An Experimental and CFD Based Synergic Approach to Improve Productivity and Quality of Continuous Cast Aluminum Wire Rod

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Abstract

Continuous casting and rolling (CCR) is the most preferred route to manufacture the electrical conductor grade aluminium wire rod throughout the globe. Due to very high production speed and continuous nature of the CCR process, various quality issues like mechanical property variations and cast bar cracking are the major challenge for achieving a high productivity rate with stringent quality requirements. The main areas of improvement to address these quality issues are proper solidification of the cast bar and sufficient flow of liquid metal through tundish into the caster. The focus of present study is to resolve the wire rod UTS (Ultimate Tensile Strength) variation and cast bar cracking issues of Properzi™ wire rod mill at Hindalco Industries Ltd., and further improving productivity. While analyzing process data of Properzi™ mill, it was a mystery to understand variation in UTS properties after caster, while process parameters were quite stable before caster. During our investigation, we found that the unstable airgap formation between cast bar and mold surface during solidification is identified as the root cause for UTS variation of the wire rod and cast bar cracks. The cooling pattern optimization to achieve stable airgap during solidification of cast bar is successfully conducted at plant with systematic DOE (Design of Experiments) approach, and the optimal casting recipe at an increased casting speed is developed. The implementation resulted in reduction of UTS variation to approximately half, while cast bar crack instances were limited to assignable causes only. Later, to further improve the flow behavior of the liquid metal through tundish, the understanding was developed by developing a CFD (Computational Fluid Dynamics) model. The model is calibrated using the melt level fluctuation data at plant. The simulation results are used to understand the areas of recirculation, back flow and high turbulence regions. Also, the CFD model is used to compare various possible design modifications to improve the liquid metal flow through tundish.

Keywords: Electrical conductor (EC) grade wire rod, Aluminium continuous casting and rolling (CCR), Ultimate tensile strength (UTS) variation, Cast bar cracks, Computational fluid dynamics (CFD) modelling.

1. Introduction

Continuous casting is gaining popularity in the production of aluminium, copper, and steel billets, bars, and slabs due to its advantages of high productivity, excellent quality, and cost-effectiveness. The continuous casting and rolling (CCR) process, characterized by its continuous and rapid nature, requires careful control of various parameters to ensure the desired quality of the wire rod. There are several configurations available for the Continuous Casting and Rolling (CCR) setup, which involve pouring liquid metal from a furnace into a copper mold with a trapezoidal or rectangular shape. To facilitate the solidification of the cast bar, water jets are used to cool the mold from all four sides. The cooling water for the caster is divided into multiple zones, each with a separate pressure control system. A bar cooler is employed to further adjust the temperature of the solidified cast bar to the desired level to produce varying ultimate tensile strength (UTS) wire rod as required by customer. Once the solidified cast bar reaches the desired temperature, it passes through multiple stands of rough and finish rolling mill to produce a wire rod of desired diameter. The rolled wire rod is then coiled and sent for wire drawing, where it is further processed.

Figure 1 illustrated a basic schematic of the CCR process with a circular configuration. Researchers have primarily focused on studying the flow behavior of the liquid metal as it moves from the tundish into the mold, as well as the heat transfer that occurs during the solidification process. These aspects are crucial as they significantly influence the quality of the solidified cast bar and the resulting wire rods.

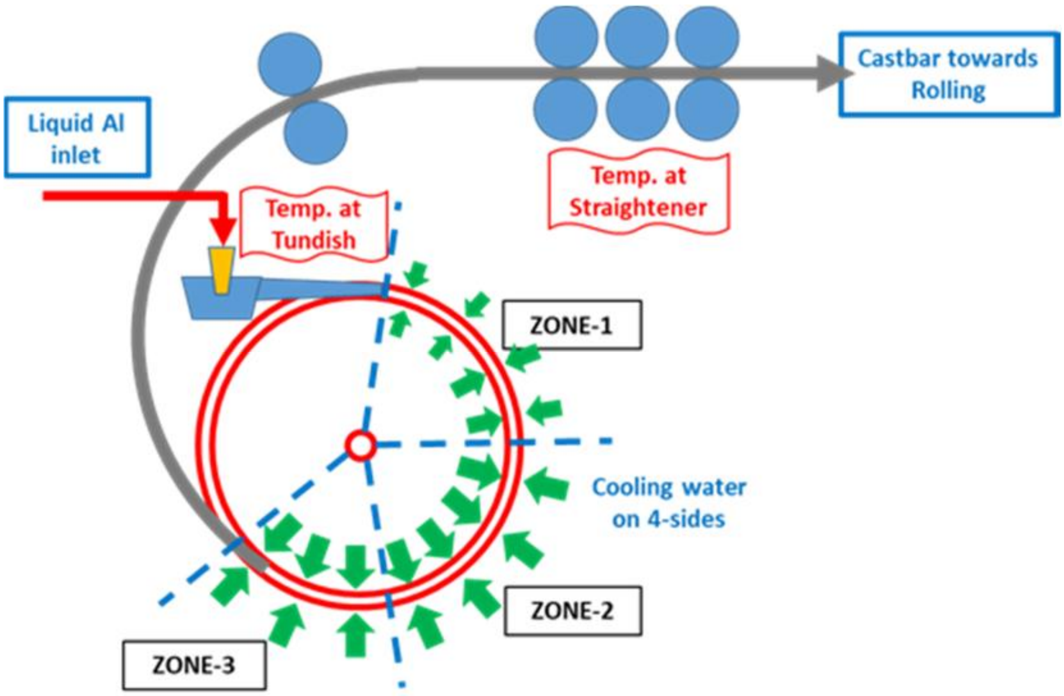

Figure 1. Schematic of CCR with circular configuration.

Researchers have extensively studied the transportation and solidification processes of the liquid metal pool in the continuous casting mold [1-3]. In order to simulate flow behavior, predict inclusion trajectories, inclusion removal fraction, free surface waves, and other relevant phenomena, researchers have employed various methods such as Volume of Fluid (VOF), Eulerian-Eulerian, and Lagrangian approaches [4]. A. Braun et al. compared the flow field obtained from a water model using Particle Image Velocimetry (PIV) in a steady-state condition with values predicted by a developed Computational Fluid Dynamics (CFD) model [5]. R Chaudhary et al. investigated the effect of stopper rod misalignment on nozzle and mold flow velocities using both a water model and a CFD model of continuous casting [6]. Z. He et al. demonstrated that incorporating a turbulence inhibitor in the tundish results in reduced metal velocity towards the tundish floor and lower turbulence kinetic energy on the melt's top surface compared to other designs [7]. Chouharia et al. focused on the impact of rolling energy inputs and

8. References

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