ABSTRACT

TITLE: A PROCESS FOR REFINING OF LOW CARBON ALUMINIUM KILLED (LCAK) STEEL ADAPTED TO AVOID NOZZLE CLOGGING DURING CASTING.

A process for refining of Low Carbon Aluminium Killed (LCAK) steels adapted to avoid nozzle clogging in continuous bloom/slab caster is disclosed. Selective flux composition is developed for production of low alumina low sulphur LCAK steels adapted to ensure desired slag properties and avoid clogging of ladle nozzle and SEN by alumina. Importantly, the process involves designing of flux addition and de-oxidation in LF favoring producing clean LCAK steel to ensure low level of oxygen and sulphur and avoid further alumina generation during casting process. The process ensures achieving low melting point, low viscosity and high sulphide capacity slag to maximize de-sulphurisation during refining operation. Optimum CaSi wire injection favour forming liquid calcium aluminates followed by inclusion floatation treatment at the end of refining operation and removal of alumina from liquid steel to slag phase, thus favoring continuous casting free of clogging and wide scale application in steel plants.

We Claim:

1. A flux composition favouring slag generation adapted for Low Carbon Aluminium Killed (LCAK) Steel favouring avoiding ladle nozzle clogging and SEN clogging during continuous casting of blooms/slabs comprising:

Lime in an amount of 10 to 12 kg/t (depending on turndown sulphur in BOF);

Aluminium in an amount of 2.5 to 3.0 kg/t (based on oxygen consumption);

SiMn in an amount of 1.0 to 2.0 kg/t (based on grade requirement);

Calcined Bauxite in an amount of 3.0 to 3.5 kg/t; and

Pet coke in an amount of 0.8 to 1.0 kg/t

2. A flux composition as claimed in claim 1 adapted to favour said slag generation comprising:

Low melting point in the range of 1440 to 14600C;

Low viscosity in the range of 0.60 to 0.90 Pa s at 15500C; and

High sulphide capacity in the range of 0.009 to 0.015

3. A flux composition as claimed in anyone of claims 1 or 2 wherein said slag generated comprises:

CaO in the range of 40.0 to 46.0% preferably about 42.0%;

SiO2 in the range of 12.0 to 18.0 preferably about 15.0%;

Al2O3 in the range of 20.0 to 25.0% preferably about 22%;

MgO around 10%; and

(FeO+ MnO) in an amount of < 2.0%

With slag melting point in the range of 1440 to 14600C and Slag Viscosity at 15500C of 0.60 to 0.90 (Pa s) preferably 0.75.

4. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel adapted to avoid ladle nozzle clogging and SEN clogging during continuous casting of blooms/slabs, comprising

Selective flux addition and de-oxidation such as to achieve low level of dissolve oxygen in the range of 2.0 to 7.0 ppm and sulphur in the range of 0.012 to 0.018% in steel;

Cutting supply of oxygen to steel for further alumina generation during casting process;

Optimization of CaSi wire injection based on the Oxygen and sulphur level at specified temperature to form liquid calcium aluminates for easy removal of alumina from liquid steel to slag phase;

Argon purging through mono-block for minimization of alumina deposit during casting.

5. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel as claimed in claim 4, wherein said flux and de-oxidation practice involving sequential additions comprising;

Lime in an amount of 10 to 12 kg/t;

Aluminium in an amount of 2.5 to 3.0 kg/t;

SiMn in an amount of 1.0 to 2.0 kg/t;

Calcined Bauxite in an amount of 3.0 to 3.5 kg/t; and

Pet coke in an amount of 0.8 to 1.0 kg/t; to generate desired slag comprising;

CaO in the range of 40.0 to 46.0% preferably about 42.0%;

SiO_2 in the range of 12.0 to 18.0 preferably about 15.0%;

Al_2O_3 in the range of 20.0 to 25.0% preferably about 22%;

MgO around 10%; and

(FeO+ MnO) in an amount of < 2.0%; having slag melting point in the range of 1440 to 1460^{0}C and Slag Viscosity 0.60 to 0.90 (Pa s) at 1550^{0}C of preferably 0.75 Pa s.

