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Efficiency of Furnace Slag Cutoff in the Process of Steel Reladle

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The features of slag cutoff in the process of 300-ton melt reladle are considered. It is shown that the efficiency of slag cutoff can change substantially depending on the pouring scheme (one or two open sliding shutters). Steel reladle enables to lower the sulfur content considerably with the use of relatively low-cost and not scarce slag-forming mixture.

Keywords: SLAG, CUTOFF, STEEL, LADLE, POURING, EFFICIENCY, LADLE-FURNACE, SULFUR REMOVAL

Introduction

Steel refining and finishing procedures usually take place in a ladle and are carried out with the use of ladle-furnace units and vacuum vessel [1, 2]. New high-basic slag is built up to provide the maximum efficiency of refining process in the ladle. Upon that, slag mass entering the ladle from steelmaking unit is suggested to be minimized in this flow diagram. This slag reduces efficiency of sulfur removal when using the slag-forming mixture in the process of tapping, leads to increased loss of ferroalloy added, complicates the formation of refining slag, raises electric power consumption for heating and decreases steel yield because of drop in slag mass and corresponding loss of metal with metallic beads, and also has a negative effect on durability of ladle refractories [3].

Many slag cut-off systems for tapping steel from convertor, open-hearth furnace and arc steel-smelting furnace were developed in last decades [4-6]. Several tons of slag containing about 25-30% FeO enter the ladle when tapping metal from two-bath steelmaking unit, which complicates an effective steel refining in the ladle-furnace unit. For these conditions, slag cut-off is accomplished by steel reladle. This scheme has advantages in view of active cut-off of discharging jet during reladle. However, it also has disadvantages related to steel loss: steel residue in the ladle, in the case of its formation, was poured into steel mould with further blooming mill processing. Nevertheless, for conditions of transient stage of steel-smelting complex upgrading this scheme was used due to the following:

– radical decrease of final slag amount which enters the steel-teeming ladle;

– use of kinetic energy of metal jet dropping from 6-7 m height. This kinetic energy provides the developed surface of contact between metal and refining agents and considerably improves the processes of sulfur removal, deoxidation and alloying as well as homogenization of a liquid bath;

– creation of conditions for an effective utilization of relatively low-cost and not scarce desulfurizers;

– elimination of emergencies related to steel reladle through a steel-teeming ladle with no pouring nozzle, if steel level exceeds its specified capacity;

– stabilization of freeboard in the ladle for treatment on the ladle-furnace unit.

Results and Discussion

Low-carbon silicon-free steel grades 1006, 1008 and 1010 were applied for determination of slag amount that enters a ladle during reladle. The composition before tapping from two-bath steelmaking unit was, %: S not more than 0.035, P not more than 0.015 for steel 1006 and not more than 0.020 for steels 1008 and 1010. Steel oxidation in the furnace was decreased by addition of 1 ton of sluggish iron in 10 minutes or 1 ton of low-silicon ferrosilicon briquettes in 5 minutes prior to tapping. 200-300 kg of calcined dolomite or magnesite was added to reduce slag activity when tapping. Ladle lining was made of chamotte brick. Further, periclase-carbonaceous refractories were used for lining.

