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(54) PROCEDURE AND INSTALLATION FOR ELIMINATING IMPURITIES IN A CONTAMINATED MOLTEN METAL

(57) A process of eliminating impurities dissolved in a contaminated liquid metal, continuously, by applying an electromagnetic field generated by linear induction pumps on the contaminated metal crosswise to a second duct through which the metal flows. The current density circulates lengthwise to the duct, and therefore, according to Lorentz force law, an electromagnetic force that is perpendicular to both is produced. When the impurities have a difference in electrical conductivity of at least one order of magnitude in decimal power, the resulting force that acts upon the particles causes a relative movement of these with respect to said metal, such that they can be moved and separated from said molten metal in a previous metallurgical step a particle is formed having an adequate electrical conductivity. The installation includes the aforementioned components in order to carry out the process.

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] This invention lies within the field of the elimination of impurities in contaminated metals, also known as purification, the most representative example being that of aluminum alloys contaminated with iron.

BACKGROUND OF THE INVENTION

[0002] In the metallurgical industry treatments are performed on secondary materials that allow such material to be re-used in the production process with properties as similar as possible to those of the primary material but at a much lower cost.

[0003] In particular, in aluminum alloys, oxides and iron are the greatest contaminants found. These aluminum alloys are very easily contaminated with iron due to direct contact with tools and molds during the entire production process and the presence of oxides is due to the high reactivity of the metal in the presence of oxygen.

[0004] There are numerous studies that have focused on attempting to reduce the presence of impurities in molten metals, more specifically there is a large number of studies aimed at trying to reduce the deleterious effect of the presence of iron by precipitation by gravity, centrifugal methods, addition of neutralizing components, rapid setting or supercritical heating 300°C above the melting point. The precipitation and centrifuge separation processes, such as that of Patent with publication number JPH11229055, do not have industrial interest since they are difficult to implement due to their excessively low efficiency and non-continuous processing. Despite the fact that the neutralizing, rapid setting and supercritical heating processes reduce the impact of iron, they do not eliminate the detrimental effects of its presence.

[0005] Currently the only real alternative implemented at an industrial level for eliminating iron consists of the dilution with primary aluminum to reduce the content in iron and other contaminants down to values accepted by the standards, with the high financial costs this entails.

[0006] Separation using an electromagnetic force, as stated in Leenov's article (Daniel Leenov, Alexander Kolin "Theory of Electromagnetophoresis. I. Magnetohydrodynamic forces experienced by spherical and Symmetrically oriented cylindrical Particles", The journal of Chemical Physics, vol. 22 No. 4, 1954), which theoretically evaluates the effect that an electromagnetic force causes on a spherical particle, is presented as a new method capable of eliminating the presence of these iron-rich impurities or other contaminants and which could be applied with high efficiency, allowing a continuous procedure of industrial interest.

[0007] There are preliminary studies that have suggested solving the problem described, such as:

- non-continuous processes that focus on using electromagnetic forces by creating a cylindrical force inside the metal and separating the inclusions by the centrifuge effect, sending them to the walls, as is the case of Yamao's document (Fumitaka Yamao, Kensuke Sassa et al., "Separation of Inclusions in Liquid Metal Using Fixed Alternating Magnetic Field", Tetsu-to-Hagane, vol. 83, No 1, 1997);
- use of a high-power magnetic field to remove inclusions such as that explained in the document by Waki (Norihisa Waki, Kensuke Sassa et al., "Magnetic Separation of Inclusions in Molten Metal Using a High Magnetic Field", Tetsu-to-Hagane, vol. 86, No 6, 2000);

[0008] Both processes are based on the separation of the impurities already present within the metal due to the effect of fluid dynamic forces and the difference in densities and not on the elimination of harmful components dissolved within the metal and which may not be separated and eliminated simply with the use of fluid dynamic forces or by movement of the metal.

[0009] Leenov's document theoretically reflects how electromagnetic forces may actually affect compounds that may be formed with the impurities to be extracted from the metal.

