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INFLUENCE OF CONDITIONS OF STEEL FLOW-OUT FROM TUNDISH ON CLOGGING NOZZLES AND SUBMERGED ENTRY NOZZLES

Abstract

One of the important indexes for exploitation CCM is index of quantity high condition product per 1 ton liquid steel. During experimental investigations it was determine that high quality stoppers and submerged nozzles can provide necessity duration of casting without additional actions. In this case most important point is maximal lifetime of submerged nozzles. It was shown that as minimum two factors can result for destruction of submerged nozzle (*Al*-killed steels): erosion refractory in slag line, clogging of hole by Al_2O_3, slag's drops and solidified steel clusters.

Clogging effect in submerged nozzles causes by precipitation particles of Al_2O_3, slag's drops and solidified steel clusters. It has big result with character flow motion in the inner part of submerged nozzle.

It is shown that for *Al*-killed steel really lifetime of submerged nozzles is not enough for continuous casting with long sequence. Therefore it would rather to use system "nozzle-submerged nozzle" with possibility to change submerged nozzles time to time. For this system we can recommend to use argon injection cross stopper and argon protection joint chink between nozzle and submerged nozzle. It will improve alumina clogging suppression effects in 1,5–2,0 times.

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WPJYW WARUNKУW WYPJYWU STALI Z KADZI POЊREDNIEJ NA ZARASTANIE DYSZ I DYSZ ZANURZONYCH

Streszczenie

Jednym z istotnych wskaџnikуw dziaіania urz№dzenia do ci№gіego odlewania jest wskaџnik uzysku produktu wysokiej jakoњci na 1 tonк ciekiej stali.
Badania doњwiadczalne wskazuj№, їe zamkniкcia wysokiej jakoњci i wylewy zanurzone pozwalaj№ na piynny proces odlewania bez koniecznoњci dodatkowych dziaіaс. W przypadku stali uspokojonych glinem stwierdzono, їe zniszczenie wylewu zanurzonego moїe byж skutkiem dwуch czynnikуw: erozji materiaіуw ogniotrwaіych na linii їuїla i blokowania otworu wylewu przez tlenek glinu, krople їuїla i zestalone klastrowe wtr№cenia. Zarastanie ma istotny wpіyw na charakter przepіywu metalu w wewnкtrznej czкњci zanurzonego wylewu. Pokazano, їe w przypadku stali uspokojonych glinem їywotnoњж dysz zanurzonych nie wystarcza na odlewanie w dіuїszych sekwencjach. Dlatego powinno siк stosowaж ukіad typu „wylew-wylew zanurzony” z moїliwoњci№ wymiany wylewуw zanurzonych od czasu do czasu. Dla .tego rodzaju ukіadуw moїna zaleciж krzyїowe zamkniкcie i argonowe zabezpieczenie poі№czenia miкdzy wylewem‍a wylewem zanurzonym, co pozwoli zmniejszyж efekty zarastania tlenkiem glinu rzкdu 1,5 do 2 razy.

1. Introduction

One of the important indexes for exploitation CCM is index of quantity high condition product per 1 ton liquid steel. During experimental investigations it was determine that high quality stoppers and submerged nozzles can provide necessity duration of casting without additional actions. In this case most important point is maximal lifetime of submerged nozzles. It was shown that as minimum two factors can result for destruction of submerged nozzle (*Al*-killed steels): erosion refractory in slag line, clogging of hole by Al_2O_3, slag's drops and solidified steel clusters.

