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Oxygen Control

Successful Continuous Billet Casting through Oxygen Control in Mixed Operation

Successful continuous billet casting through oxygen control in mixed operation

Presentation given by Dr. Wolfgang Glitscher at SEASI conference Saigon Vietnam, year 2000

Abstract:
Most western billet casters are operated mixed, as open stream caster with metering nozzles producing reinforcing concrete grades, and as shrouded mould level controlled caster producing quality long products. This mixed production allows for a flexible adaptation to changing market conditions, as downstream processing equipment is equally suited in most cases. Today's lean steel plant logistics require a flexible use of the available steel casting ladles. In most cases the same ladle serves the shrouded caster with aluminum killed steel, and is used without relining for the next campaign for silicon killed steel casting. In such a scenario castability problems are observed in open stream casting whenever a ladle is used having been charged with an aluminum killed grade before.
Precise oxygen probes ensure a correct level of dissolved oxygen in the steel casting ladle, and enable correcting means in the tundish to prevent nozzle clogging during casting and pin hole formation in the as-cast billet.

Looking at today's continuous billet casters and their product mix we see internationally
3 shop types casting

a) Reinforcing concrete steels in open stream
b) Quality long product steels submerged with tundish nozzle control
c) Both, a) and b) in a certain percentage share.

This paper deals with steel shops with a product mix as per c). Let us name it "mixed operation". The intention is to give a short but practical guideline for metallurgists, casters and engineering specialists, and last but not least for the responsible steel shop managers.

Steel casting ladles and their associated installations and consumables such as ladle heaters, sliding gates, porous plugs etc. are a major cost factor in a steel plant, plus they block space. This means the number of necessary ladles should be kept to a minimum but allowing for enough flexibility in production. It will be outlined that a "lean" ladle management is possible as well in "mixed operation" but requiring a dedicated control technique.

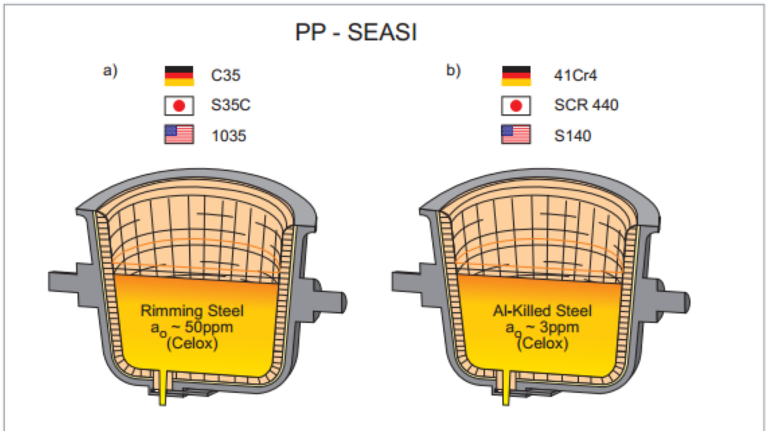

Fig. 1 : Oxygen activity status of ladles prior to continuous casting.
a) Rimming steel grade
b) Al-killed steel grade

FIG. 1 SHOWS GIVES AN EXAMPLE FOR 2 TYPICAL GRADES BEING CAST ON A BILLET CASTER:

Left a ladle filled with a Si-killed reinforcing concrete grade, and right a ladle with an Al-killed quality grade. The relevant Celox® oxygen levels are due to the difference in deoxidation practice. As a result totally different ladle top slags form in these cases. The next figure (Fig. 2) illustrates the main difference:

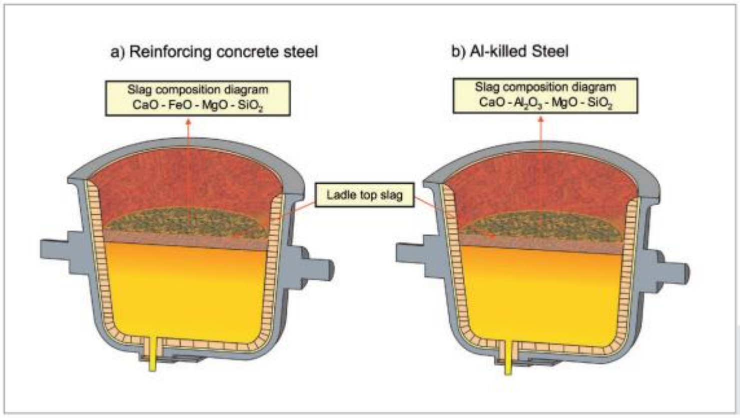

FIG 2: MAIN DIFFERENCES IN LADLE TOP SLAG COMPOSITION WITH
A) REINFORCING CONCRETE STEEL AND
B) AI-KILLED STEEL

The main slag components in case of concrete steel are calcia, magnesia, silica and iron oxide. CaO comes from lime addition, magnesia from ladle refractory bricks, silica mainly from deoxidation, and FeO in equilibrium with 50ppm oxygen activity in the steel. Especially dolomite or magnesia ladle refractory lead to higher MgO content in the slag, whereas high alumina refractory sends eroded alumina to the ladle top slag. The important point is that typical concrete steel top slags as standard exceed 10% FeO. Aluminum killed grades show significantly higher alumina content in its top slag, and if correctly treated very low FeO values down to less than 1%. Main slag components are thus calcia, alumina, magnesia, and silica.