[0010] There are electromagnetic systems for metal decanting that exert electromagnetic forces on the conducting metal, most of which use electrodes that must be introduced into the liquid metal in order to pass an electric current through them, which has two great drawbacks: the new contamination of the metal since there is no metal material that withstands the corrosive effect of molten aluminum, and the electrical risk and requirement for industrial-level insulation these devices require in order to implement it in an industrial process without risk of electrocution.

[0011] On the other hand, we also know the use of other metal decanting systems, such as linear induction pumps, which avoid contact with the metal and are more versatile with respect to their properties, using alternating current instead of direct current, as with the electrode systems. However, we have not found any evidence of its use to affect the presence of particles inside a conductive metal.

[0012] In all the above, we have not encountered any disclosure of a continuous and efficient process that has been implemented at an industrial level.

[0013] In the analysis of more industrial references related to the system proposed we have found the patent with publication number WO/2007/018243, which refers to an industrial system for eliminating impurities contained in the metal without resorting to any metallurgic treatment. As with the documents by Yamao and Waki, this system shall never be capable of eliminating the excess above the standard of elements that are dissolved in the metal since when in solution they present no difference regarding conductivity and are therefore not affected by electromagnetic forces.

[0014] Moreover, there is also the problem associated with in-situ contamination of the metal, since the process is performed inside a ferromagnetic duct, and all the time the metal is molten within this duct it shall be contaminated by the iron present in the walls of the container and therefore not only it does not solve the problem, but rather it worsens it.

[0015] There is thus still a need for purifying metals contaminated with impurities via installations and a continuous process in liquid state without contact with other metal elements.

DESCRIPTION OF THE INVENTION

Problems solved by this invention

[0016] This invention is capable of eliminating both exogenous impurities, such as oxides previously formed in the molten metal, for example, as well as endogenous impurities that are dissolved in the metal, the latter being those of greater interest and which shall be affected by a first phase of metallurgical treatment. Thanks to this treatment, the impurities to be eliminated shall become new compounds the electrical conductivity of which shall allow the particles to be eliminated to be affected by an electromagnetic field in an entirely different manner from the base metal.

[0017] In a second physical or separation treatment phase an electromagnetic force generated by linear induction pumps is applied that produced a relative movement between the particle and the metal containing it, which allows this to be an external treatment, without contact and safe, without requiring the insertion of any metal component in contact with the molten metal, thus preventing possible contamination, such as the degradation of these components.

[0018] The metal is always contained within a ceramic channel or duct, never in contact with metallic components, thus preventing contamination from tools during the entire process.

[0019] The purifying process is performed continuously and may be adapted to any melting or maintenance furnace of those commonly used in the foundry industry.

How this is achieved in this invention

[0020] The present invention is established and characterized in the independent claims, while the dependent claims describe additional characteristics thereof.

[0021] The object of the invention is a purification process and installations for molten metals contaminated with impurities that is industrially viable. The technical problem to be solved is to configure the elements of the installations and to establish the steps of the process in order to achieve said objective.

[0022] The invention is based on the capacity of moving a particle with different conductivity from that of the metal containing it, the base metal, with a difference of at least one order of magnitude, referring to the decimal power (10^1), due to the effect of an electromagnetic field. With this measurement of the difference we refer to ten times both lower or greater, or in other words, a difference of more/less ten times (± 10, $10 < difference = x - y < 10$; "x" being the conductivity of the particle and "y" that of the base metal).

[0023] Therefore, the first step in the process consists in transforming an impurity, the metallurgical or metallurgical treatment step, in the event that such impurity is dissolved within the metal matrix, as an endogenous impurity, into a final particle with a conductivity of at least one order of magnitude of difference with that of the metal, relating to the decimal power, for which an initial element or compound is added to the molten metal. Therefore, we achieve an intermetallic compound or final particle that can be affected by the action of an electromagnetic field. Therefore, the process includes first of all a metallurgical or metallurgical treatment step to be performed in a furnace, in which to melt and mix the metal to be purified with the necessary alloying elements.

