Thermo-Mechanical Finite Element Model of Bulging and Hot Tearing During Continuous Casting of Steel Billets

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Bulging and hot tear cracks are important problems during billet casting without submold support, especially at high casting speed. A finite-element model, CON2D, has been developed to simulate temperature, stress, and shape development during the continuous casting of steel, both in and below the mold. The stress model features an elastic-viscoplastic creep constitutive equation that accounts for the different responses of the liquid, semi-solid, delta-ferrite, and austenite phases. Temperature and composition-dependent functions are also employed for properties such as thermal linear expansion. A contact algorithm is developed to prevent penetration of the shell into the mold wall due to the internal liquid pressure. An efficient two-step algorithm has been developed to integrate these highly non-linear equations. An inelastic strain damage criterion is developed to predict hot tear crack formation, which includes the contribution of pseudo-strain due to the flow of the liquid during feeding of the mushy zone. The model is validated both with an analytical solution of thermal stress in a solidifying slab and through comparison with the location of cracks in an etched steel section. It is then applied to predict the maximum casting speed to avoid crack formation due to bulging below the mold during casting of steel billets.