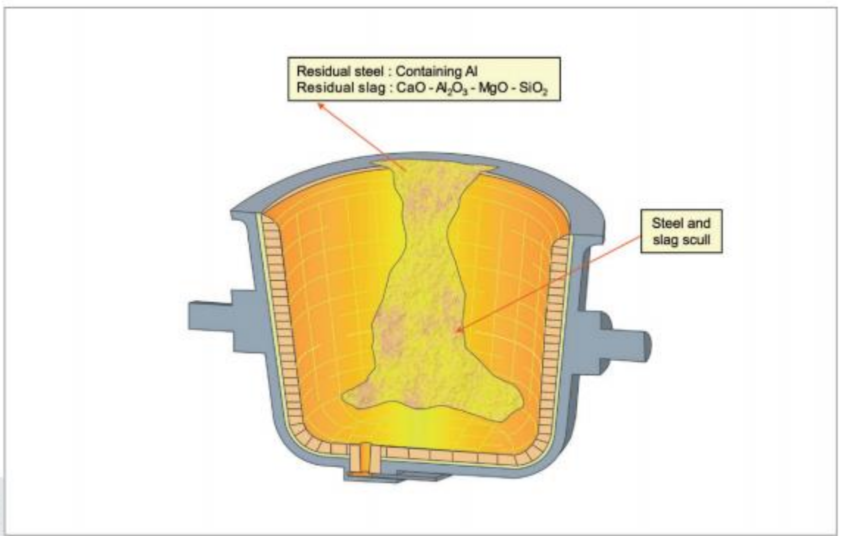

FIG 3: EMPTY AND TILTED LADLE AFTER CASTING AI-KILLED STEEL GRADE

Having cast Al-killed steel, skull consists of Al-containing steel and the relevant top slag. To a certain extent the whole lining has seen some penetration of steel and slag as well with down going level when casting. This skull and the huge slag coated ladle refractory surface send out non-metallic inclusions to the steel charge of the heat tapped next. Their dissolution into the fresh steel is dependent on temperature and gas purging intensity, but is always relatively slow, as skull and slag “stick” to the colder refractory. Thus skull inclusion flotation to top slag is also idle, and maybe still ongoing during continuous casting.

The type of inclusions in suspension with the steel in the ladle is dependent on the oxygen activity status. Fig. 4 shows 3 standard types.

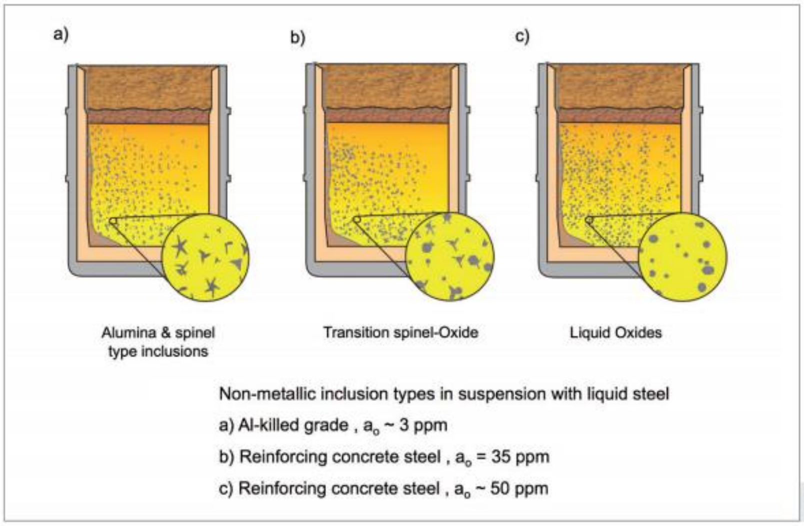

FIG 4

Left and a) an Al-killed steel grade with ~ 3ppm oxygen activity. Inclusion types are aluminates and spinels. Right and c) a concrete steel grade with ~ 50ppm oxygen. Inclusion type is spherical oxide.

In between and b) our subject of interest: inclusions in transition from alumina/spinel towards spherical oxide. Oxygen activity is 35ppm. Surprisingly literature as well gives a figure of 35 for a mass flow ratio oxygen/aluminum where Hercynite (FeO-alumina spinel) formation starts. This type is typical for a concrete steel grade tapped into a ladle having carried an Al-killed steel grade before. As a result, concrete steel in mixed ladle operation shows differences in oxygen level and inclusion types compared to a pure concrete steel production. This has an impact on castability. Alumina and spinels are known for their clogging behaviour in continuous casting. Fig. 5 shows tundish nozzle clogging in submerged casting and open stream casting.