CaSi wire injection: 44.0 to 60.0 kg preferably 0.4 kg/t

6. A process for ladle refining of Low Carbon Aluminium Killed(LCAK) Steel as claimed in claims 4 or 5, wherein major Aluminium addition is done in the ladle during tapping, instead of Aluminium wire injection in ladle before start of LF treatment, to provide sufficient time for de-oxidation products mainly alumina to float to slag phase.

7. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel as claimed in anyone of claims 4 to 6, wherein said additions favour achieving a slag composition having low slag melting point in the range of 1440 to 1460^{0}C, low slag viscosity in the range of 0.60 to 0.90 (Pa s) at 1550^{0}C and high sulphide capacity of slag to maximise de-sulphurisation during refining operation and to promote inclusion flotation and absorption by slag.

8. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel as claimed in anyone of claims 4 to 7, wherein standard practice for steel de-oxidation and refining is adapted to reduce dissolved oxygen level below 5.0 ppm.

9. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel as claimed in anyone of claims 4 to 8, wherein average sulphur content in steel is reduced to less than 0.020% which is mandatory requirement for CaSi injection for formation of liquid calcium aluminates.

10. A process for ladle refining of Low Carbon Aluminium Killed(LCAK) Steel as claimed in anyone of claims 4 to 9, wherein LF final Slag contains (FeO+MnO) less than 2% that reduced further generation of Al_2O_3 after LF treatment.

11. A process for ladle refining of Low Carbon Aluminium Killed(LCAK) Steel as claimed in anyone of claims 4 to 10, wherein practice for steel de-oxidation and its refining in LF favour producing clean steel free from suspended alumina.

12. A process for ladle refining of Low Carbon Aluminium Killed(LCAK) Steel as claimed in anyone of claims 4 to 11, wherein optimum addition of CaSi wire injected

at the temperature range of 1595 to 1605^{0}C to form liquid inclusions mainly calcium aluminates followed by inclusion flotation treatment at the end of refining operation.

13. A process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel adapted to avoid clogging of alumina in ladle nozzle/SEN substantially as herein described and illustrated with reference to accompanying example.

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FIELD OF THE INVENTION

The present invention relates to a process for refining of Low Carbon Aluminium Killed (LCAK) steels adapted to avoid nozzle clogging in continuous bloom/slab caster. More particularly, the present invention is directed to developing a flux composition for production of low alumina, low sulphur LCAK steels adapted to ensure desired slag properties and avoid clogging of ladle nozzle and Sub-entry Nozzle (SEN) by alumina. Importantly, the process of the invention involves designing of flux addition, de-oxidation practice and its refining in Ladle Furnace (LF) favor producing clean LCAK steel to ensure low level of oxygen and sulphur and to cut supply of oxygen to steel for further alumina generation during casting process. Advantageously, the process of producing LCAK steel further helps achieving low melting point, low viscosity and high sulphide capacity slag to maximize steel de-sulphurisation during refining operation. Optimum CaSi wire injection is adopted based on oxygen, sulphur and aluminium levels at specified temperature to form liquid calcium aluminates followed by inclusion floatation treatment at the end of refining operation, favoring easy removal of alumina from liquid steel to slag phase. The process of the invention is thus capable to produce LCAK steels with desired controlled oxygen and sulphur level with reduced alumina generation during casting, adapted to ensure continuous casting of bloom/slab from this grade of steel free of any clogging favoring wide scale application of this process of producing LCAK steel in steel plants.

BACKGROUND ART

It is well known in the art of steel production in the Steel Melting Shops and subsequent casting stage, that nozzle clogging is a common problem for continuous casting of Low Carbon Aluminium Killed (LCAK) steel in bloom/slab caster. LCAK quality steels are very prone to clogging by Al_2O_3 and clogging is being experienced even through slab caster route by many experienced steelmakers worldwide. The possibility of successful casting of LCAK steels at the Steel Plant of the applicants found to be even more difficult because of poor infra-structural facility at the bloom caster in terms of lower nozzle diameter (50 mm) in ladles and SEN (32 mm), non-availability of ladle to tundish argon-sealing and very high casting duration. Normal practice of ladle addition comprising Lime (~ 8.5 kg/t), SiMn (~ 5.0 kg/t) during taping followed by Aluminium wire injection (~2.0 kg/t) leads to generation of

sufficient alumina leading to nozzle clogging during casting. Early attempts to cast LCAK heats by addition of Aluminium wire for killing of oxygen and building Aluminium level in steel, led to either ladle nozzle clogging or SEN clogging during continuous casting. The most important requirement of low carbon aluminium killed steel has been to minimize generation of alumina and removal of de-oxidation product mainly alumina from liquid steel by suitable refining treatment.

