The Impact of Skim Dam Design on the Molten Aluminium Temperature Uniformity at Sheet Ingot Mold Periphery

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Abstract

The molten aluminum distribution inside the ingot cavity from the exit of the distributor bag up to the mold-metal interface is critical to ensure uniform solidification of the sheet ingot outer shell. Both the forced metal flow out of the distributor bag and the convective flows resulting from heat transfer through the bag walls influence the thermal distribution at the mold periphery. A floating ring, often called a skim dam, is regularly used in sheet ingot casting to contain floating oxides and prevent them from reaching the meniscus region where they may produce ingot defects. The skim dam, penetrating into the liquid metal, also acts as a barrier for the hot metal flows. Results presented show that it is possible to substantially affect the temperature distribution at the mold-metal interface by modifying the skim dam penetration depth. An engineered skim dam can thus be designed to reach the desired temperature distribution profile across the mold periphery by reducing the skim dam penetration depth in front of areas needing an increase in temperature and increasing the skim dam penetration depth in areas where there is a need to lower the temperature.

Keywords: Molten metal distribution, DC casting, Skim dam, Sheet ingot, Rolling ingot.

1. Introduction

Adequate temperature distribution of the liquid aluminum at the mold is one of the many requirements known in order to produce high quality rolling ingots [1-3]. Uneven distribution around the mold periphery can generate a hot spot than can often lead to ingot cracks [1]. Also, numerous metallurgical features of the ingot can be influenced by the temperature distribution at the meniscus region. The temperature in the meniscus region was demonstrated to affect the average shell thickness [4] and the presence of floating crystals [5]. Having a uniform metal temperature around the ingot perimeter is thus important but it can simultaneously be judged as one of the most challenging feature to obtain [4]. This is generally achieved through modifications of the distributor bag size, opening locations, rigidity, mesh size and submergence [3-4].

Another important feature of DC sheet ingot casting is the use of a skim dam, which is a refractory ring floating on the liquid metal around the distributor bag. It is mostly used on high magnesium alloys to contain oxide patches. These can be generated due to turbulence during the initial ingot filling or during casting from the distributor itself. If not contained, these oxides can float up to the rolling side of the ingot and often lead to ingot cracks [1,3]. The use of this floating ring has thus been generally limited to oxide retention. However, numerical studies found that the skim dam has an impact on the metal distribution and resulting temperature distribution at the meniscus region [6]. Results obtained and reproduced in Figure 1 concluded that:

"*The skim dam, being partially submerged in the liquid aluminum, was found to act as a barrier for the convective flows happening at the surface. The hot metal moving from the distributor bag to the mold interface hits the skim dam, find its velocity reduced and must pass underneath the* *skim dam to continue. By passing underneath the skim dam it goes into a colder area of the sump and thus cools before continuing its course towards the meniscus."*