2. Methods

The most cost effective way to achieve optimizing flows motion nearly head of stopper, in the inner of submerged nozzle and in the bath of molten steel in the mould is build water model for this system.
Few types of water model were tested during present investigation: full size water model with scale 1:1, diminished water model with scale 1:2 and diminished-planed water model with scale 1:2. All types of water models were builds from transparent plastic glass. As shown our investigation there is most easy and effective to use diminished-planed water model with distance between inner surfaces of plastic glasses 10–20 mm. This model is give next advantages: decreasing water volume and improvement quality of picture flow motion without essential distortion hydrodynamic effects. For selection working parameters of casting Raynold's and Froud's criterions of hydrodynamic similarity flow had be using in present water model.
The final water model layout consists of diminished-planed tundish with nozzle and adjustable stopper to control the flow, bolted to the tundish submerged nozzle and mould. It is possible to change stopper, nozzle, and submerged nozzle and mold dimension. Moreover for investigation argon injection on steel flow motion in submerged nozzle and mould it was foresee a system for gas injection into stopper and submerged nozzle for water model.
The water is circulated using a submersible pump placed in the tank used to store the water when the model is not use. A gate valve and flow meter are used to set the water flow rate into the tundish, commensurate with the casting speed to be modeled. Another gate valve is used to restrict a flow of water back to tank and thus set the meniscus height in model.
For fixing of results investigation video and photography cameras were applied.

3. Results

Schematically process of flow motion in the inner of submerged nozzle and their interaction with surrounding gas is shown on the figure 1. Generally flow motion are characterize by compact jet configuration, which decreasing section of jet from tundish nozzle to bottom of submerged nozzle (figure 1a). If process of flow motion has normal development that walls of submerged nozzle and surface of jet have not constant contact during casting. Therefore normal development of flow motion in the inner of submerged nozzle are exclude intensity precipitation of corund (Al_2O_3) inclusions on the inner surface of submerged nozzle.
But for the practice of continuous casting with system "nozzle-submerged nozzle» is observing the phenomena of suck air cross joint chink, which takes place between bottom surface of nozzle and head part of submerged nozzle. Effect sucking air into the submerged nozzle provided formation of air-water mixture zone on the external surface of jet, which has movement from tundish to mould (figure 1b). The formation of this zone causes splashes of water in the inner of submerged nozzle that improved possibilities for contact flow liquid and walls of submerged nozzle.
For the process injection inert gas cross stopper (figure 1c) flow of liquid are characterize by compact jet configuration (classic form). Injection gas is placed in the central part of jet. Of course inert gas gives protection from secondary oxidation by oxygen of air because it is decreasing effect of suck air cross joint chink, which takes place between bottom surface of nozzle and head part of submerged nozzle. Meanwhile for the molten steel bubbles of gas will improve volume in 3–4 times because of warm up effect. It will stabilize process of movement jet in the inner of submerged nozzle.

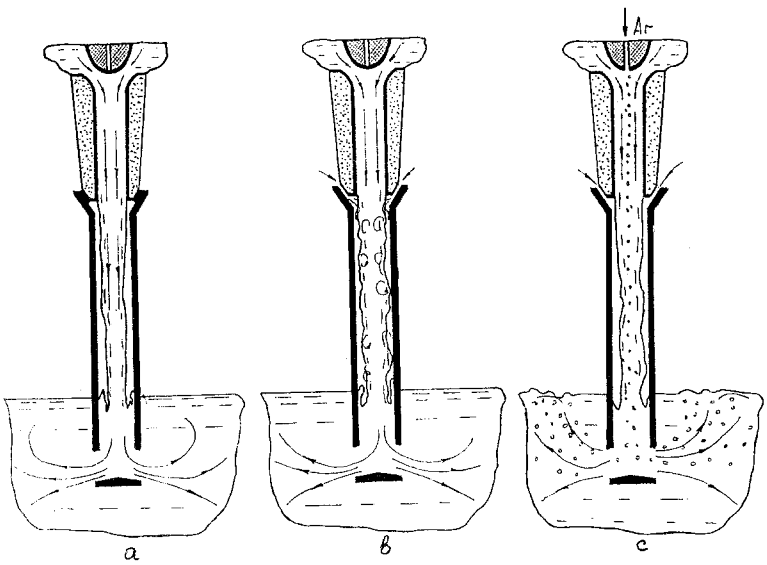

Fig.1. Schematic drawings for flow motion in the inner of submerged nozzle, which was received on the water model.