[0024] And a second physical or separation treatment step, in which the electromagnetic field is produced that acts upon the molten metal and on the particles of different electrical conductivity, wither exogenous or formed in the previous metallurgical step, from the endogenous particles.

[0025] One advantage is that the process is of low cost since these are simple steps that use forces that can be produced economically, using linear induction pumps.

[0026] Another advantage is that it is compatible with existing furnaces, since the installation produces the electromagnetic field in an inductive manner and from outside the existing furnaces, unlike methods requiring the insertion of electrodes to apply direct current.

[0027] Another advantage is that the duct through which the metal flows in this installation is ceramic and external to the furnace, and therefore simple to separate in the case, for example, of an emergency shutdown.

[0028] Another advantage is that the metal is constantly contained in ceramic channels or ducts and reservoirs ceramic, and does not therefore become contaminated with elements from the metal containers and tools, as would happen with iron.

[0029] Another advantage is that it is a selective process, which can eliminate impurities without affecting the remaining elements in the base metal alloy, if present, since it shall only affect those elements affected by the metallurgical treatment.

[0030] Another advantage is that it can be operated continuously and in an automatic manner with the use of commercial components used in automatic installations, such as controls, automatons, etc.

[0031] Another advantage is that the impurities, which usually form a kind of scum or sludge, can be eliminated easily from the container mentioned in Claim 10.

[0032] Another advantage is that it can be designed based on the flow rate requirements characteristic of each industrial installation in which it is implemented.

[0033] Another advantage is it's low maintenance cost, the same as molten metal decanting systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] This specification is supplemented with a set of drawings illustrating the preferred embodiment, which are never intended to limit the invention.

Figure 1 shows a cross section of a section of the second duct with molten metal and a particle on which the existing forces are represented.

Figure 2 shows a diagram with the elements of the installation, showing a first fusion furnace and a second metallurgical treatment furnace. Boxes with dotted lines show the components for the metallurgical treatment step (M) and for the separation treatment step (S) . The curved arrow indicates the sense in which the molten metal travels, which is clockwise.

Figure 3 shows a diagram of the installation in which the first fusion furnace and the second metallurgical treatment furnace of Figure 2 are integrated into a third fusion and metallurgical treatment furnace.

Figures 4, 5 and 6 show respectively microscope photographs of different morphologies of the compound AlSi (FeMn) : in a Chinese character, as a star, as a polygon.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

[0035] An embodiment of the invention based on the figures is provided below.

[0036] The purification process disclosed is capable of eliminating endogenous and exogenous impurities from the contaminated metal, provided that the particles have an electrical conductivity that is different in at least one order of magnitude, with regard to the decimal power, to that of the metal that contains them.

[0037] For this to occur, the electromagnetic device (3), Figures 2 and 3, generates an electromagnetic field (B) on the metal with the impurities, perpendicular to a current density (J) that is induced upon the same metal lengthwise to the second duct (6) through which it circulates, such that it produces an electromagnetic force (F_L), which according to the Lorentz force law should be perpendicular to B and J.

[0038] Figure 1 shows the diagram of forces F_L=JxB that act upon the molten metal.

[0039] The resulting force from all electromagnetic and fluid dynamic forces that act upon a particle contained within the molten metal on which B and J are applied, with a difference in conductivity of at least one order of magnitude with respect to the decimal power and the metal it is contained in, causes a relative movement of that particle with respect to that of the molten metal, in the separation step (S).

[0040] The difference in electric conductivity between the molten metal and the particle to be eliminated shall determine the magnitude and sense of this resulting force, which may be in the same sense as that of the electromagnetic force (F_L) or contrary to it.

[0041] Figure 1 shows in the black circle the particle and the resulting force that acts upon it when the conductivity of the particle is lower than that of the molten metal, in which case it is in an opposite direction to the electromagnetic force (F_L) generated on the metal.

[0042] In the event that the impurities to be eliminated do not show the necessary difference in electrical conductivity or that they are dissolved in the liquid metal, a metallurgical treatment (M) must be performed, which combines such impurities with other elements, thus transforming them into new compounds with an electrical conductivity different to that of the metal to be purified by at least one order of magnitude in decimal power, whereas the metal is still in a liquid state and at an optimal working temperature.

