MULTIPHYSICS AND MULTISCALE MODELING OF HEAT TRANSFER DURING DRAWING

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KEYWORDS

Heat Transfer, Cold Drawing, Fiber, Plasticity

ABSTRACT

A Multiphysics computational model has been developed to represent the drawing process for a fiber. The process consists of cold drawing the fiber over a series of rollers while limiting the temperature rise due to the heat generated during necking. Initial prototypes generated temperature rises of greater than 100 °F. Thus, modelling provided a method of assessing cooling methods. The primary modelling concept submerges the fiber during the rolling process to minimize the temperature rise during drawing.

To represent accurately the submerged drawing process, the model includes the deformation of a moving fiber submerged in a tank that contains water circulated by a pump. This model represents the plastic deformation due to the mechanical loading of the fiber and includes a heat source due to this plastic deformation. In addition, the model solves the conjugate heat transfer problem between the moving fiber and the cooling water. The geometry of the fiber enables two-dimensional, planar modelling of the fiber deformation process. However, the location of the inlet and outlet ports for the pump eliminates the planar approximation for the fluid flow and heat transfer. Thus, the modelling process consists of a planar model to generate plasticity and a three-dimensional model to represent the fluid flow. This approach enabled the development of a computationally efficient solid-

mechanics model that accurately modelled the fiber thickness while also solving for over the fluid flow using the length scale of the tank.

Figure 1 shows the equivalent plastic strain generated during the mechanical deformation of the fiber as it is drawn over the rollers. The model includes translation of the fiber during the mechanical deformation. Plastic deformation generates heat and increases the temperature of the fiber, as shown in Figure 2. Three-dimensional modelling of fiber cooling due to conjugate heat transfer is shown in Figure 3.

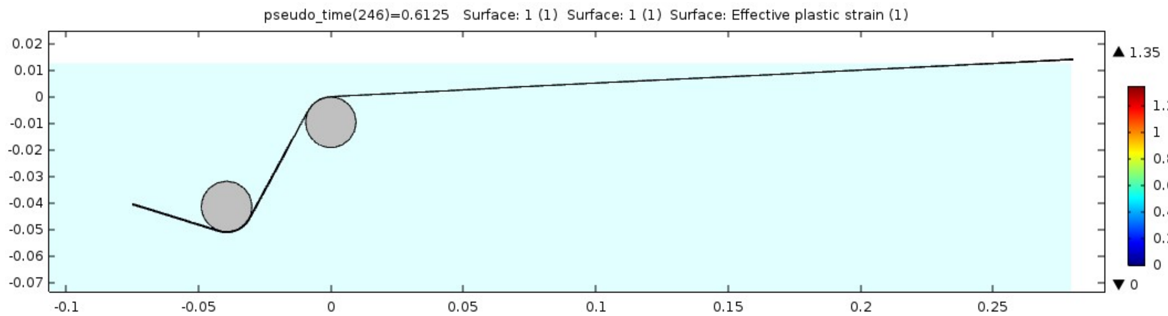

Figure 1. Two-dimensional model of plastic deformation of fiber due to mechanical load.