There has been therefore a persistent need in the art to developing a process for production of LCAK steel involving selective flux addition and de-oxidation practice directed to meeting the controlled low sulfur and oxygen level in steel as well as avoid further alumina generation during casting leading to clogging. Present work establishes the process of making clean steel and development of methodology for low carbon Al – killed grades of steel through bloom caster. In order to avoid clogging of alumina in ladle nozzle and SEN, suitable flux and de-oxidation practice has been designed to achieve a low melting point, low viscosity and high sulphide capacity slag to maximize de-sulphurisation during refining operation and to promote inclusion flotation and absorption by slag.

OBJECTS OF THE INVENTION

The basic object of the present invention is thus directed to developing a selective flux composition and providing a process for production and refining of LCAK grades of steel in LF, suitable for casting in continuous bloom/slab caster without any problem of clogging of ladle nozzle/sub entry nozzle by alumina.

Another object of the present invention is directed to developing a process for production and refining of LCAK steel by involving a selective flux composition and de-oxidation practice adapted to ensure low oxygen and sulphur content in steel within desired limit and also desired slag properties.

A further object of the present invention is directed to developing a process for production and refining of LCAK steel wherein the generation of alumina is minimized and de-oxidation product mainly alumina is removed from liquid steel to avoid clogging during casting.

A still further object of the present invention is directed to developing a process for production and refining of LCAK steel wherein supply of oxygen to steel is cut to avoid further alumina generation during casting process.

A still further object of the present invention is directed to developing a process for production and refining of LCAK steel wherein CaSi wire injection is optimized to form calcium aluminate for easy removal of alumina to slag phase by inclusion floatation treatment at the end of refining operation.

A still further object of the present invention is directed to developing a process for production and refining of LCAK steel wherein argon purging through mono-block stopper of tundish is optimized to minimize the alumina deposit during casting.

A still further object of the present invention is directed to developing a process for production and refining of LCAK steel wherein LF final slag (FeO+MnO) generation is limited to less than 2% so that further generation of alumina after LF treatment is reduced.

SUMMARY OF THE INVENTION

The basic aspect of the present invention is directed to a flux practice favouring slag generation adapted for Low Carbon Aluminium Killed (LCAK) Steel favouring avoiding ladle nozzle clogging and SEN clogging during continuous casting of blooms/slabs comprising:

Lime in an amount of 10 to 12 kg/t (depending on turndown sulphur in BOF);

Aluminium in an amount of 2.5 to 3.0 kg/t (based on oxygen consumption);

SiMn in an amount of 1.0 to 2.0 kg/t (based on grade requirement);

Calcined Bauxite in an amount of 3.0 to 3.5 kg/t; and

Pet coke in an amount of 0.8 to 1.0 kg/t

Another aspect of the present invention is directed to a flux composition adapted to favour said slag generation comprising:

Low melting point in the range of 1440 to 1460^{0}C;

Low viscosity in the range of 0.60 to 0.90 Pa s at 1550^{0}C; and

High sulphide capacity in the range of 0.009 to 0.015

A further aspect of the present invention is directed to said flux composition wherein said slag generated comprises:

CaO in the range of 40.0 to 46.0% preferably about 42.0%;

SiO_2 in the range of 12.0 to 18.0 preferably about 15.0%;

Al_2O_3 in the range of 20.0 to 25.0% preferably about 22%;

MgO around 10%; and

(FeO+ MnO) in an amount of < 2.0%

With slag melting point in the range of 1440 to 1460^{0}C and Slag Viscosity at 1550^{0}C of 0.60 to 0.90 (Pa s) preferably 0.75.