[0043] One option in order to achieve these compounds is to resort to elements between groups IV and VII of the periodic table, namely to eliminate iron, which could be manganese or zirconium.

[0044] Another important aspect is the shape of the compound to be eliminated, since the resulting force is greater the greater the volume/surface ratio of the impurity. Thus, for example, in the case of eliminating iron, adding manganese produces the compound AlSi(FeMn), which also has three different morphologies: as a Chinese character (Figure 4), a star (Figure 5), or a polygon (Figure 6). It has been proven that the most advantageous configuration is that of the polygon, since it has a greater volume/surface ratio.

[0045] Figure 2 shows a diagram of the installation for eliminating impurities in a contaminated metal that includes a first fusion furnace (1) in which said metal can be melted and which is independent from a second furnace (2) for metallurgical treatment (M). An initial element or compound is added to the molten metal that combines with the impurity in order to form an intermetallic compound or final particle with a suitable electrical conductivity. Both furnaces (1, 2) are connected by a first ceramic duct (5).

[0046] After the second furnace (2) there is a second ceramic duct (6) through which the molten metal can travel to the electromagnetic device (3).

[0047] In said electromagnetic device an electromagnetic field is created by means of linear induction pumps, the field lines of which are crosswise to the movement of the fluid contained in the second duct (6). There is thus a resulting force (R) acting upon the final particle that is capable of moving it, separation step (S). The action of the magnetic field is performed where the molten metal circulates; for the sake of simplicity we indicate the corresponding duct, although it could also be a deposit close to the electromagnetic device (3) or even inside it.

[0048] Figure 3 shows the variant in which the first (1) and second (2) furnaces are integrated into a third fusion and metallurgical treatment (M) furnace (9). Obviously, the first connection duct (5) between the first (1) and second (2) furnaces is removed.

[0049] Another option, as shown in Figures 2 and 3, which in order to ensure greater flow rates and efficacy of the process, the configuration includes a boost pump (4) to ensure the required flow rate in the event of a very large installation; form the electromagnetic device (3) exits a third duct (7) that connects to such boost pump (4) from which exits a fourth duct (8) to the corresponding furnace (1, 9). Said boost pump (4), although not shown, may be located anywhere in the installation, even inside any of the furnaces (1, 2, 9), since its function is that inherent to any boost pump, of propelling the fluid passing through it.

[0050] Optionally, the electromagnetic device (3) comprises a ceramic reservoir, not shown, in which the particles containing impurities are deposited separately from the molten metal.

Claims

1. A process of eliminating impurities dissolved in a contaminated molten metal, continuously, such impurities being both exogenous to the molten metal and endogenous to it, **characterized in that** an electromagnetic field (B), generated by linear induction pumps, is applied on the contaminated metal that flows through a second ceramic duct (6) and through which a current density (J) is induced in a longitudinal direction to that of the duct, as a result of the electromagnetic force produced in the metal, Lorentz force (F_L), and the fluid dynamic forces derived from the movement of the metal, a resulting force (R) acts on the particle that causes a relative movement of said particle with respect to that of the molten metal, when the difference in electrical conductivity between the molten metal and the particle is of at least one order of magnitude with respect to the decimal power, said difference in conductivity is achieved in endogenous impurities by creating an intermetallic compound or final particle by the reaction between the impurity to be eliminated and the addition of an initial element or compound in a metallurgical step (M) prior to the application of the electromagnetic field, the separation phase (S).

2. A process according to Claim 1 in which the initial element or compound that combines with the impurity is one selected from between groups 4 and 7 of the periodic table.

3. A process according to Claim 1 in which the exogenous particles to be eliminated are oxides of the base metal.

4. A process according to Claim 2 in which in order to eliminate iron the initial element is manganese or zirconium.

5. A process according to Claim 4 in which the intermetallic compound AlSi(FeMn) is obtained, the particles of which acquire a morphology of a Chinese character, a star and/or a polygon.