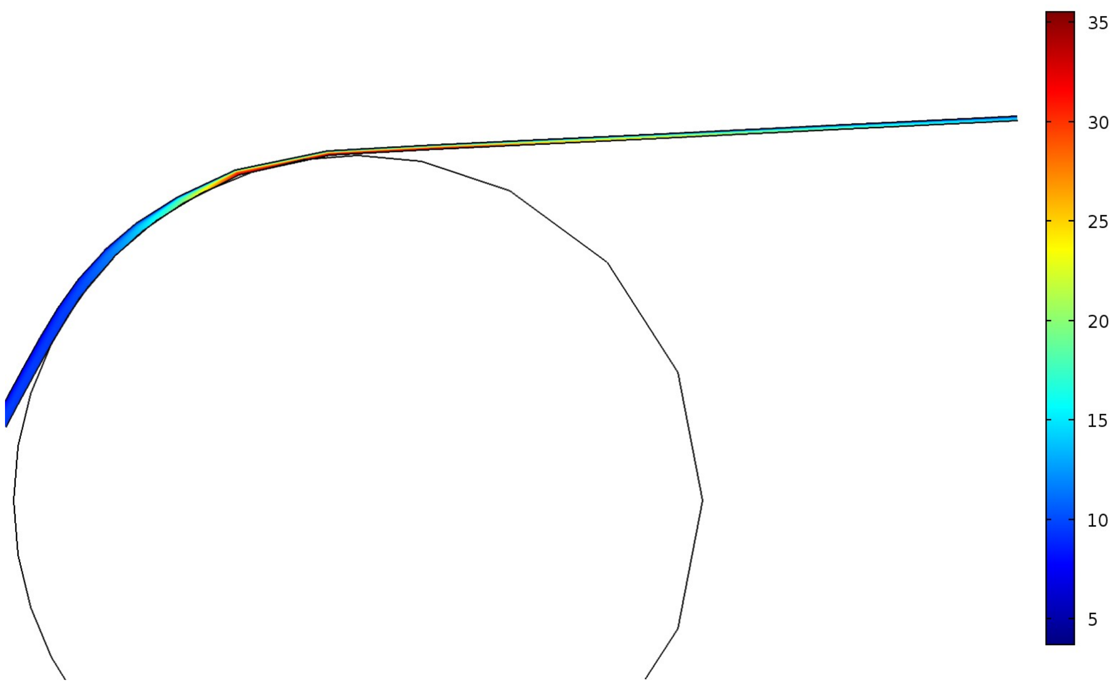

Figure 2. Two-dimensional model of the fiber temperature increase due to plasticity-generated heating (Temperature rise in °C).

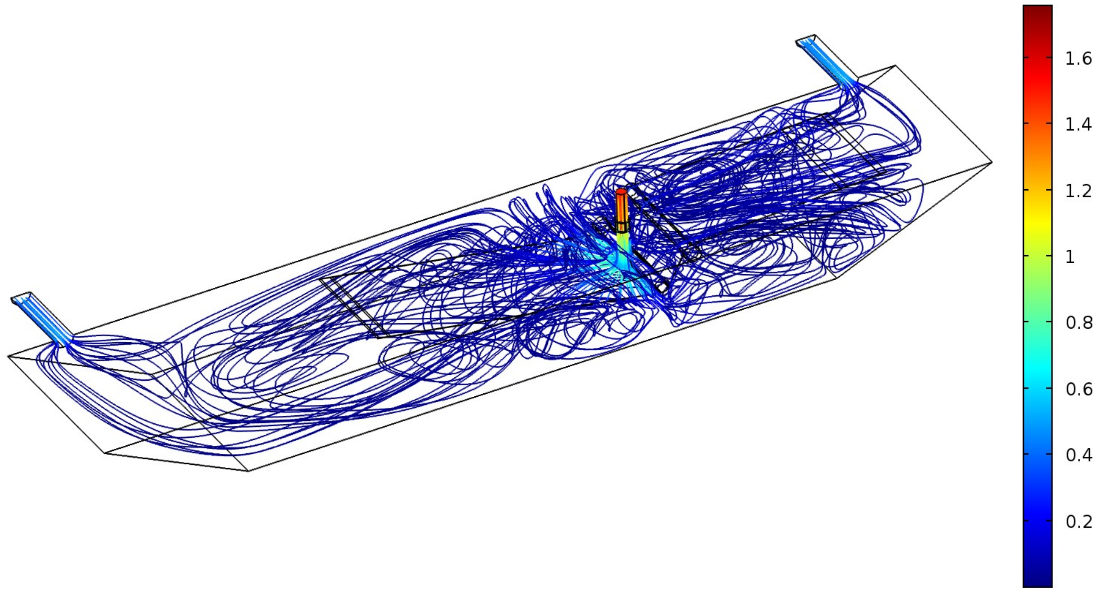

Figure 3. Three-dimensional model of fluid flow in cooling tank (streamlines colorized based on velocity with units of m/s).

To include the effects of cooling on the temperature dependent material properties, the two and three-dimensional models are solved as coupled models.