METHOD FOR REFINING STAINLESS STEEL WITH HIGH PURITY

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ABSTRACT

The present invention relates to a method of refining a stainless steel with high purity in which a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein the occurrence of the refractory hard inclusion material is suppressed by controlling composition and basicity of the slag after the refinery surface reduction process and using the desulphurization process, so that ductility of the inclusion material can be improved and surface defects and cracks of a product can be prevented.

The present invention provides a method of refining a stainless steel in which a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein a basicity of a slag obtained after reduction process by using the argon oxygen decarburization (AOD) refining furnace is controlled to be in a range between 1.5 and 1.8, wherein a dolomite is used as a refractory material for the ladle, and wherein a composite (% Al₂O₃+%MgO) in the slag is less than 13.

![Graph](image-url)
Fig. 6

The diagram shows a scatter plot with the following axes:

- **[S], ppm** on the y-axis, ranging from 0 to 200 ppm.
- **CaO/SiO₂, ACD** on the x-axis, ranging from 2.80 to 2.80.

The plot includes data points that indicate the upper limit of concentration [S]. The data points cluster around the upper limit, suggesting a relationship between the CaO/SiO₂ ratio and the [S] concentration.
METHOD FOR REFINING STAINLESS STEEL WITH HIGH PURITY

BACKGROUND

[0001] 1. Field of the Invention

[0002] The present invention relates to a method for refining a stainless steel, and more particularly, to a method for refining a stainless steel with high purity in which a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein the occurrence of the hard inclusion material having a high melting point is suppressed by controlling composition and basicity of the slag after the refining surface reduction process and using the desulfurization process, so that ductility of the inclusion material can be improved and surface defects and cracks of a product can be prevented.

[0003] 2. Discussion of Related Art

[0004] Generally, in case an inclusion material in a stainless steel having a high melting point and being a hard inclusion material, the inclusion material defects or cracks on the surface of the product causes surface. The process for removing the inclusion material or lowering the melting point for softening is carried out in a secondary refining furnace by using an argon oxygen decarburization (AOD) method or a vacuum oxygen decarburization (VOD) method in the process of refining the stainless molten steel.

[0005] In the refining furnace, oxygen gas is blown into molten steel and a decarburization refining process for removing carbon is carried out. After that, in order to reduce the chromium oxide generated during the decarburization refining process, a reducing agent such as Si or Al and a basic flux, which mainly consists of CaO, are added. And then, in order to facilitate deoxidization and removing of the inclusion material, the molten steel is stirred with an inert gas such as Ar.

[0006] In case of no restriction of particular components or inclusion materials, a low-cost Fe—Si is used as the reducing agent. Refinery methods for preventing product defects due to the hard inclusion material generated in the stainless steel refining process are disclosed in Japanese Unexamined Patent Application Publication Nos. Heisei 4-99215, Heisei 3-267312, Heisei 10-158720, Heisei 6-306438, and Heisei 8-104915. All the methods are adapted to a mirror-like surface finishing in which the surface defects due to the inclusion material are easy to occur. In all the methods, the inclusion materials are arranged no to be extended in a line shape during the rolling process for the products.

[0007] In the Japanese Unexamined Patent Application Publication No. Heisei 04-99215, Al in the raw material is intended to be restricted. However, in fact, it is difficult to restrict Al in the raw material during the process of fabricating the stainless steel by using a scrap. In addition, in the Japanese Unexamined Patent Application Publication Nos. Heisei 3-267312 and Heisei 10-158720, the formation of the hard inclusion material may be restricted by controlling the basicity of the slag in the refining furnace and the concentrations (% Al₂O₃) and (% MgO). However, it is difficult to suppress the formation of the hard inclusion material by adjusting only the composition of the slag in the refining furnace.

[0008] Additionally, in the Japanese Unexamined Patent Application Publication No. Heisei 6-306438, the condition that the concentrations (% MgO) and (% Al₂O₃) in the slag are 7% or less and 5% or less and the basicity is in a range between 1.3 and 1.9 is disclosed in order to prevent occurrence of the hard inclusion material MgO·Al₂O₃. However, it is difficult to lower the concentration (% MgO) in the slag below 5% while using magnesium chromites as a refinery refractory material and it is also difficult to control the concentration stably.

[0009] In addition, in the aforementioned prior arts similar to the Japanese Unexamined Patent Application Publication No. Heisei 8-104915, the basicity of the slag in the refining furnace is characterized and controlled to be low (CaO/SiO₂<2). However, in such a case of the basicity of the slag being low, oxygen is increased and purity in the molten steel is deteriorated. Furthermore, in the refining furnace, it is difficult to remove sulfur in the molten steel.

