Multiscale modelling of microstructure evolution during twin roll casting

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Twin roll casting (TRC) is an energy efficient way to manufacture near-net shape sheets of light alloys, such as magnesium, for lightweight applications in the automotive and aerospace industry [1].

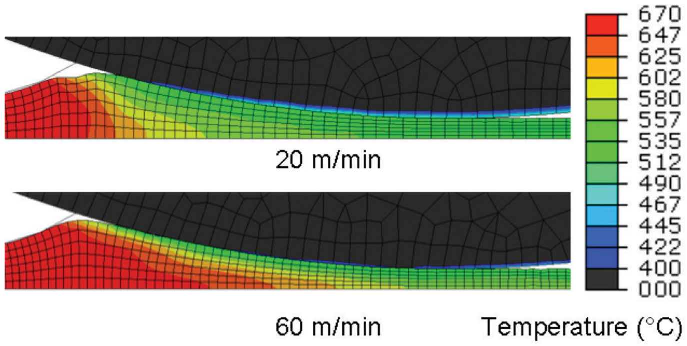

FIGURE 1. Modelled temperature distributions resulted from different casting speeds.

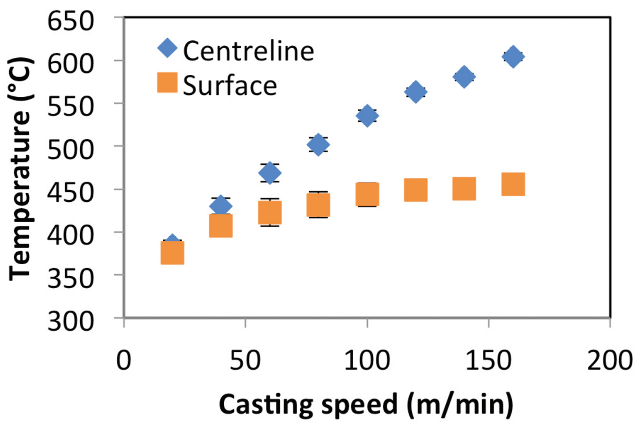

FIGURE 2. The effect of casting speed on the exit temperature on the strip surface and at the centreline, assuming a high gap conductance between the rolls and the strip.

However, challenges remain in eliminating unfavourable microstructural features, such as coarse columnar dendrite grains and centreline segregation, in the as-cast alloy sheets, due to the complex nature of the TRC process [2]. By modelling the effects of melt conditioning, alloy composition, and casting parameters on the microstructure development during TRC, feedback can be provided to optimise the TRC process to develop high performance alloys with improved mechanical properties, tailored for specific applications.

A multiscale model is used to simulate the evolution of microstructure during TRC, in which the process of grain growth in fluid flow is modelled via phase field simulation coupled with lattice Boltzmann model, and a Lagrangian macroscale model is applied for heat transfer and deformation analysis, which provides the boundary conditions for the microscale model. Results from 2D temperature-displacement simulations via ABAQUS show quantitatively the correlation between the casting speed and the depth of melt sump, exit temperature of the strip and the rate of heat transfer, as shown in Figure 1 and 2. The results also show that further decrease of the roll temperature below room temperature has a negligible effect on the modelled temperature profile of the strip. Meanwhile, the depth of melt sump is shown to increase significantly as the assigned gap conductance between the rolls and the strip decreases. The gap conductance is taken as an adjustable parameter, which will be obtained by comparing the modelled strip temperature profiles with the experimentally obtained strip temperature data.

Based on the macroscale modelling results, an upper bound of the casting speed, for which the strip can completely solidify before it exits the rolls, can be deduced for TRC with specific strip thickness, roll dimension, and alloy composition. By casting at higher speeds, manufacturing efficiency can be improved, and the deformation zone can be reduced, which is particularly favourable in TRC of magnesium alloys.

In summary, a multiscale model is proposed to model the evolution of microstructure during TRC, which consists of heat transfer modelling at macroscale, and modelling of solidification with fluid flow at microscale. Results from the macroscale model can be used to deduce the upper bound casting speed.

In the future, the multiscale model will be further developed and tuned to model quantitatively the solidification of more complex, industrially relevant alloy compositions. This will include comparison with the experimental data for Al and Mg alloys, to calibrate the adjustable parameters in the model. The results will be summarised into microstructure selection maps, to help improve process design and manufacturing efficiency for different solidification processes.

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