Magnesium Technology 2014
Edited by: Martyn Alderman, Michele V. Manuel, Norbert Hort, and Neale R. Neelameggham
TMS (The Minerals, Metals & Materials Society), 2014

THERMODYNAMIC AND KINETIC CALCULATIONS FOR TRC (TWIN ROLL CASTING) Mg ALLOY DESIGN

In-Ho Jung[1] and Manas Paliwal[1]

[1]Department of Mining and Materials Engineering, McGill University; 3610 University, Montreal, Quebec, H3A2B2, Canada

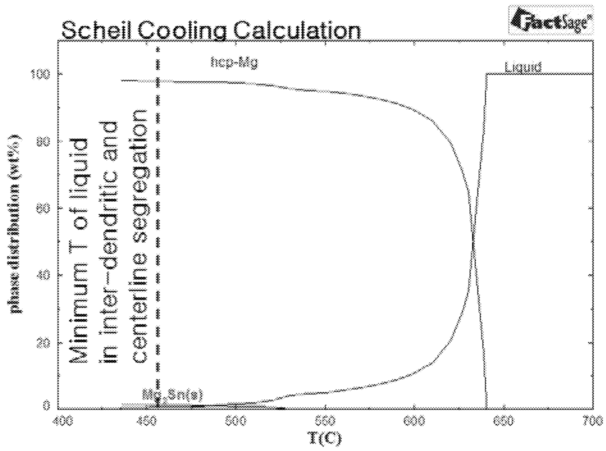
Keywords: Twin Roll Casting, Mg alloy, Inverse segregation, Thermodynamic calculations

Abstract

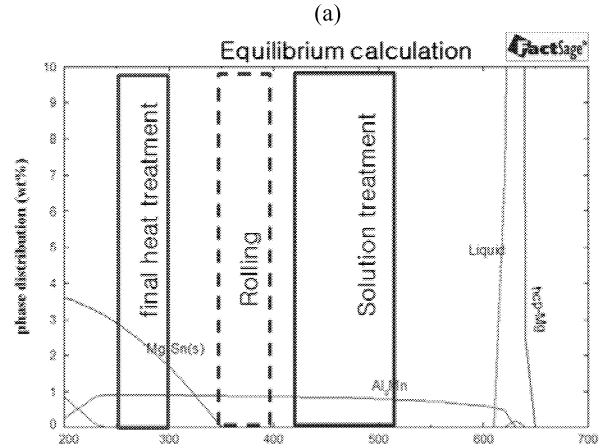
Twin roll casting (TRC) process is most cost competitive casting process to produce wrought Mg alloys. At the moment, this process is successfully applied to the production of AZ series Mg alloys with low Al content. From microstructure viewpoint, one of the most concerns in the process is the control of inverse segregation which is inherent problem in TRC process. The inverse segregation is known to be formed when the remaining highly solute enriched liquid between solidified columnar zone is squeezed out through the weak columnar layer due to the compressed force during the solidification in TRC process. The alloys with a large amount of remaining liquid at low temperature and a long solidification range can be more prone to produce severer inverse segregation in TRC process. The other constraint of TRC alloys is the secondary phase amount during rolling process. Too much secondary phase can increase the roll force and induce defects during warm rolling. However, the precipitation of secondary phase at low temperature during the final heat treatment will be beneficial for increasing strength. In the design of new TRC Mg alloys, all these aspects should be considered.

In the present study, the simple calculation scheme to predict as-cast microstructure of Mg alloy in twin roll casting was developed based on non-equilibrium Scheil cooling calculations. This calculation can give the evaluation of the tendency for the formation of inverse segregation. In addition, the equilibrium calculations were performed to evaluate the heat treatment condition for homogenization (300°C ~ 450°C) and final annealing process (150°C ~ 200°C) for secondary phase precipitation. FactSage thermodynamic software with FTlite database was used for the thermodynamic calculation. The newly developed kinetic solidification model was also used to calculate the solidification behavior at the cooling rate of TRC process. All the possible conventional alloying elements for Mg alloys were classified into primary alloying elements and secondary alloying elements based on the solubility limit of alloying element in hcp Mg. Then, the combinations of primary and secondary alloying elements were tested to find the optimum TRC alloys which can have similar or less inverse segregation tendency as AZ31 alloy, have similar or low roll force, but have a large precipitation hardening during final heat treatment. Several modifications of Mg-Al based alloys and Mg-Sn based alloys were designed for the possible candidates of TRC process.

For example, Fig. 1 shows the thermodynamic and Scheil cooling calculation for the Mg-3%Sn-1%Al-0.3%Mn alloy. According to the Scheil cooling calculations in Fig. 1(a), the amount of remaining liquid during the solidification (that is, the liquid amount concentrated between growing columnar dendrites from the water-cooled rolls) in this alloy is smaller than that of AZ31 alloy. Therefore the tendency of inverse segregation becomes lower. The amount of Al_6Mn phase for this new alloy is almost the same as the AZ31 at the temperature between 350°C to 500°C. Thus, if the work hardening by Al and Sn in the hcp Mg is similar, the rolling behavior of new alloy would be similar to that of AZ31 alloy. After the rolling process, the alloy can be heat treated below 300°C and can produce a large amount of Mg_2Sn phase. As the precipitation can occur at solid state, the fine Mg_2Sn precipitates can be formed homogeneously in the matrix Mg phase which can increase the strength significantly.



(a)



(b)

Fig. 1. TRC alloy design calculations. (a) Scheil cooling calculation and (b) equilibrium calculation for Mg-3%Sn-1%Al-0.3%Mn alloy.