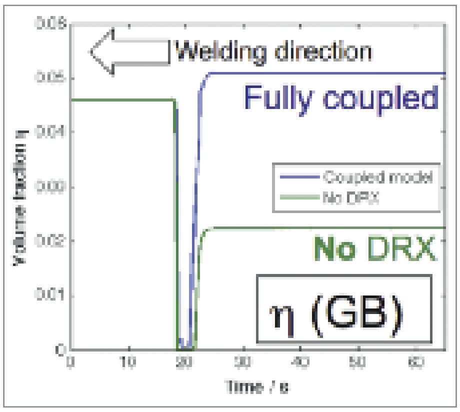

Fig. 3 Prediction of the effect of grain refinement in the stir zone on grain boundary precipitation (7xxx aluminium alloy). Only the fully coupled model that considers dynamic recrystallization (DRX) correctly predicts the large fraction of grain boundary precipitation observed in practice.

Publications: J. D. Robson, L. Campbell, Materials Science Forum 706, 2012, pp. 1008-1013

J. D. Robson, L. Campbell, Science and Technology of Welding and Joining, 15:2, 2010, pp. 171-176

J. D. Robson, L. Campbell, 8th International Conference on Friction Stir Welding, Symposium Proceedings, Germany, 18-20 May 2010 (CD-ROM).