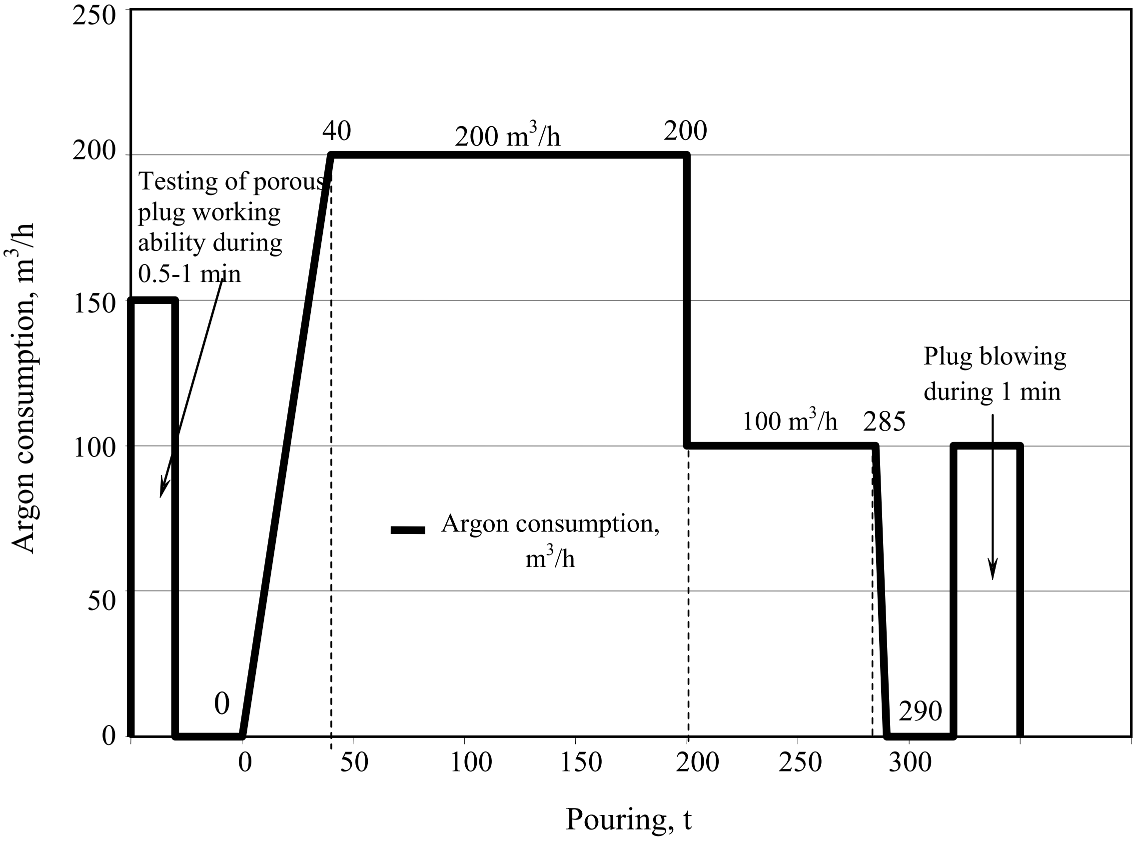

Figure 1. Schedule of argon supply at reladle

Steel was reladled into steel-teeming ladle with basic periclase-carbonaceous lining through a pouring nozzle, refractory slabs of sliding shutter and collecting channel with diameter 70 mm. In the beginning of melting, the outlet ladle was as high as 500 mm, and went down to 100 mm above steel-teeming ladle after opening the sliding shutter.

Fractionated solid slag-forming mixture was added into teeming ladle in amount of 2 tons per melting for steel sulfur removal. Solid slag-forming mixture was supplied by doses by means of opening and closing the sliding shutter or continuously with a regulated consumption in order to improve material recovery and increase the extent of sulfur removal. For preparation of solid slag-forming mixture, we used lime IS-2 with fraction of 15-25 mm according to technical specifications of Ukraine 26.5-00193714-042-2001 with content of CaO+MgO not less than 88% and calcium fluoride FK-75 (fractions not more than 50 mm) in accordance with GOST 29220-91. Results of 60 experimental melting operations have shown that extent of desulfuration at the various ratios of mixture components was approximately the same and was on the average of 37-40% for silicon-free steels 1006. Duration of reladle was 10-20 minutes. The following options were investigated: pouring through two shutters from start to finish of reladle; pouring through one shutter from start to finish of reladle; pouring approximately 65-70% of steel through two shutters and pouring the rest through one sliding trap. It was determined that some hundreds of kilograms of slag entered the steel jet at the finishing stage when reladling through two sliding shutters. Pouring through one sliding trap lasted up to 20 minutes. That is why reladle of 65-70% of steel through two sliding traps with further reladle through one sliding trap was accepted as a basic scheme.