6. Installation for eliminating impurities dissolved in a contaminated metal, comprising a first fusion furnace (1) in which said metal can be melted and a second metallurgic treatment (M) furnace (2) in which an initial element or compound can be added to the metal so that it combines with the impurities to be eliminated in order to form an intermetallic compound or final particle, **characterized in that** after the second furnace (2) there is a second ceramic duct (6) through which the molten metal can travel to an electromagnetic device (3) that can create an electromagnetic field via linear induction pumps, the field lines of which are perpendicular to the longitudinal axis of said second duct (6), so that a resulting force (R) acts upon the final particle that may oppose that caused by the electromagnetic field on the fluid, Lorentz force (F_L), and therefore it is carried through said second duct (6) .

7. A installation according to claim 6 wherein both furnaces (1, 2) are connected via a first ceramic duct (5) .

8. A installation according to claim 6 wherein the first and second furnaces (1, 2) are conformed in a single third furnace (9).

9. A installation according to any of the previous claims in which from the electromagnetic device (3) exits a third duct (7) that connects to a boost pump (4) from which exits a fourth duct (8) to the corresponding furnace (1, 9).

10. A installation according to any of the previous claims in which the electromagnetic device (3) comprises a ceramic reservoir in which the particles containing the impurities are gathered separated from the molten metal.

Statement under Art. 19.1 PCT

Differences between the claims as filed and the claims as amended under Art.19 PCT = EP entry:

- claim 1 is modified by replacing the word "liquid" with "molten" so that in said claim only the word "molten metal" appears with reference to the state of the metal; the basis for such modification is found in the Examiner's note that few metals are in the liquid state at room temperature, such as Hg, when the application as filed relates to molten metal: in the background of the invention, in page 1-line 30, page 4-line 4, page 5-line 6; in the description of the invention, in page 5-line 22, page 6-line 5, page 26-line 26, page 7-lines 18 and 28; in the description of the figures, in page 9-lines 17 and 26; in the detailed description, page 10-lines 28 and 32, page 11-lines 2, 5 and 13, page 12-lines 14, 22 and 33, page 13-line 27;

- claim 2 is modified by replacing the Roman numerals "IV" and "VII" by the corresponding Arabic numerals "4" and "7"; the basis for such a modification is in the application as filed, page 11-lines 27 to 30, wherein the option to remove iron using manganese or zirconium as an specification of elements of groups IV and VII is mentioned, when said manganese or zirconium elements are not in those groups but in groups 4 (Ti, Zr, Hf) and 7 (Mn, Tc, Re);

- the rest of the claims remain unchanged.

