

Activities

The continuous casting of thin aluminum strip with a single-wheel melt spinning process offers great potential for low-cost production of finished products with unique surface textures. To perfect this process requires fundamental understanding of the phenomena which control solidification shape, including flow oscillations in the melt pool, meniscus interaction with the wheel surface, intermittent solidification against the moving wheel, and thermal distortion.

This project has supported work on several fronts, including the following 5 computational modeling subprojects, designed to augment the analytical and experimental work being conducted at Cornell, and to demonstrate and extend the new computational methodologies developed in this work to other processes:

1) Development of a computational fluid flow model of the molten metal delivery system in the Cornell strip-casting process. Three different undergraduate students, assisted by a senior graduate student, have developed a 3-D finite difference model of fluid flow in the Cornell process using the Volume-of-Fluid method in the CFD package Fluent and applied the model to provide the pressure distribution in the system, as well as the steady-free surface shape.

2) Comparison of computational methods for modeling turbulent fluid flow in molten metal systems, such as the strip caster. The first sub-project identified deficiencies in the ability of standard computational flow models to match the real process. This sub-project was undertaken to evaluate the various models currently available, through comparison with high-fidelity LES and DNS solutions computed for simple flow systems, in order to find the most accurate and efficient methods to model turbulent flow in practical engineering problems. This work is described in a submitted journal paper.

3) Development of a quantitative, computational model of heat transfer and solidification coupled with the transient flow of molten aluminum during the melt spinning of aluminum. Most previous models have coupled fluid flow and solidification together in the same simulation, but this is extremely computationally intensive when done with a mesh that is fine enough to capture the phenomena. In previous work, we developed a method to uncouple the phenomena at the solidification front, by replacing the fluid flow field with an internal source term, but this only works for our in-house code. As part of the current work, we have developed a method to implement this method into the commercial package, ABAQUS, using a user-defined subroutine to incorporate the superheat in with the latent heat. As described in two journal publications, this new multi-physics method has been demonstrated in test problems, and applied to simulate coupled fluid flow, heat transfer, solidification, and stress analysis in a real casting process with complex geometry. It better matches the measured solidification front shape.

4) Development of an efficient thermal-stress model of solidification. This project has involved development of user-defined subroutines to enable the commercial code ABAQUS to simulate realistic highly-nonlinear constitutive behavior using an explicit numerical method, which is more efficient than previous implicit methods. As described in a journal paper, it was first applied to analytical test problems and continuous casting of steel, where previous results was available to validate the new algorithms. It is now ready to apply to other solidification processes, such as the aluminum strip casting process being developed at Cornell.

5) Application of these models to the strip casting process, to test hypotheses and improve understanding of what controls initial solidification at the contacting point between the molten metal meniscus, the rotating substrate (that may contain a “write head” to manipulate it), and the atmosphere. The formation of internal holes in the product have been simulated computationally, by extending the heat conduction method previously developed to model the effect of gaps on the formation of mesa-scale surface depressions in the melt-spun product. Quantitative criteria have been found to predict the onset of hole formation and critical line-defects which can cut the strip product.