

Prevention of nozzle clogging in continuous casting of steel



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Prevention Of Nozzle Clogging In The Continuous Casting Of Steel

There have been four documented causes for nozzle clogging in continuous casting steels; build up de-oxidations such as Al_2O_3 (1), solid steel build up, buildup of complex oxides such as spinels, and the buildup of reaction products such as CaS (4). While some causes are more detrimental than others, all are a problem. Different steels will yield a different potential nozzle clogging cause (3), for example, a re-sulfurized free machining steel is going to have much more of an issue with the formation of calcium sulfides than spinels. No matter what cause is all nozzle clogging can be detrimental to a continuous casting process. Looking at Figure 1, it is easy to see how the deposit of clogging material on the side walls of the nozzle can cause irregular flow from the tundish into the mold. Irregular flow through a tundish nozzle enhances the probability of generating a number of quality defects such as re-oxidation of the steel and slag entrapment (4). Nozzle clogging also affects productivity in that less steel is able to be cast because of the blockage in the nozzle. In simple business terms, less steel equals less profit. Another thing to consider is the life of the tundish is often limited to the life of the nozzle due to clogging. If nozzle clogging can be controlled enough to extend the nozzle life even one or two heats longer, that results in substantial process cost savings.

The most effective way to prevent, or at least lessen, nozzle clogging in the continuous casting of steels is to modify the inclusions in the steel to a liquid rather than a solid at steel casting temperatures (2). This is typically done by the addition of calcium to the steel at the end of the steel refining process.

Looking at Figure 2, a pure Al_2O_3 inclusion's liquidus temperature is

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considerably higher than that of steel casting temperatures, and that by adding the right amount of calcium to the inclusions in the steel the inclusion's liquidus temperature can potentially be lowered to below steel casting temperatures ($12\text{CaO} \cdot 7\text{Al}_2\text{O}_3$).

Calcium is typically added to the melt one of three ways; by CaSi powder, CaSi wire, or calcium injection with argon. CaSi powder has the poorest recovery because calcium's vapor temperature is lower than steel making temperatures (5). Therefore by simply throwing calcium powder on top of the melt, the majority of the calcium will vaporize into a gas and leave the system without being absorbed into the steel. Figure 3 shows the vapor temperature for calcium related to depth into the steel melt and we can see that the deeper into the melt the calcium is able to get (i. e. the greater the pressure) the higher the vapor temperature is for calcium (5). This is the basis by which CaSi wire is used. CaSi wire is a steel wire shell packed with calcium as the core. As the wire is injected into the melt the calcium is protected by the steel shell from melting and not exposed to the high melt temperatures until deep enough into the melt to provide enough pressure to avoid the calcium from vaporizing. Calcium injection uses this same principle by sticking a lance into the melt deep enough to avoid vaporization and blows calcium into the melt by the use of inert argon.

It's one thing to make inclusions liquid and it's a completely different challenge to keep it liquid throughout the entire casting process. This is often the difficult aspect of nozzle clogging prevention given that all of your inclusions modification control is performed at the LMF or degasser and not at the caster. One thing many steel producers will try to do is reduce the <https://assignbuster.com/prevention-of-nozzle-clogging-in-continuous-casting-of-steel/>

number of inclusions present in the steel during the casting process (2). The easiest thing to do in lowering the number of inclusions in the steel is to increase the size of the inclusions. By Stokes law, larger inclusions will have a greater upward velocity out of the steel and into the slag thus not being cast through the nozzle. Another practice steel producers use to reduce inclusion counts in their steel is to have proper geometry in the tundish as the caster. By adding tundish components such as dams and weirs (shown in Figure 4) inclusion flow can be directed to give optimum exposure to the slag (4). Weirs are used to direct steel flow down whereas dams are to direct flow upwards. By having two sets of weir-dam combinations between the ladle shroud and nozzle, the inclusions in the steel are exposed to the tundish slag all while maintaining minimum turbulence (5).

Unfortunately not all inclusions in the steel can be removed and therefore the remaining inclusions must remain liquid through the nozzle to prevent clogging. To achieve this it is crucial that the steel is protected from re-oxidation from atmospheric oxygen (2). To ensure this many tools are used. Starting from the ladle, a ladle shroud is used from the ladle to tundish in order to funnel the liquid steel from the ladle to under the slag layer in the tundish (Figure 4). An impact pad is often used as shown in Figure 4, to reduce the turbulence in the tundish (5). Increased turbulence can disrupt the slag surface in the tundish as expose the liquid steel to the atmosphere causing re-oxidation and possibly slag entrapment. To help prevent steel-slag interaction, baffles are often used (Figure 5) which slows down steel flow but also allows steel to flow through the holes. In order to prevent the steel exposed to the surface from re-oxidizing tundish fluxes are used to act

as a protective barrier between the steel and atmosphere as shown in Figure 6 (2). Tundish refractories must also be considered to ensure no or very little reaction occurs between the steel and refractory occurs (2). If it were to occur and solid inclusions precipitate in the steel, all the effort put forth into the steel up until the point could be useless.

Once the steel is secure in the tundish one more step is required and that is to get the steel through the nozzle and into the mold. Just as in the tundish, re-oxidation of the steel and any negative reaction between the nozzle refractory and steel must be avoided. To ensure this, typically submerged entry nozzles or submerged entry shrouds are used as the nozzle which will provide a barrier between the steel and atmosphere all the way into the mold. Typically made of alumina graphite, the added graphite prevents wetting of the inclusions onto the nozzle walls (4). Argon purging in various parts of the side walls of the nozzle are also often used to separate any would be oxygen from the steel.

In conclusion, preventing nozzle clogging is not successfully completed by one simple action but rather many actions working together: inclusion count reduction, inclusion modification by the use of calcium, protecting from re-oxidation of the steel, proper tundish geometry, and proper tundish and nozzle refractories (2). While the concept of making only liquid inclusions appears simple in application, it can be rather difficult to maintain these liquid inclusions throughout the entire casting process.

Sources Cited

1. Zhang, Lifeng; Thomas, Brian; Inclusions in Continuous Casting of Steel. Nationals Steelmaking Symposium. Mich, Mexico. November 2003. page 138-183.
2. Alekseenko, A. A. Problems of Nozzle Clogging during Continuous casting of an Aluminum-Killed Low-Carbon Low-Silicon Steel. Russian Metallurgy, Vol. 2007. page 634-637.
3. Girase, N. U. Development of indices of quantification of nozzle clogging during continuous slab casting. Iron and Steelmaking. Vol. 34; No. 6. 2007. page 506-512.
4. Zhang, Lifeng, Wand, Yufeng, and Zuo, Xianjmun. Flow Transport and Inclusion Motion in Steel Continuous-Casting Mold under Submerged Entry Nozzle Clogging Condition. Metallurgical and Materials Transaction. Vol. 39B. August 2008. page 534-550
5. The Making, Shaping and Treating of Steel, 11th Edition Casting Volume; AISE Steel Foundation. Pittsburg, PA. Copy Right 2003