OPTIMIZATION OF SECONDARY COOLING PERCENTAGE DURING SEMI-CONTINUOUS COPPER CASTING PROCESS

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Sufficient cooling is essential to reduce casting defects and to get high productivity in semi-continuous casting of copper billet. On the other hand, low rate solidification is desired in order to develop coarser grain size and softer metal for less energy losses and metal discards in extrusion. Cooling intensity and percentage in both primary and secondary cooling stages was inspected to optimize microstructure and quality of billets. A three-dimensional steady-state numerical model was developed including solidification behavior of copper through mushy zone. Solid shell thickness, pool length, and mushy zone thickness are monitored during the reduction of the cooling rate in the mold region. Adequate primary cooling range is concluded, as a function of mold inlet water temperature, to be between 43 and 63°C. For moderate pool length according to solidification time, not reduced total heat removal, a cooling rate with less available inequality along the billet, and at the range of adequate primary cooling, perfect secondary cooling percentage sets at the range of 52–67%. At this range and for a specified speed of casting, melt at the core needs between 600 and 750 s to start solidification and solidification needs between 125 and 225 s to complete.

KEY WORDS: *copper, semi-continuous, casting, primary cooling, secondary cooling, metal casting*

1. INTRODUCTION

Thousands of tons of copper are manufactured every year as rods, tubes, bars, and other diverse section products in casting-extrusion-drawing processes. Copper or brass is cast in a semi-continuous casting process as solid billets with a soft structure for extrusion purpose. The quality of the extruded rods and tubs depends on the processing factors of casting, extrusion, and drawing. In addition, energy consumption and waste metal discarded during the extrusion process also depends on each of the processing parameters for all production processes. The product quality, microstructure, and reduction of casting defects depend essentially on the cooling process during the casting process. Adequate cooling is required for and to accelerate casting process, whereas extreme and rapid cooling may increase the strength of the billet and in turn increase the energy of extrusion and increase the quantity of discards in the extrusion process. The heat removal rate and direction affect the solidification process and in turn will affect the microstructure of the product. It is well known that the latest physical properties of the product are a function of its microstructure. In the casting process, the smaller the grain size is, the greater the energy consumption is in the following extrusion process, which is not preferable for the manufacturer.

Most of the literature has focused on heat transfer in steel and aluminum casting (Lait et al., 1974; Hardin et al., 2003). In addition, they have marginalized the effect of heat transfer on the subsequent process [in billet casting, the following extrusion process, Shi and Guo (2004)]. The study of heat transfer in casting of the copper round section thin wire is different from that of a heavy billet prepared for extrusion. Some researchers have focused on heat transfer in casting mold (Vapalahti et al., 2006) and through the gap between the mold and the cast (Kelly et al., 1988). Other researchers have studied the turbulence induced by a metal liquid flow (Ruhul Amin and Mahajan, 2006) or the heat transfer in copper strip other than billets (Mahmoudi et al., 2003). Hameed and Abed (2014) studied the effect of developing design of nozzles for sufficient and uniform secondary cooling to enhance the quality of cast copper. In

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