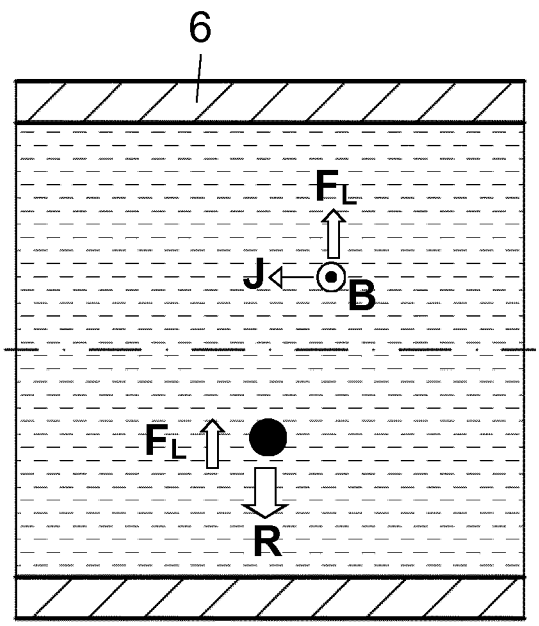

Fig. 1

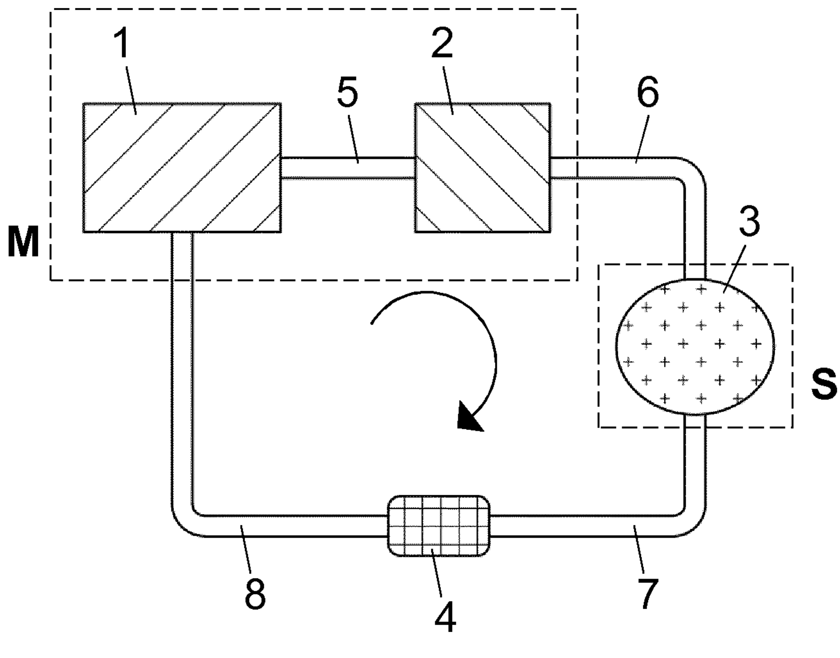

Fig. 2

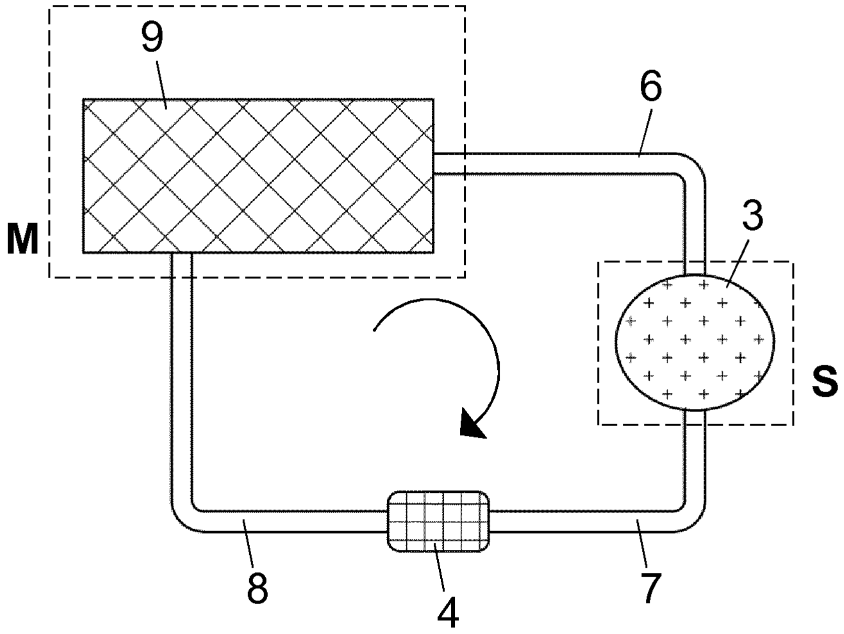

Fig. 3

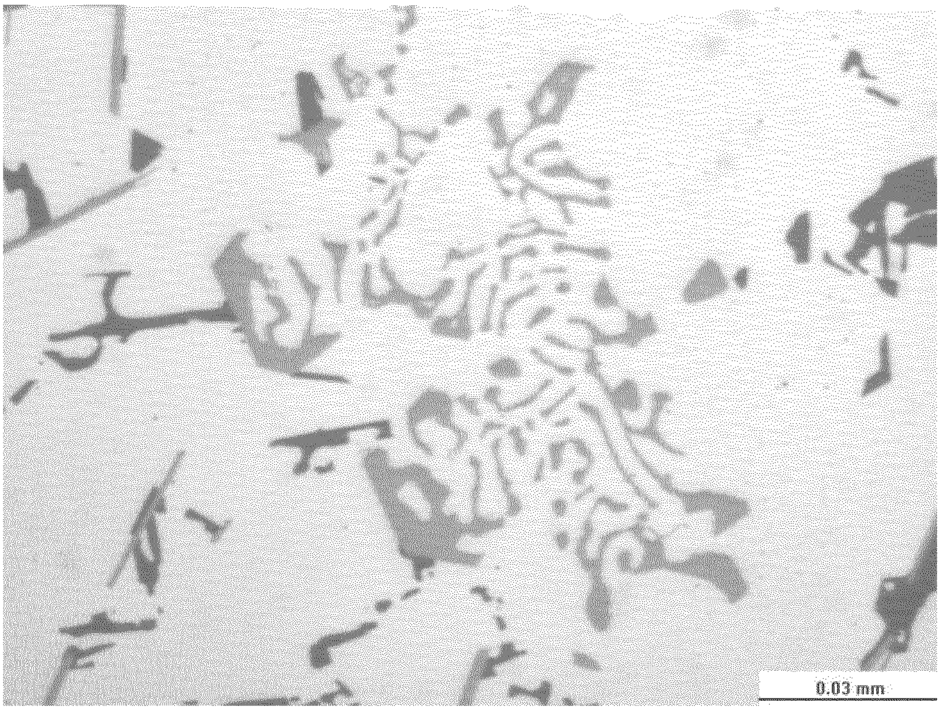

Fig. 4

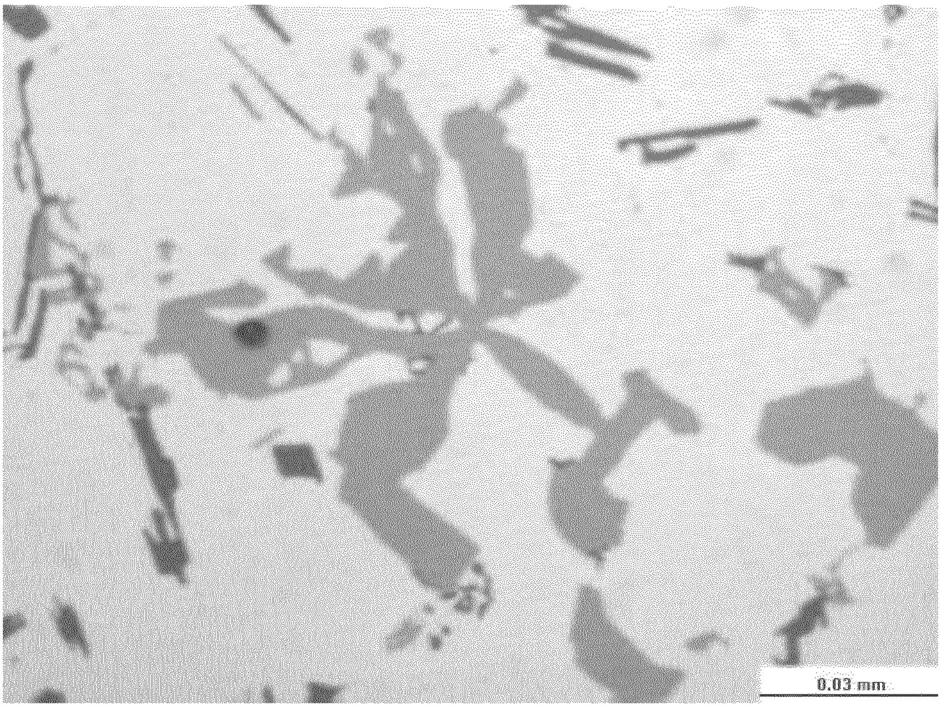

Fig. 5

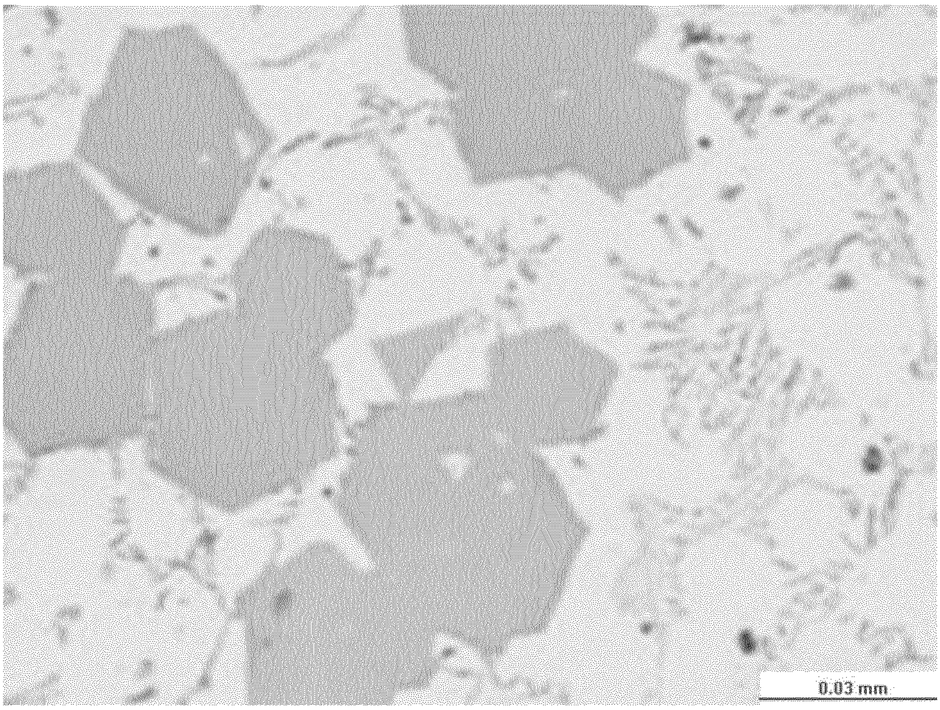

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/ES2016/070618

A. CLASSIFICATION OF SUBJECT MATTER
INV. C22B9/00 C22B21/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Week 199619 Thomson Scientific, London, GB; AN 1996-185239 XP002767642, & JP H08 60263 A (ASAI S) 5 March 1996 (1996-03-05) abstract	1-9
X	DATABASE WPI Week 200274 Thomson Scientific, London, GB; AN 2002-688158 XP002767643, & KR 2002 0036124 A (HANYANG EDUCATIONAL FOUND) 16 May 2002 (2002-05-16) abstract	1-9