SUMMARY OF THE INVENTION

[0010] In order to solve the problems in the prior art, an object of the present invention is to provide a method of refining a stainless steel, and more particularly, to a method of refining a stainless steel with high purity in which a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein the occurrence of the refractory hard inclusion material is suppressed by controlling composition and basicity of the slag after the refining surface reduction process and using the desulfurization process, so that ductility of the inclusion material can be improved and surface defects and cracks of a product can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The aforementioned aspects and other features of the present invention will be explained in the following description, taken in conjunction with the accompanying drawings, wherein:

[0012] FIG. 1a is a view illustrating line defect on a surface of a cold rolled steel coil out of defects due to a hard inclusion material (MgO·Al₂O₃) of an STS steel;

[0013] FIG. 1b is a view illustrating crack during fabrication of a product having defects due to the hard inclusion material of the STS steel;

[0014] FIG. 2 is a graph illustrating a relation between a spinel occurrence and a surface defect index of the surface of the cold rolled steel coil;

[0015] FIG. 3 is a graph illustrating an affect of an AOD slag basicity on the spinel occurrence;

[0016] FIG. 4 is a graph illustrating a relation between the AOD slag basicity and [F (% O)] in a molten steel;

[0017] FIG. 5 is a graph illustrating a relation between a spinel occurrence in a slab inclusion material and (% Al₂O₃)+(% MgO) in a ladle slag; and

[0018] FIG. 6 is a graph illustrating a relation between the AOD slag basicity and a sulfur concentration in molten steel.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0019] Now, the present invention will be described in detail with reference to the accompanying drawings.
Generally, in case of using Si as a reducing agent at an AOD reduction refinery, the hard inclusion material MgO-Al2O3 causes surface defects or cracks of products. The origin of the inclusion material generated during the refining process of the stainless steel is as follows. In case of using Si as a reducing agent at the reduction refinery, if Al-containing material is added or if the concentration T[Al] in the molten steel is above a predetermined value, the hard inclusion material MgO-Al2O3 or the inclusion material Al2O3 is generated.

In addition, in case of using Si as the reducing agent at a reduction refinery, the inclusion material is grown as the slag particles suspended in the molten steel function as nuclei in the reduction refining process or a ladle-steel-drawn-out process. The slag suspended in the molten steel from the steel-drawn-out process to the casting process is combined with Al2O3 generated by the deoxidation reaction which is carried out along with the temperature drop of the molten steel, whereby the composition changes. Therefore, the concentration of Al2O3 in the inclusion material is increased. The increase in the concentration of Al2O3 depends on the T[Al] in the molten steel and the basicity of the slag.

The T[Al] in the molten steel is affected by the ladle refractory material or Al2O3 in the slag besides Al in the alloy steel. On the other hand, if the concentration of MgO and Al2O3 is high, MgO-Al2O3 is extracted in some portion of the spherical inclusion material. In addition, the number and amount of the in-steel inclusion material are essentially dependent on the concentration of T[O]. However, since the concentration T[O] is dependent on the basicity of the slag, the amount of the inclusion material can be controlled by the CaO/SiO2. If the basicity of the slag after the refining furnace reduction process is high, the T[O] and the concentration of sulfur in the molten steel can be effectively lowered. However, the inclusion material MgO-Al2O3 is easy to generate.

Therefore, it is important to reduce the basicity of the refining furnace slag in order to suppress the generation of the inclusion material MgO-Al2O3 and to reduce the amount of the inclusion material. In addition, it is necessary to lower the concentration of Al2O3 and MgO in the slag. Sulfur causes a problem in case of the basicity of AOD slag being lowered in a range between 1.6 and 1.8; it is necessary to remove sulfur in the molten steel in electric furnace at the electric furnace—the AOD or VOD process or before the VOD refining furnace process.

FIG. 1a illustrates line defect on a surface of a cold rolled steel coil out of defects due to the hard inclusion material (MgO-Al2O3) of the STS steel, and FIG. 1b illustrates cracks during fabrication of a product having defects due to the hard inclusion material of the STS steel. The origins of the defects and cracks are the hard inclusion material MgO-Al2O3 which mainly occurs at the casting slab.

