Two-Pass Rolling Simulation

Summary
Hot rolling is a basic metal forming technique that is used to transform preformed shapes into final products or forms that are suitable for further processing. The process typically involves passing heated stock pieces through multiple sets of forming rolls until the desired cross-sectional shape is achieved. The important aspects of this manufacturing operation are the elongation and spread of the material during the rolling process. Abaqus contains all the features necessary to model this process and has been used extensively within the metal processing industry to optimize roll pass designs.

Background
A two-pass rolling simulation, which is part of the multi-pass operation required to form a rail, is discussed. The process starts with a heated preformed stock that is rolled between a pair of shaped rolls. During the rolling process the stock is cooled by spray-applied cooling fluid. After the first pass the stock cools before being passed through another pair of shaped rolls. The desired rail cross-section is produced by repeating this process with new roll shapes at each rolling stage of the multi-pass operation.

Finite Element Analysis Approach
The analysis steps used to model the two-pass rolling process are as follows:

1. The first roll pass in Abaqus/Explicit proceeds until the steady-state rolling solution is achieved.
2. A two-dimensional mesh of the deformed cross-section at the steady-state plane is extracted using Abaqus/CAE. The final temperatures on the steady-state plane are also extracted.
3. A two-dimensional transient thermal analysis in Abaqus/Standard is used to model the cooling during the 45 sec between roll passes.
4. A new model of the cross-section with a finer mesh is generated in Abaqus/CAE. In a second thermal analysis, the submodeling capability in Abaqus/Standard is used to transfer the temperatures from the cooling analysis of Step 3 to the finer mesh. The purpose of the analysis is only to transfer the temperatures to the new mesh.
5. The new cross-section mesh and temperature data from Step 4 are used to construct the three-dimensional mesh for the second roll pass in Abaqus/Explicit.
6. The second roll pass in Abaqus/Explicit proceeds until the steady-state rolling solution is achieved.

Roll Pass Analyses
For each roll pass analysis the rolls are modeled as isothermal, analytical rigid bodies, and heat transfer occurring between the rolls and the deformable rail is included. Heat can be generated in the rail due to both plastic work and frictional contact effects. The heat loss from the rail due to the fluid cooling is accounted for with convective heat transfer boundary conditions; radiation to the ambient environment is also included. Therefore, these analyses are performed using a fully coupled thermal-stress solution in Abaqus/Explicit.