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2017	14/03/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Riederer, Florian

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INTERNATIONAL SEARCH REPORT

International application No
PCT/ES2016/070618

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 590 200 B1 (LUDWIG REINHOLD [US] ET AL) 8 July 2003 (2003-07-08) the whole document -----	1-9

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/ES2016/070618

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP H0860263	A	05-03-1996	NONE	
KR 20020036124	A	16-05-2002	NONE	
US 6590200	B1	08-07-2003	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H11229055 B **[0004]**
- WO 2007018243 A **[0013]**

Non-patent literature cited in the description

- **DANIEL LEENOV ; ALEXANDER KOLIN.** Theory of Electromagnetophoresis. I. Magnetohydrodynamic forces experienced by spherical and Symmetrically oriented cylindrical Particles. *The journal of Chemical Physics,* 1954, vol. 22 (4 **[0006]**
- **FUMITAKA YAMAO ; KENSUKE SASSA et al.** Separation of Inclusions in Liquid Metal Using Fixed Alternating Magnetic Field. *Tetsu-to-Hagane,* 1997, vol. 83 (1 **[0007]**
- **NORIHISA WAKI ; KENSUKE SASSA et al.** Magnetic Separation of Inclusions in Molten Metal Using a High Magnetic Field. *Tetsu-to-Hagane,* 2000, vol. 86 (6 **[0007]**