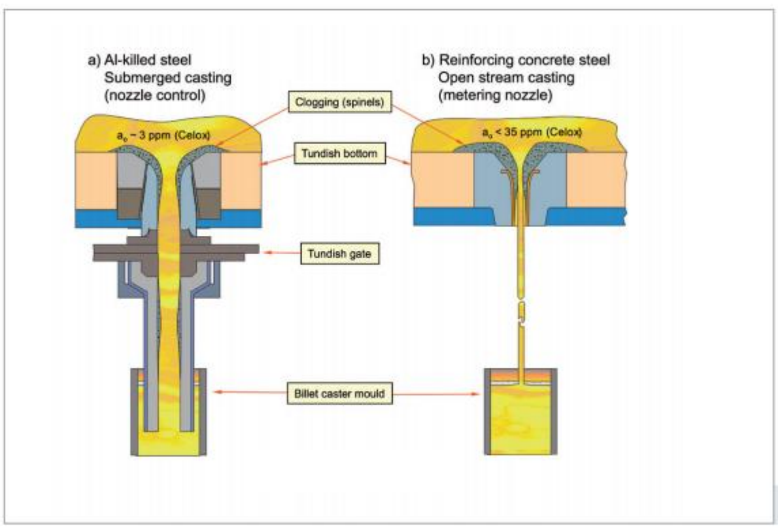

FIG 5: BILLET CASTER TYPES

In case of a slide gate or stopper controlled nozzle as per a) the bigger nozzle clogs just partly, and steel flow is almost unhampered, especially when Al-killed steel is Calcium treated. On the right side in open stream casting the tundish nozzle is much smaller in diameter, ~16mm is typical. In the event of clogging the tundish nozzle freezes rapidly with the consequence of a premature “end of casting”. Steel plants in mixed operation report this phenomenon of metering nozzle clogging just when relatively low in oxygen activity, i.e. lower than 35ppm. With rising oxygen activity clogging disappears completely allowing for long sequence casting. The most obvious reason is the difference in inclusion morphology. Alumina, spinels, and inclusions in transition clog whereas spherical oxides don’t. A practical solution is needed to ensure good castability over the full foreseen sequence in the same way as Calcium treatment does for Alkilled grades. The key word here is oxygen control via the Celox®

route. This method guarantees could castability for steel casting ladles in mixed operation, precise steel oxidation (50ppm should be max.), and thus avoids pinhole formation in the as-cast billet. Fig. 6 illustrates the treatment:

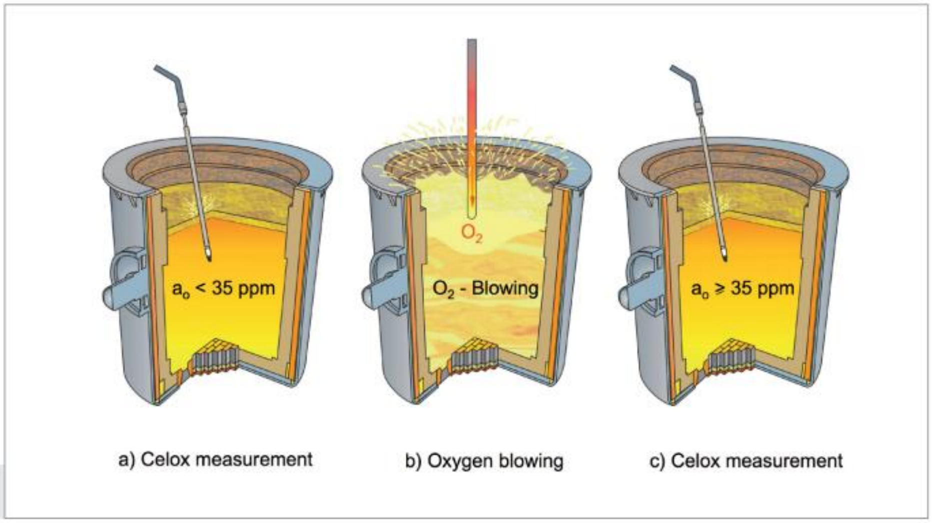

FIG 6: CASTABILITY CONTROL BY CELOX® METHOD

Prior to sending the ladle from treatment station to the caster a Celox® measurement is taken. A result lower than 35ppm indicates coming clogging problems. Slight oxygen lancing by shallow gas injection corrects the oxygen activity to the desired range of 35 to 50ppm ensuring good castability.

Summary:

The Celox® sensor method, as the world's standard for oxygen control in liquid steel, enables a lean ladle management in shops running in mixed operation, producing both, concrete and quality Al-killed grades. Significant investment can be saved and operational costs are optimized.