## Benchmark Problem 1

A six-pass plate welding problem from literature [1] is used to illustrate the application of the Abaqus Welding Interface (AWI) to setup welding simulations. The problem consists of two low carbon steel flat plates of size 150 X 140 X 12 mm, that form a V-groove between them, welded together in six passes. In [1], temperature histories at select locations in both the left and the right plates obtained from thermocouple measurements during welding are reported. The finite element mesh used for the AWI model of the same plate problem is shown in Fig. 1. The locations where the temperature histories will be monitored are highlighted in Fig. 2 & 3, and match the thermocouple locations from [1]. The material properties and film coefficients for convective cooling are the same as what was used in [2], where the same plate problem was analyzed.
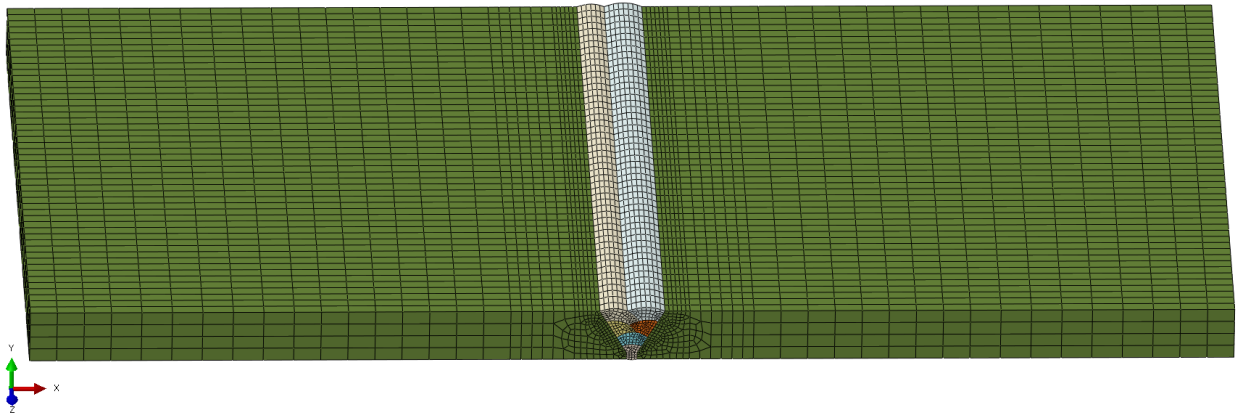


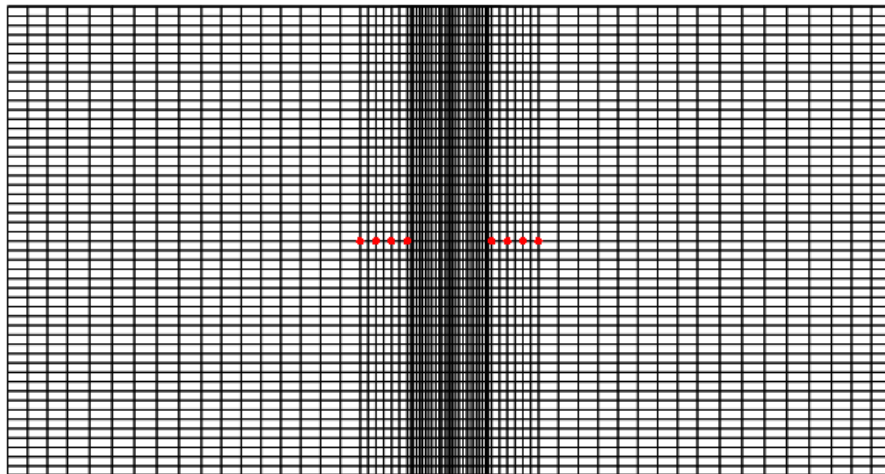**Figure 1 Finite element mesh of the plate welding problem**



