SOLIDIFICATION BEHAVIOR IN THE PRESENCE OF EXTERNAL FIELDS

Solidification Behavior in the Presence of External Fields: Part II

ANDREW KAO ^{1,3} and LANG YUAN^{2,4}

1.—School of Computing and Mathematical Sciences, University of Greenwich, London SE10 9LS, UK. 2.—College of Engineering and Computing, University of South Carolina, Columbia, SC 29201, USA. 3.—e-mail: A.Kao@greenwich.ac.uk.
4.—e-mail: langyuan@cec.sc.edu

The introduction of external fields, such as electromagnetic fields, ultrasonic excitation, and mechanical shearing, to solidification processes has encompassed novel applications to refine grains, homogenize segregation, break up agglomeration of particles, and prevent defect formation. Advances in experimental methods, materials characterization, and computational modeling have led to new insights into controlling microstructure and defects during solidification. This two-part topic “Solidification Behavior in the Presence of External Fields” highlights most recent investigations into the use of external fields in a broad range of industrial manufacturing processes. The second part includes the use of ultrasonic treatment, high-shear processing, electromagnetic levitation, and pulsed electric currents.

Ultrasonic treatment (UST) in alloy processing is an emerging technology that has been shown to produce grain refinement and degassing. Typically, UST has been studied under batch conditions and treating a single volume of fluid; here, two papers are presented that investigate extending these findings to continuous processes in direct chill (DC) casting.

The paper by Subroto et al, titled “Structure Refinement upon Ultrasonic Melt Treatment in a DC-Casting Launder,” describes an experimental and numerical study of UST in a pilot-scale DC casting launder. Their findings show that by controlling the fluid flow conditions the residence time can be increased, leading to increased grain refinement and degassing. This is a promising first step to upscaling UST to industrial-scale applications.

The second ultrasonics paper on DC casting by Tonry et al., and titled “Contactless Ultrasonic Treatment in Direct Chill Casting,” concerns the use of a contactless sonotrode in UST as a continuous process through a detailed numerical study coupling electromagnetism, ultrasonics, heat transfer, fluid flow, and solidification. A key finding is that the system tends to a single stable resonant mode in the melt pool with increasing length of the billet. This could allow for a single driving frequency to be used throughout the entire process.

High-shear melt conditioning (HSMC) technology is a process that draws the melt into a high-speed rotor–stator mixer. An intense shearing field is generated that leads to beneficial effects such as grain refinement. The paper “Numerical Assessment of In-Line Rotor–Stator Mixers in High-Shear Melt Conditioning (HSMC) Technology” by Lebon et al. describes a numerical investigation of the performance of three differing rotor–stator mixers running in both batch and continuous modes. Their findings show that smaller hole size in the mixers provides better de-agglomeration of oxide particles, but at the expense of melt redistribution into the bulk.

Impurities, such as iron, can be detrimental to the materials performance of polysilicon. Ren et al. presented a new method by introducing a pulsed electric current for the first time to a solidifying silicon ingot in the paper titled “Separation of Impurity Iron from Polysilicon by Pulsed Electric Current.” They reveal that pulsed electric current treatment can reduce the solubility of iron in polysilicon and promote iron to form clusters. This mechanism can potentially lead to an efficient means of achieving high quality polysilicon ingots with low energy consumption compared with traditional methods.

Electromagnetic levitation provides a contactless method for achieving high undercooling. This allows fundamental studies of rapid solidification to be conducted. The paper by Douglas Matson, titled

Lang Yuan and Andrew Kao are guest editors for the Solidification Committee of TMS and coordinated the topic Solidification Behavior in the Presence of External Fields in this issue.

(Received September 2, 2020; accepted September 9, 2020;
published online September 30, 2020)

“Influence of Induced Convection on Transformation Kinetics During Rapid Solidification of Steel Alloys—the Retained Damage Model,” describes a theoretical model that predicts the incubation delay during the transformation from ferrite to austenite. The retained damage model extends previous related models through the incorporation of free energy driving primary recalescence and damage induced by flow.

Finally, in “Numerical Modeling of the Macrosegregation Improvement in Continuous Casting Blooms by Using F-EMS” by Shaoxiang Li et al., a three-dimensional mathematical model is described based on segmentation that couples the electromagnetic field, melt flow, heat transfer, solidification, and solute transport in the whole casting domain.

The model has been established to study solute transport at the final stage of solidification in a bloom continuous casting process.

The papers in this special topic, “Solidification Behavior in the Presence of External Fields,” can be accessed via the November issue’s Table of Contents page at <https://link.springer.com/journal/11837/72/11/page/1>.

CONFLICT OF INTEREST

Both authors state that there is no conflict of interest.

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