

**MATERIALS ENGINEERING
SEMINAR**

**“Thermomechanical Modeling of Stress Development and Phase Evolution During Cooling of
Continuously-cast Boron-containing Steel”**

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ABSTRACT

The automotive industry is using advanced high strength steels (AHSS) to improve the fuel efficiency of passenger vehicles by lightweighting strategy. The higher strength of AHSS allows vehicle manufacturers to implement thinner and lighter components while still meet the safety requirements. Press hardened steels (PHS) exhibit the highest tensile strength among AHSS and are widely used for manufacturing crash relevant automotive parts. Boron-containing steel with enhanced hardenability is the most commonly used grade of steel for press hardening. The addition of a small amount of boron, 0.002 – 0.005 wt%, can effectively increase hardenability. However, boron addition also causes problems in commercial production of steel slabs by continuous casting. Defects including transverse corner cracks, surface cracks, and internal halfway cracks are sometimes found in continuously-cast boron-containing steel slabs during or after the final cooling process. These problems can arise during the post-casting cooling because boron addition changes the phase transformation behavior of steel.

The cooling of slabs during and after continuous casting is a multiphysics process including coupled heat transfer, solidification, solid-solid phase transformations, and deformation. Numerical models are helpful for a better understanding of the cooling process and the interaction of different physical phenomena in it. In this work, a 3-D thermomechanical finite volume model (FVM) with coupled heat transfer, stress, and phase transformation calculations is developed to investigate the temperature history, phase evolution, and stress development during cooling.

The model is used to simulate the cooling process of continuously-cast steel slabs at different post-casting stages. The effect of boron addition on stress development and phase evolution during cooling of a single slab is investigated via simulations of both boron-containing and non-boron steels. The results show the slab with boron consists of mostly bainite, in contrast to the non-boron grade which is mostly ferrite and pearlite after cooling.

Higher tensile stresses, both peak and residual, and plastic strains, which could lead to cracking, are observed at the edge of slab in the boron-containing grade. The effect of slowing the cooling rate by using a radiation shield is studied for the boron-containing steel. The reduced thermal gradient and the increased ferrite formation reduce the stresses in the slab. The cooling process of a stack of multiple slabs is also simulated to study the influence of slab stacking on cooling rate and slab deformation. Slower cooling rates can be achieved in stacked slabs and the compressive load provided by slabs above the slab can prevent large deformation and flatten the slab during cooling. The combination of slab stacking and radiation shield is modeled to study the stress development under a slow cooling rate that is feasible in practice. Boron addition also affects the water quenching process of steel strips on the runout table after hot rolling. Simulations of strips with and without boron show different cooling curves, residual stress and phase distributions as austenite decomposition does not occur for boron-containing steel due to the fast cooling rate. Therefore, the cooling strategy on the runout table should be adjusted accordingly to control the coiling temperature and improve strip quality.