In 0.5-1 minutes after reladle start, 300 kg of aluminum was added into teeming ladle, further 0.5 ton of metallic manganese and 2 tons of solid

Table 1. Chemical composition of steel after reladle

Steel grade	C	≥Mn	≤P	≤S	Al	≤Si	≤Cu	≤Ni	≤Cr
1006	0.020-0.050	0.200	0.015	0.020	0.005	0.010	0.060	0.050	0.050
1008	0.050-0.070	0.300	0.020	0.020	0.005	0.010	0.060	0.050	0.050
1010	0.060-0.080	0.350	0.020	0.020	0.005	0.010	0.060	0.050	0.050

slag-forming mixture were added for 1006 steel. For steels 1008 and 1010, only 2 tons of solid slag-forming mixture was supplied from a storage hopper.

In 1-3 minutes prior to the beginning of reladle process, argon was supplied in vent kits of steel-teeming ladle under pressure 0.8-1.2 MPa. Argon consumption in the process of reladle was adjusted according to **Figure 1** as follows:

1. Testing of porous plug working ability at argon consumption 100 m^3/h.
2. Blowing at argon consumption 50 m^3/h before addition of solid slag-forming mixture.
3. Argon blow after addition of aluminum ingots and solid slag-forming mixture in the teeming ladle at argon consumption 200 m^3/h prior to reladle of 200 t steel, after that argon consumption decreased down to 100 m^3/h.
4. When metal weight in the teeming ladle was 290 t, argon supply on distant sliding shutter in relation to the place of solid slag-forming mixture addition was stopped; as far as slag appeared or ladle was filled with metal to the level 300 mm below the upper filling of ladle, nearby sliding shutter was closed.

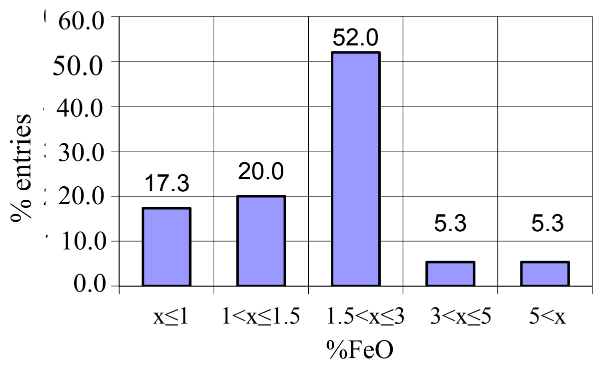

Figure 2. FeO content in the ladle slag after reladle

Chemical composition of steel grades after reladle is presented in **Table 1**.

Amount of slag entered the ladle was determined by the balance of ferric oxides.

$$(\%FeO)_1m_1+(\%FeO)_2m_2=(\%FeO)_3(m_1+m_2) \quad \text{(Eq. 1)}$$

where $(\%FeO)_{1,2,3}$ – FeO content in the furnace slag, built up slag through reladle and final slag of reladle, respectively, %; $m_{1,2}$ – the weight of furnace slag in the teeming ladle and slag built up in the process of reladle, kg.

The frequency distribution of FeO content in the slag after reladle on 340 smelting operations is presented in **Figure 2**. It is shown that the basic amount of smelting operations was in the range of FeO content 1.5-3.0 %, which corresponds to entry of 160-300 kg furnace slag in the ladle.

Such FeO content in the slag is considered to be high enough in view of effective sulfur removal in steel and requires increase in refining slag weight. FeO content in slag over 5 %, obtained in some cases, is explained by deviations from the standard reladle technology, for example, reladle with two opened sliding shutters till the end of reladle, errors in determination of metal weight in the ladle and so on.

Conclusions

Industrial estimation of efficiency of furnace slag cut-off system by reladle method is carried out at OJSC “Alchevsk Iron & Steel Works”. It is shown that depending on the pouring scheme (one or two open sliding shutters), efficiency of slag cutoff can change substantially.

Meanwhile, reladle enables to lower the sulfur content considerably when using relatively low-cost and not scarce slag-forming mixture.

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Эффективность отсечки печного шлака при переливе стали из ковша в ковш

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Рассмотрены особенности отсечки шлака при переливе 300-т плавки из ковша в ковш. Показано, что в зависимости от схемы разливки (один или два открытых шиберных затвора) эффективность отсечки шлака может существенно изменяться. Перелив стали из ковша в ковш позволяет значительно снизить содержание серы при использовании относительно дешевых и недефицитных ТШС.

