DEVELOPMENT OF ULTRA-CLEAN AND LOW-COST PROCESS FOR GALVANIZED STEEL BY LADLE FURNACE

BY

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SYNOPSIS:

The standard process of high quality galvanized steel (GI) was used to be slag modification & Rheinstahl Heraeus (RH) process in China Steel Corporation (CSC). However, cost and environment pollution resulted from dust and odor have always been the primary issues. Hence, CSC has developed Ladle Furnace (LF) slag modification process. It improves dust and odor problem by excellent dust collecting equipment, and molten steel temperature control by LF electrodes instead of the addition of alumina in RH top oxygen blowing with Kawasaki top oxygen blowing (KTB). The LF process is now successfully replacing part of the slag modification & RH process in CSC. It not only improved environmental pollution problems but also optimized the allocation of different steel refining equipment to produce galvanized steel with a low-cost and high quality process.

Keywords: Slag Modification, Ladle Furnace, RH, Refining, KTB

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1. INTRODUCTION

Galvanized steel (GI) are widely used in construction, 3C products, home appliance, automobiles and so on. Different applications of GI have different quality demands. For example, GI used for antenna, kitchenware and computer case are strictly appearance required, therefore the cleanliness resulted from steelmaking process is concerned.

Because oxygen is blown into molten steel in the converter, it leads to highly oxidizing slag. In experience, if the iron oxide is more than 11% of slag in converter, the slag will oxidize Al, Ti in the molten steel. It causes nozzle clogging and results in large clusters of alumina, and may seriously deteriorate the cleanliness of molten steel in the subsequent refining and continuous casting process [1~2].

In CSC, the traditional clean steel making process was Basic Oxygen Furnace (BOF) - slag modification (in Ladle) – RH - Continuous Casting (CC). In order to reduce slag oxidation and avoid aluminum re-oxidation in molten steel after RH refining, lime, aluminum and aluminum slag are added into ladle during and after BOF tapping, then bottom stirring is taken for 3 minutes at stirring station. However, this traditional process had a few disadvantages such as high cost, instability and pollution. Because metallurgical reaction in RH is not completed, and dust collection equipment in stirring station is not very effective.

LF has some advantages over stirring station & RH such as better efficiency of metallurgical reaction, better dust collecting equipment and temperature elevation without aluminum oxygen top blowing. In this paper, a new slag modification process by ladle furnace is proposed. It shows benefits for cost reduction and quality.

2. EXPERIMENTAL PROCEDURES

2.1 Process design

LF slag modification process was developed in order to mitigate the disadvantages of the original process performed in converter tapping and RH. To achieve this operation, the slag modification stage had been moved from stirring station to LF station. By the excellent dust collection ability in LF station, the disadvantage of dust and odor had been resolved. While converter tapping, lime and aluminum are added into ladle for preliminary deoxidation of the molten steel, and consequently lime, aluminum slag and fluorite for slag modification in LF station. Because of better metallurgical reaction in LF, the amount of slag modification additives can be reduced. The difference of additives amount between LF process and traditional one is shown in Table.1.

When temperature of molten steel is not enough in RH process, the only way to increase temperature is adding aluminum and blowing oxygen. However, it potentially results in additional alumina and worse cleanliness. Even with increased recirculation time, it is difficult to make sure all alumina removed completely. Therefore, molten steel
temperature is elevated by electrodes instead of alumina addition in LF process. Finally, the bottom stirring time was set to be more than 6 minutes in order to promote inclusion floating and achieve better cleanliness. The flow chart of LF slag modification process is shown in Fig.1.

Table. 1 The amount of additives between RH and LF

<table>
<thead>
<tr>
<th></th>
<th>slag modification &amp; RH process</th>
<th>LF slag modification process</th>
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<tbody>
<tr>
<td>Lime</td>
<td>800 kg</td>
<td>800 kg</td>
</tr>
<tr>
<td>Aluminum</td>
<td>270 kg</td>
<td>150 kg</td>
</tr>
<tr>
<td>Aluminum slag</td>
<td>270 kg</td>
<td>200 kg</td>
</tr>
<tr>
<td>Fluorite</td>
<td></td>
<td>100 kg</td>
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Fig.1 the flow chart of LF slag modification process

2.2 Quality Evaluation and Verification

As mentioned previously, slag modification is a key process improving steel cleanliness for high-grade galvanized products. The major concern of process change is assuredly the influence to downstream quality. In CSC practice, from the records of high-grade GI steel rejected in CSC continuous galvanizing line, surface line crack takes most part of the rejection caused by steelmaking defects, which is about 96%. Hence, the rejection rate of this defect is a necessary item to track.

The morphology and analysis of surface line crack is shown in Fig.2 and Fig.3. Small particles were observed under surface line crack in microscope. The composition of small particles was alumina by EDX analysis.

Considering the effectiveness of the change in slag modification process and its potential risk to downstream rejection, three major methods were chose for the evaluation of steel cleanliness and quality, which are respectively:

(1) The contents of iron oxide and manganese oxide in slag
Slag oxidability after slag modification can be determined according to slag composition.

(2) Analysis results of aluminum by ASPEX

ASPEX is a method that specialized in automated particle analysis, which can rapidly detect the size, shape and elemental composition of the sample.

(3) The rejection rate of high-grade GI products caused by surface line crack

3. RESULTS AND DISCUSSION

3.1 Slag composition

Fig.4 shows the slag composition between different steel making processes. The average iron oxide was about 22.1% in BOF, and the manganese oxide and alumina were quite low. After slag modification, the iron oxide decreased and alumina increased sharply. The result indicates that slag oxidability has been reduced. Besides, Fig.4 shows slag composition of LF process was close to traditional process.

3.2 Alumina analysis

Fig.5~6 show the ternary phase diagrams of traditional and LF process from ASPEX analysis. Almost all inclusions were alumina in these two different processes because they
were both Al killed steel. Since the results of ternary phase diagrams from ASPEX and analysis of surface line crack were all alumina, three indicators have been selected to monitor alumina condition in the melt, which were alumina features/mm², number of alumina $\geq 50 \, \mu m$, and alumina inclusion index. The samples of two different processes were gathered from tundish at same ladle weight. Fig.7 is the results came from the analysis of more than 30 heats. Three indicators of LF process were not worse than traditional process, even slightly better. It proves that steel cleanness of LF process was equal or better to traditional process.

Fig.5 traditional process

Fig.6 LF process

Fig.7 results of inclusion analysis by ASPEX

3.3 Rejection rate of surface line crack

In addition to slag composition and alumina, the quality of product in continuous galvanizing mill has been reviewed. On the basis of same steel grade, inspection level and thickness range, it reveals that there is no significant difference in the rejection rate caused by line crack defect between two processes.

3.4 Benefits
Traditional changed to LF process has benefits. It could optimized the BOF blowing conditions and the allocation of different steel refining equipment to produce galvanized steel with a low-cost and high quality process. By internal evaluation it cuts the cost by approximately 3% comparing with the original process.

4. SUMMARY
The LF slag modification process for high clean galvanized steel has been developed in CSC in order to lower the cost and environmental pollution problems of standard process. By the verification on melt cleanliness and downstream rejection rate, it was confirmed that the change of slag modification process doesn’t results in unfavorable consequent on high-grade GI quality. Several benefits for steelmaking shop were achieved by shifting part of slag modification work from traditional process to LF. It could optimized the BOF blowing conditions and the allocation of different steel refining equipment to produce galvanized steel with a low-cost and high quality process.

5. REFERENCES