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Experimental evaluation of MHD modeling and engineering applications

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Electromagnetic stirring (EMS) has been recognized as a mature technique in steel industry to control the as-cast structure of steel continuous casting, and computational magnetohydrodynamic (MHD) methods have been applied to study the EMS efficiency. Most MHD methods de-coupled the calculations of electromagnetic and flow fields or simplifications were made for the flow-electromagnetic interactions. However, the experimental validations of the MHD modeling have been rarely reported or very limited. In our previous work [Zhang et al., Metall. Mater. Trans. B, 53, 2022. 2166-2181], we have presented a benchmark, i.e., a series of laboratory experiments, to evaluate the MHD methods. The magnetic field distribution within the magnetic inductor, the torque experienced by solid casting under a rotating magnetic field (RMF), and the RMF-induced rotational flow of the liquid melt (Ga75In25) were experimentally measured to validate MHD modeling. The MHD calculation is performed by coupling ANSYS Maxwell and ANSYS Fluent. Various MHD calculation methods and coupling schemes are investigated. The Lorentz force, as calculated by analytical equations, ANSYS Fluent addon MHD module, and external electromagnetic solver, is added as the source term in Navier–Stokes equation. By comparing the simulation results with the benchmark experiments, the calculation accuracy with different coupling methods and modification strategies is evaluated. Based on this, a necessary simplification strategy of the MHD method is established. This contribution will demonstrate some engineering applications, including the unidirectional solidification of aluminum-based casting, and continuous and semi-continuous casting processes of steel.

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