Big influence for the flow motion can exert location of stopper relatively of nozzle's saddle (figure 2). Visible deformation of jet configuration had note in the case if displacement of axis stopper relatively axis nozzle was more likely 25–30% from radius of nozzle hole (figure 2b). This deformation of jet provides a changer of flow trajectory to the any wall of inner surface at submerged nozzle. As result liquid has slide along submerged nozzle during whole casting process. It causes good condition for precipitation of corund (Al_2O_3) inclusions, slag drops and solidify metal on the inner surface of submerged nozzle. Moreover deformation of jet can develop with erosion head of stopper and nozzle's saddle during continuous casting.

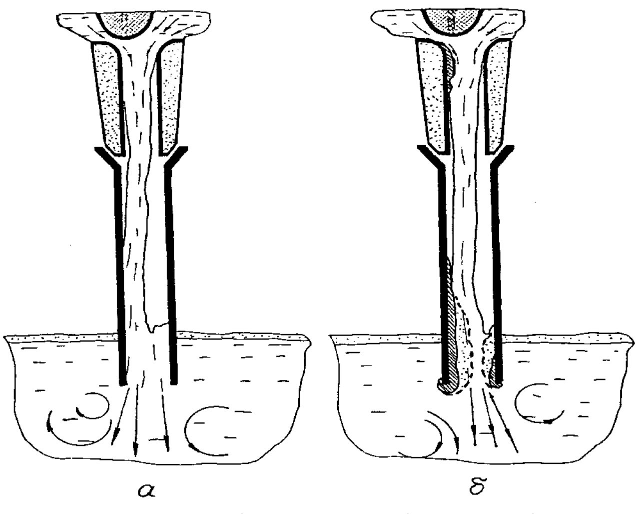

Fig.2. Schematic drawing to explanation of mechanism deformation of jet and its sliding along surface of submerged nozzle (water model).

4. Discussion

Lifetime of submerged nozzle limits of long continuous casting sequence. It was shown that as minimum two factors can result for destruction of submerged nozzle (Al-killed steels): erosion refractory in slag line, clogging of inner hole by particles of Al_2O_3, slag's drops and solidified steel clusters.

Most of qualitative results of submerged nozzle wear are in line with know facts: ZrO_2 resists in slag line well to the nozzle wear. Normally ZrO_2 resist can be lift up lifetime of submerged nozzle in 2–3 times. Therefore lifetime of submerged nozzle in slag line can compile 7–9 heats in connection with fluorine content in casting powder and content manganese in steel.

From another hand lifetime of submerged nozzle has result with clogging phenomena for Al-killed steels. It was determined that clogging process can closed submerged nozzle after 2,5–4 heats in dependence from content of *Al* and degree of secondary oxygen steel. Alumina clogging suppression effects are improved by special anti clogging coats. In this case lifetime of submerged nozzle can lift up on 30–50%. Some more additional improvement of lifetime can provide application of argon injection into steel jet cross stopper. But all this actions provide for improvement lifetime of submerged nozzle (clogging phenomena) in 1,5–2,0 times. Besides it is necessary remember that lifetime
of submerged nozzle can be decrease in the case if conditions for flow motion will not positive enough (for instance placed stopper head relativity of nozzle).

5. Conclusions

We are concluding that for casting *Al*-killed steels lifetime of submerged nozzles has limits with bath reasons erosion in slag zone and clogging. It is possible to cast from one submerged nozzle enough limited quantity of steel. Accordingly after few heats (4–6 or little more) it is necessary to stop casting or change submerged nozzle on new one.

Clogging effect in submerged nozzles causes by precipitation particles of Al_2O_3, slag's drops and solidified steel clusters. It has big result with character flow motion in the inner of submerged nozzle.

Therefore for organization continuous casting with long sequence (10–12 heats or more from one tundish) it is necessary to use system "nozzle-submerged nozzle" with possibility to change submerged nozzles time to time. In this case the phenomena of suck air cross joint chink between nozzle and submerged nozzle must be to take into consideration. On the practice we can recommend protection with argon rink or tube wool.