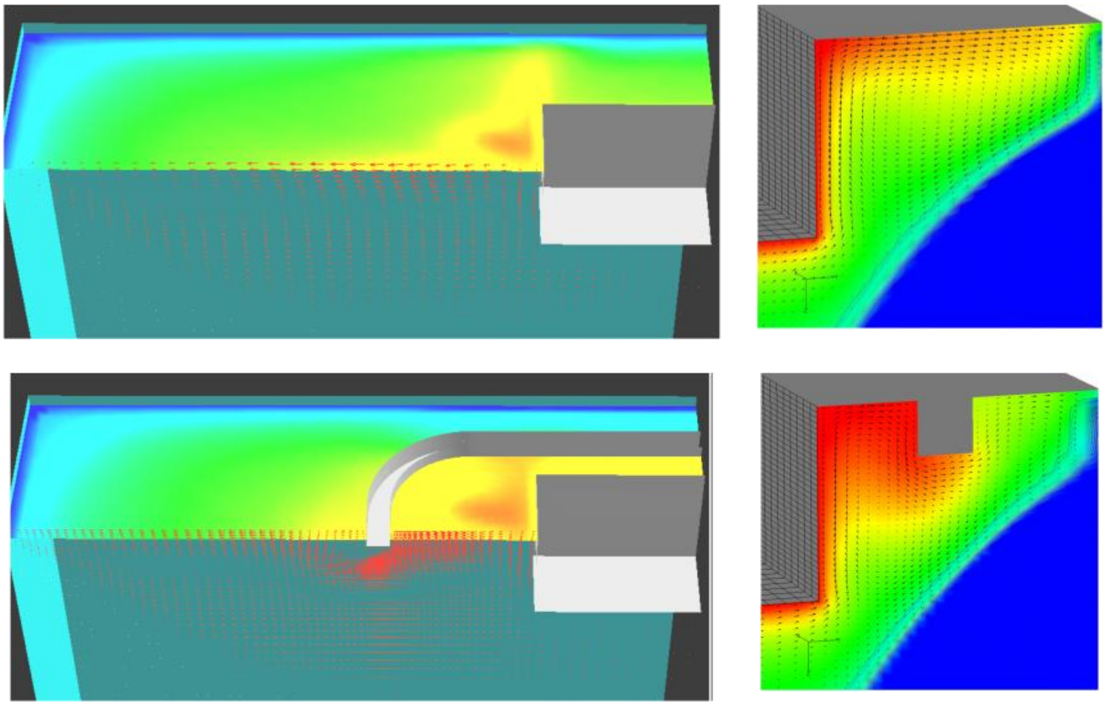

Figure 1. Simulation without and with a skim dam [6]. Left: centre cross-section parallel to rolling face, Right: centre cross-section perpendicular to rolling face.

The skim dam could potentially be used in combination with the distributor bag as another tool for the casthouse metallurgist to influence metal distribution and uniformity of temperature. However, physical studies on the impact of the presence and design of the skim dam on the temperature distribution at the meniscus region are non-existent.

2. Impact on the Presence of a Skim Dam on Metal Distribution

In order to validate the impact of the presence of a skim dam on the metal distribution inside the ingot, a cast of 3xxx alloy was made using a 448 mm by 1569 mm mold. A casting speed of 50 mm/min was used and a skim dam was present from cast start. Temperature measurements near the meniscus were done in steady state from 850 to 950 mm of cast length. The skim dam was then raised and the thermal conditions were let to stabilize before doing some new measurements from 1350 to 1450 mm of cast length. The temperature measurement at the meniscus were taken using an array of thermocouples, at 15 mm of depth under the liquid metal surface and 15 mm away from the mold face at a 100 mm interval along the mold face for a quarter of the ingot. The skim dam used was 33 cm × 75 cm with a L shape cross-section of 51 mm height by 51mm wide, having a leg thickness of 25 mm and penetrating approximately by 25 mm into the liquid metal as presented in Figure 2. The size of the distributor bag used was (W×L×D) 13.5 cm × 42 cm × 12 cm and having open mesh at both ends including 4.5 cm on both sides.

5. Operational Considerations

A few elements must be considered before operationalizing the use of a skim dam as an aid to obtain uniform metal distribution. First, a skim dam is not often used with non-Mg bearing alloys. Broadening the use of a skim dam to other alloy families adds another equipment that must be installed and maintained to ensure proper operation. Positive impacts must be seen on the scalping depth or rolled surface quality to warrant the use on non-Mg alloys. Secondly, the skim dam must be designed according to the distributor bag used, to complement it. Any changes in distributor bag type or size with ingot format or alloys should ideally be met with a change in the skim dam design. Thirdly, adequate centering of the skim dam around the bag during casting is important for performance and consistency. An off center skim dam will direct flows unevenly within the mold cavity. A more robust skim dam fixation than the simple chains used in this study is recommended to prevent horizontal movement of the skim dam while it floats on the liquid metal surface. Lastly, as the main purpose of the skim dam is to retain oxides, a minimal penetration depth is more than likely required to achieve this function. This was however not evaluated in this study.

6. Conclusion

The use of a skim dam during casting was found to generate an overall colder temperature distribution at the meniscus region around the periphery. Modifying the skim dam to have different penetration depth around its periphery demonstrated a significant impact on metal distribution. Areas with no penetration allow the unhindered passage of the hot metal while areas with significant penetration act as a wall and force the metal to pass underneath resulting in cooling. It was possible using engineered skim dams to vary the temperature uniformity along the rolling face of sheet ingot by 40 to 50 %. However, before using this to complement the distributor bag some operational aspects must be considered.

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8. References

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