**Figure 2 Top view of the meshed plate showing thermocouple locations**
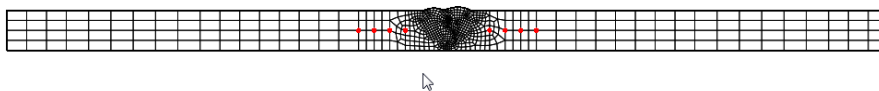


**Figure 3 Side view of the meshed plate showing thermocouple locations**

**Input Parameters and Options for the AWI Model of the Plate.** A target torch temperature of 2800 F was assumed, and each bead was subdivided into ten (element-based) *chunks* (Fig. 4). In general, with the prescribed temperature approach, temperature magnitude above liquidus temperature will need to be used to ensure adequate penetration of heat. In the present example, the liquidus temperature is approximately 2700 F. A total torch time of 6.2 seconds was used for each chunk, based on the average of the torch speeds for the six passes for the particular case presented in [1]. The *ramp and hold* option was used, with the temperature ramped up to target temperature over 10 % of the torch time and held constant for the remainder of the torch time for each chunk. A two-minute interpass cool-down step was also inserted between all passes, consistent with the welding process described in [1]. This was easily accomplished by utilizing the *user-defined step* option provided by the AWI, which allows extra analysis steps to be inserted within any weld pass, in addition to the standard steps created for all passes in the AWI.
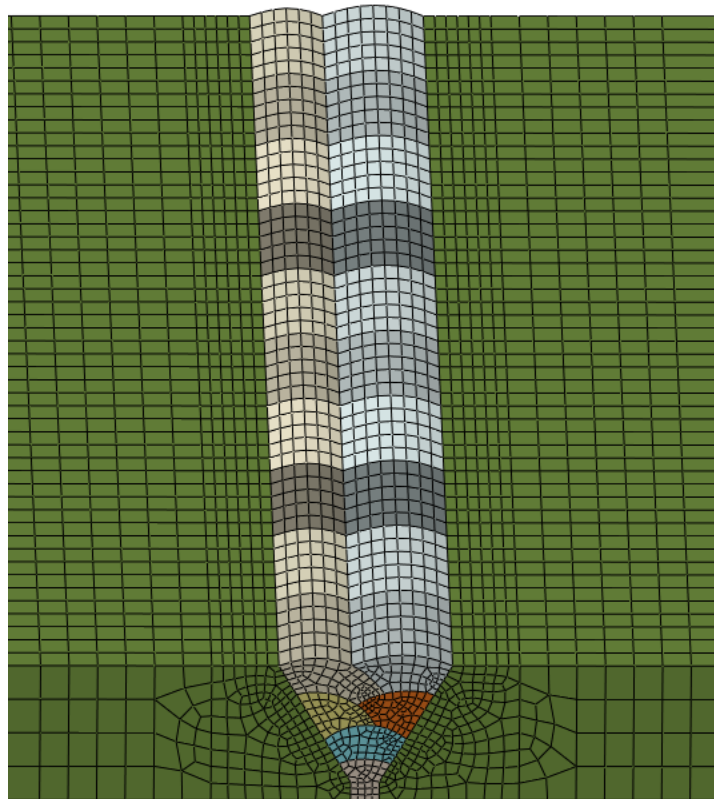