FIG. 2 is a graph illustrating a relation between a spinel occurrence and a surface defect index of the surface of the cold rolled steel coil. Herein, the spinel occurrence and the surface defect index are defined, as follows.

spinel occurrence (%)=(number of spinel generating inclusion materials)(number of observed inclusion materials)x100, and

Surface defect index=(number of line defects due to the inclusion materials)(1 km cold rolled steel coil)

As shown in the figure, the surface defect index is closely related to the spinel occurrence in the slab spinel. It can be understood that good surface quality having surface defect index of one or low can be obtained at the spinel occurrence of 40% or less.

In order to achieve the object, the present invention provides a method of refining a stainless steel in which a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein a basicity of a slag obtained after reduction process by using the argon oxygen decarburization (AOD) refining furnace is controlled to be in a range between 1.5 and 1.8, wherein a dolomite is used as a refractory material for the ladle, and wherein a composite (% Al2O3)(% MgO) in the slag is less than 13.

In addition, the present invention provides a method of refining a stainless steel, wherein the desulphurization process in molten steel is carried out between the electric furnace and the argon oxygen decarburization (AOD) refining furnace.

In addition, the present invention provides a method of refining a stainless steel wherein a ladle furnace is used to compensate for a temperature drop of the molten steel during the desulphurization process.

The reason for limitation of the slag basicity after the refining furnace reduction process to the range between 1.5 and 1.8 is that the occurrence of MgO-Al2O3 in the slab inclusion material is 80% or more at the slag basicity of 1.8 or more although the occurrence of MgO-Al2O3 in the slab inclusion material is 50% or less at the slag basicity of 1.8 or less. In addition, that is because the number and size of the in-steel inclusion material are increased and the capability of removing sulfur of the slag is drastically reduced at the slag basicity of 1.5 or less. In addition, the reason that dolomite is more preferred ladle refractory material that alumina is that the alumina refractory material is reacted with the slag and the concentration of Al2O3 in the slag is increased. If the concentration of Al2O3 in the slag is increased, the concentration of Al in the molten steel is increased. Finally, the concentration of Al2O3 in the inclusion material is increased. Therefore, the occurrence of the MgO-Al2O3 is increased.

In addition, the reason for the limitation of the sum of the concentrations of Al2O3 and MgO in the ladle slag to 1.3% or less is that the occurrence of MgO-Al2O3 in the inclusion material greatly depends on the concentrations of Al2O3 and MgO. If the sum of the concentrations of the two components is 13 or more, the occurrence of the MgO-Al2O3 is drastically increased.

Furthermore, in order to suppress the occurrence of the MgO-Al2O3 in the inclusion material, it is difficult to lower the basicity of the refining furnace to the range between 1.5 and 1.8. Therefore, the process for removing sulfur is needed prior to the refining furnace process. Sulfur in the molten steel during the electric furnace—refining furnace process can be removed after or before the refining furnace. In case of removing sulfur after the refining fur-
furnace, since the basicity of desulphurization slag should be adjusted to be two or more, it is impossible to prevent occurrence of MgO.Al₂O₃ in the slag.

[0035] Accordingly, it is preferable that the removing of sulfur in the molten steel is carried out after the electric furnace process before the refining furnace process. In addition, since the temperature is dropped during the process of removing sulfur, an apparatus for raising the temperature is needed in order to perform the post process smoothly. The preferred apparatus for raising the temperature is a ladle furnace. Since the ladle furnace utilizes electrodes to directly heat the molten steel and the slag, the desulphurization slag is easy to melt and the desulphurization efficiency is advantageously improved.

[0036] Now, the present invention will be described in detail by using the examples.

EXAMPLES

[0037] In a fabricating process of the STS 430 steel (16.5% Cr) using an electric furnace, an AOD refining furnace, a ladle, and a continuous casting, a raw material consisting of a scrap and ferro-chromium (Fe—Cr) is melted in a 90 ton electric furnace, and then subjected to a decarburization refining in the AOD by using oxygen-Ar mixed gas. After the decarburization refining, in order to reduce and withdraw the oxidized chromium, a reduction refining is carried out while Si, quicklime, and fluorite being added and Ar gas being blown into. And then, the steel is drawn out. In the ladle, the final contents and temperature are adjusted while a stirring process being carried out in the Ar gas. After that, by the continuous casting, a slab having a width of 1200 mm and a thickness of 200 mm is cast. The cast slab is subjected to a hot rolling process and a cold rolling process. As a result, a 0.6 mm cold rolled steel sheet is fabricated.