A still further aspect of the present invention is directed to a process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel adapted to avoid ladle nozzle clogging and SEN clogging during continuous casting of blooms/slabs, comprising

Selective flux addition and de-oxidation such as to achieve low level of dissolve oxygen in the range of 2.0 to 7.0 ppm and sulphur in the range of 0.012 to 0.018% in steel;

Cutting supply of oxygen to steel for further alumina generation during casting process;

Optimization of CaSi wire injection based on the Oxygen and sulphur level at specified temperature to form liquid calcium aluminates for easy removal of alumina from liquid steel to slag phase;

Argon purging through mono block for minimization of alumina deposit during casting.

According to yet another aspect of the present invention is directed to said process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel, wherein said flux and de-oxidation practice involving sequential additions comprising

Lime in an amount of 10 to 12 kg/t;

Aluminium in an amount of 2.5 to 3.0 kg/t;

SiMn in an amount of 1.0 to 2.0 kg/t;

Calcined Bauxite in an amount of 3.0 to 3.5 kg/t; and

Pet coke in an amount of 0.8 to 1.0 kg/t; to generate desired slag comprising

CaO in the range of 40.0 to 46.0% preferably about 42.0%;

SiO_2 in the range of 12.0 to 18.0 preferably about 15.0%;

Al_2O_3 in the range of 20.0 to 25.0% preferably about 22%;

MgO around 10%; and

(FeO+ MnO) in an amount of < 2.0%; having Slag melting point in the range of 1440 to 1460^{0}C and Slag Viscosity 0.60 to 0.90 (Pa s) at 1550^{0}C of preferably 0.75 Pa s.

CaSi wire injection: 44.0 to 60.0 kg preferably 0.4 kg/t

Importantly in said process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel, major Aluminium addition is done in the ladle during tapping, instead of Aluminium wire injection in ladle before start of LF treatment, to provide sufficient time for de-oxidation products mainly alumina to float to slag phase.

According to yet another aspect of the present invention is directed to a process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel wherein said additions favour achieving a slag composition having low slag melting point in the range of 1440 to 1460^{0}C, low slag viscosity in the range of 0.60 to 0.90 (Pa s) at 1550^{0}C and high sulphide capacity of slag to maximise de-sulphurisation during refining operation and to promote inclusion flotation and absorption by slag.

According to an advantageous aspect of the present invention is directed to said process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel, wherein standard practice for steel de-oxidation and refining is adapted to reduce dissolved oxygen level below 5.0 ppm.

Also average sulphur content in steel is reduced to less than 0.020% which is mandatory requirement for CaSi injection for formation of liquid calcium aluminates; and LF final Slag contains (FeO+MnO) less than 2.0% that reduced further generation of Al_2O_3 after LF treatment.

According to yet another aspect of the present invention directed to said process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel, wherein said practice for steel de-oxidation and its refining in LF favour producing clean steel free from suspended alumina.

Importantly, in said process for ladle refining of Low Carbon Aluminium Killed (LCAK) Steel, optimum addition of CaSi wire injected at the temperature range of 1595 to 1605^{0}C to form liquid inclusions mainly calcium aluminates followed by inclusion flotation treatment at the end of refining operation.

The objects and advantages of the present invention is described in greater details with reference to the following accompanying illustrative example.

DETAILED DESCRIPTION OF THE INVENTION WITH REFERENCE TO EXAMPLE

The present invention is directed to developing a process for production and refining of Low Carbon Aluminium Killed (LCAK) steel involving selective flux and de-oxidation practice adapted to avoid Ladle and SEN clogging during bloom/slab casting in continuous bloom/slab caster by limiting oxygen and sulphur to desired level as well as to adopt inclusion floatation treatment to minimize alumina deposition which is responsible for nozzle clogging.

The flux and de-oxidation practice according to the invention and the refining treatment of steel involved the following steps to develop a standard operating practice for production of clean low oxygen low sulphur LCAK steel to avoid ladle nozzle clogging and SEN clogging by alumina deposits:

1. Designing of flux and de-oxidation practice for low carbon Al-killed steel to achieve low level of oxygen and sulphur in steel and to cut supply of oxygen to steel for further alumina generation during casting process.

2. Optimisation of CaSi wire injection based on the Oxygen and sulphur level at specified temperature to form liquid calcium aluminates for easy removal of alumina from liquid steel to slag phase.