**Figure 4 Division of beads into discrete chunks in the torch direction**

**Results.** A direct comparison of the predicted temperature results from the AWI model to the thermocouple data from [1] is not attempted (primarily due to insufficient information on the total time scale of the results presented in [1]), but the AWI results shown in Fig. 5 & 6 reproduce the trends well as compared to the data reported in [1]. Since a precise control of energy input is not possible when the temperature-based heat input is used, some trial and error with respect to parameters such as the number of discrete chunks the bead is subdivided into in the torch direction, the target torch temperature used for the temperature boundary condition, time to ramp up to the torch temperature, and the time the boundary is held at torch temperature would be necessary to calibrate and benchmark different classes of welding problems. The sum of the nodal reaction fluxes (variable RFLE) in the whole model can be compared with the desired power input during these trial-and-error runs. AWI makes it easy to change any of the parameters related to welding model setup and regenerate the model, and can be used within an optimization loop with a program such as Isight (which has a data matching component) to determine the correct values of the parameters.
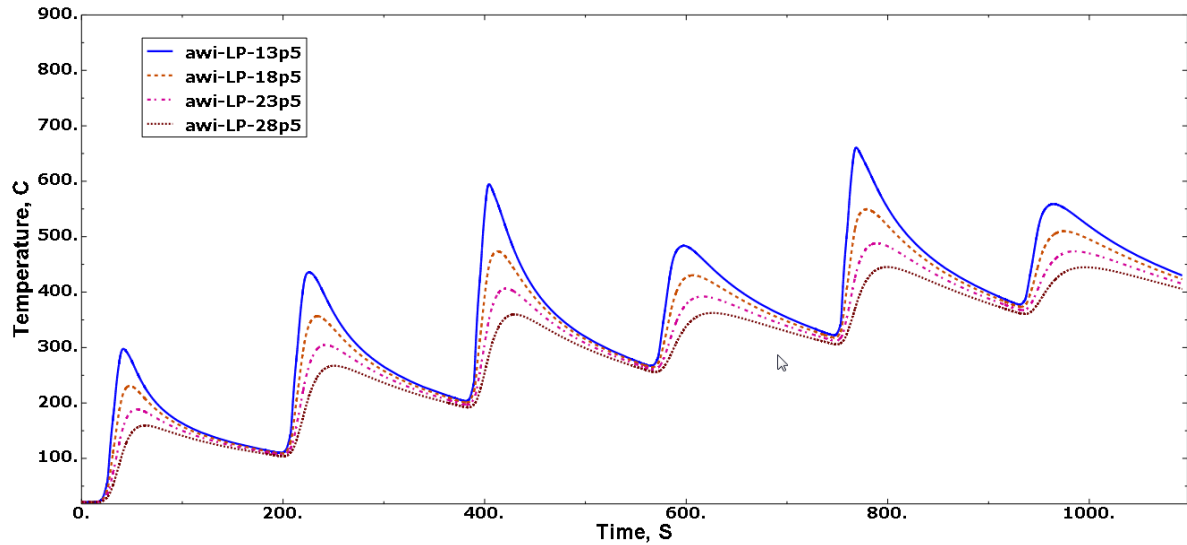
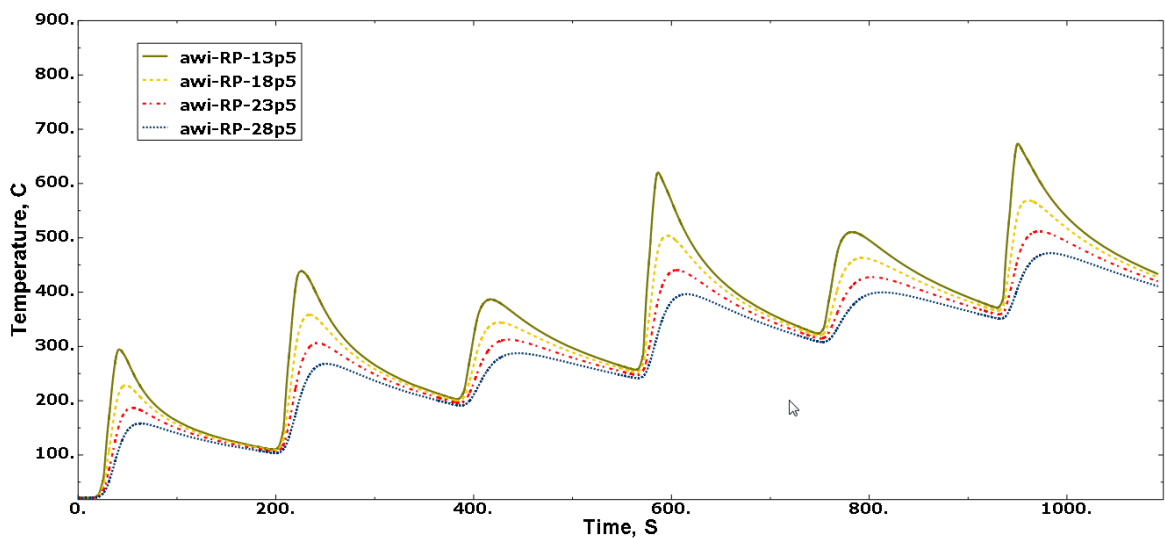**Figure 5 Predicted thermal histories at left plate TC locations from AWI model**



**Figure 6 Predicted thermal histories at right plate TC locations from AWI model**

## References

[1] S. Murugan, P.V. Kumar, B. Raj, M.S.C. Bose, Temperature distribution during multipass welding of plates, International Journal of Pressure Vessels and Piping 75 (1998) 891–905.

[2] David J. Dewees, Comparison of 2d and 3d welding simulations of a simple plate, Proceedings of the ASME 2012 Pressure Vessels & Piping Division Conference, July 15-19 (2012), Toronto, Ontario, Canada