[0038] The following table 1 illustrates contents in the STS 430 steel used in the present invention. Inspection of the inclusion material is carried out by taking sample on the center of slab, observing the inclusion material up to the depth of 1 mm from the top surface of the sample with an optical microscope, and detecting the contents and the occurrence of the hard inclusion material MgO.Al₂O₃ over five inclusion materials per specimen with an electronic microscope (SEM, EPMA).

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<tr>
<th>Contents (wt %) of STS 430 Steel</th>
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[0039] In addition, the following table 2 illustrates the basicity of the slag after the AOD reduction process, the composite (% MgO+% Al₂O₃) in Ladle Slag, the spinel occurrence in the slab inclusion material according to the conditions of the ladle refractory material, and the concentration of sulfur in the molten steel after AOD desulphurization process.

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<th>Conditions and Results of Examples of the Present Invention and Comparative Examples</th>
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* dolomite refractory material (MgO: 38.5%, CaO: 59.5%)
* alumina refractory material (Al₂O₃: 85%, SiO₂: 7%)

[0040] In the examples of the present invention and the comparative examples, the concentration of T.Al is 0.003% or less. In the examples of the present invention, it can be understood that the occurrence of the hard inclusion material is stabilized as 20% or less. FIG. 3 illustrates a relation between the basicity of the slag after the AOD reduction process and the spinel occurrence in the slab inclusion material. Referring to the drawings, the spinel occurrence is low in the basicity of 1.8 or less. As shown in 2, when the spinel occurrence in the slab inclusion material is lowered, the defect index of the surface of the cold rolled steel coil is lowered.

[0041] In addition, FIG. 4 illustrates a relation between the AOD slag basicity and the slab T[%, O]. The slab T[%, O] is further increased as the basicity is lowered. In particular, slab T[%, O] is drastically increased in the basicity of 1.5 or less. FIG. 5 is a graph illustrating a relation between a spinel occurrence in a slab inclusion material and the (% Al₂O₃)+(% MgO) in a ladle slag. Referring to the figure, it can be understood that the occurrence of
MgO, Al₂O₃, and the occurrence of the hard inclusion material are lowered when the concentration of (Al₂O₃ + MgO) in the ladle slag is 13% or less.

[0042] FIG. 6 illustrates a relation between a concentration of sulfur in molten steel and the AOD slag basicity after AOD reduction process. Since the upper limit in the [% S] specification of STS 430 0.01, the concentration of sulfur should be 0.008 or less at the final point of the AOD process in consideration of sulfur pick-up. However, the upper limit in the [% S] specification is exceeded if the basicity is adjusted in a range between 1.5 and 1.8, as shown in the graph.

[0043] The distribution ratio of sulfur in the slag, that is, the ratio of the concentration of sulfur in the slag to the concentration of sulfur in the molten steel is about 30. By using this, the initial concentration of sulfur in the AOD refining furnace should be 0.015% or less in order to meet the specification of the concentration of sulfur in the molten steel. In other words, since the initial concentration of sulfur in the AOD refining furnace process is in a range between 0.025 and 0.020%, only if 25~50% desulfurization before the AOD refining furnace process is carried out, the stable control of the AOD slag can be obtained in order to suppress the occurrence of the hard inclusion material in the slab.

[0044] As described above, according to the method of refining the stainless steel with high purity of the present invention, the occurrence of the refractory hard inclusion material can be suppressed by controlling composition and basicity of the slag after the refinery surface reduction process and using the desulfurization process, so that it is advantageous that the ductility of the inclusion material during the post process can be improved and surface defects and cracks of a precut can be prevented.

[0045] Although the foregoing description has been made with reference to the preferred embodiments, it is to be understood that changes and modifications of the present invention may be made by the ordinary skilled in the art without departing from the spirit and scope of the present invention and appended claims.

What is claimed is:
1. A method of refining a stainless steel in where a raw material melted in an electric furnace is processed in an argon oxygen decarburization (AOD) refining furnace to be output to a ladle and then subjected to a continuous casting, wherein a basicity of a slag obtained after reduction process by using the argon oxygen decarburization (AOD) refining furnace is controlled to be in a range between 1.5 and 1.8,
   wherein a dolomite is used as a refractory material for the ladle, and
   wherein a composite (% Al₂O₃ + % MgO) in the slag is less than 13.
2. The method of refining a stainless steel according to claim 1, wherein the desulfurization process in molten steel is carried out between the electric furnace and the argon oxygen decarburization (AOD) refining furnace.
3. The method of refining a stainless steel according to claim 2, wherein a ladle furnace is used to compensate for a temperature drop of the molten steel during the desulfurization process.

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