3. Installation of argon purging system through mono-block stopper of tundish and optimisation of argon purging for minimisation of alumina deposit during casting.

The modified flux addition and de-oxidation practice with the objective of reducing oxygen and sulphur level in steel and to avoid nozzle clogging by alumina during bloom/slab casting, shall be clearly apparent from the following accompanying Example I.

Example I:

According to an embodiment of the process of the invention involving the modified flux and de-oxidation practice, following pattern of additions are used for ladle refining:

Lime in an amount of 10 to 12 kg/t;

Aluminium in an amount of 2.5 to 3.0 kg/t;

SiMn in an amount of 1.0 to 2.0 kg/t;

Calcined Bauxite in an amount of 3.0 to 3.5 kg/t; and

Pet coke in an amount of 0.8 to 1.0 kg/t; to generate desired slag composition.

CaSi wire injection: 44.0 to 60.0 kg preferably 0.4 kg/t

The above additions favour reducing the oxygen and sulphur content in steel to the desired low levels and achieving a slag composition having low melting point, low viscosity and high sulphide capacity. Importantly in said addition practice, major

Aluminium addition is done in the ladle during tapping, instead of Aluminium wire injection in ladle before start of LF treatment, to provide sufficient time for de-oxidation products mainly alumina to float to slag phase. Optimum addition of CaSi wire injected to form liquid inclusions mainly calcium aluminates followed by inclusion flotation treatment at the end of refining operation. The above addition pattern maximizes de-sulphurization during refining operation and promotes inclusion floatation and absorption by slag. The comparison of proposed flux and de-oxidation practice according to the invention with the conventional practice is given in the following Table I.

Table I:

Process Parameters	Earlier Practice	Modified Practice
Ladle De-oxidation (Avg. additions in kg)	Lime – 8.5 kg/t SiMn- 5.0 kg/t	Lime – 10.0 kg/t Aluminium cube - 2.5 kg/t SiMn- 2.0 kg/t Calcined Bauxite – 3.0 kg/t Pet Coke – 1.0 kg/t
Addition Before Start of LF Treatment	Aluminium wire - 2.0 kg/t	NIL
Avg. Slag Analysis (%)	CaO - 45.54 SiO_2 - 25.35 Al_2O_3 - 4.25 MgO - 11.12 FeO+MnO - 10.72	CaO - 42.42 SiO_2 - 15.78 Al_2O_3 - 22.82 MgO - 9.38 FeO+MnO < 2.0
Avg. Slag Melting Point (^{0}C)	1511	1449
Avg. Slag Viscosity at 1550^{0}C (Pa s)	1.86	0.75

Industrial/plant scale trial of flux and de-oxidation practice and refining treatment of LCAK steels as given above has been conducted with 120t heat size and has been standardized to ensure desired results. The plant trial also has been successfully carried out without ladle nozzle clogging or SEN clogging during continuous casting and the process is well established and capable of commercial production of LCAK heats. The modified flux and de-oxidation practice has resulted the following benefits

apart from meeting the stringent quality requirement of customer for specific application:

1. Developments of standard practice for steel de-oxidation and refining, reduced dissolved oxygen level below 5.0 ppm.
2. Average sulphur in steel found to be less than 0.020% which is mandatory requirement for CaSi injection to produce liquid calcium aluminates.
3. LF final Slag (FeO+MnO) is found to be less than 2% that reduced further generation of Al_2O_3 after LF treatment.

It is thus possible by way of the present invention to providing a process for refining of low carbon aluminium killed steel adapted to avoid clogging of ladle nozzle or SEN during continuous casting operation. The process of the invention involving selective flux and de-oxidation practice ensuring low level of sulphur and oxygen in steel, Ladle refining involving CaSi injection at the end of the refining process to form liquid calcium aluminate for easy removal of alumina from liquid steel to slag phase, and argon purging through mono-block stopper of tundish minimize alumina deposit after ladle refining during casting and thus avoiding ladle nozzle or SEN clogging by alumina. The ladle refining of LCAK steel with selective flux and de-oxidation practice on one hand meets the stringent quality requirement of customer for specific application and on the other hand ensure uninterrupted production free of nozzle clogging and thus enhancing the productivity and favoring wide scale application of the process in steel plants.