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PRODUCTION OF CLEAN FINE GRAIN STEELS
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6 Claims

ABSTRACT OF THE DISCLOSURE

A method of limiting nonmetallic inclusions and producing fine grain steels in improved ferrous metal alloys wherein a granular compacted iron, aluminum, and niobium composition is introduced into the melt at a predetermined rate.

This invention relates to the making of improved steels and a ferrous alloy and particularly, to a composition for addition to an iron bearing melt to inexpensively provide a clean, fine-grain steel.

Fine grain steels are required in various applications, such as for large diesel engine crankshafts, bull gears, track shoes or links, truck parts, landing gears for airplanes, etc. Great care had to be exercised in every step of the processing in order to pass rigid specifications and to make the steel suitable for withstanding demanding service. Heretofore, it has been necessary to utilize relatively involved and expensive procedure in making steels to meet such requirements. In this connection, it has been customary to utilize electric furnace melts and vacuum degassing operations which made the metal expensive from the standpoint of the user.

It is well known that steels are melted and refined in various types of furnaces, including electric, open hearth, basic oxygen furnaces, with and without vacuum degassing and inert gas utilization. It has been customary to utilize additions, including silicon for the purpose of deoxidizing the melt. In many applications, a maximum grain size of the finished steel is specified. Aluminum has been found to be an easily utilized and a less expensive element for controlling grain size and, in this connection, is usually added to the ladle or after the metal has been poured off from the furnace.

Since aluminum readily picks up oxygen to form alumina and in fact, has been used as the deoxidizing agent, it has been found that it tends to associate itself with silica to form an alumina silicate, i.e., $Al_2O_3 \cdot SiO_2$, or to exist as Al_2O_3 . We have found that these nonmetallics tend to lag or are sluggish in the melt, in the sense that they stay therein and do not fully move into the slag blanket. As a result, they produce inclusions throughout the steel which are readily visible on micrographic inspection and may cause failures. This is the reason why open hearth or oxygen furnace steel has not heretofore been satisfactory for more critical utilizations, such as those above enumerated, although they are much less expensive than more intricate procedures, such as vacuum degassing, electric furnace melting, etc.

It has thus been an object of our invention to solve the problem of eliminating nonmetallic inclusions in steels and particularly, in those requiring a fine grain structure;

Another object of our invention has been to devise a composition which, when added to a melt, will enable the use of some aluminum for producing fine grain without an attendant forming of alumina or alumina silicates;

Another object of our invention has been to develop a procedure for providing a fine grain steel in which utilization may be made of less expensive steel melting and re-

fining methods while, at the same time, effectively limiting nonmetallic inclusions in the ingot as formed;

A further object of our invention has been to devise a composition for addition to a melt that will provide a desired fine grain structure and, at the same time, limit the previous attendant disadvantageous forming of non-metallic inclusions.

These and other objects of our invention will appear to those skilled in the art from the description thereof.

In devising our invention, we discovered that niobium (columbium) could be utilized in controlled amounts as a composition addition with aluminum in such a manner as to control and substantially limit the formation of nonmetallic inclusions, particularly in the nature of alumina, and that a fine grain high quality steel could thus be produced inexpensively whose micrographs show little or no evidence of nonmetallic inclusions. In this connection, we found that it was advisable to add silicon and other deoxidizing elements to the melt separately and ahead of our composition and to provide a composition containing aluminum with niobium in a controlled amount with respect thereto.

We made the discovery that although a silicon oxide does, itself, tend to have a good fast and complete movement from molten metal to the surface, or in other words, into the slag blanket of the melt, that aluminum oxide in the melt which has an affinity to combine with silicon oxide, tends to hold back such movement and cause a lag, such that particles or inclusions are left in the melt and do not reach the surface thereof and thus, the slag blanket.

Instead of the normal 2 pounds of aluminum per ton of melt, we add only about 0.4 of a pound of aluminum per ton and thus, materially reduce the amount that is available for forming Al_2O_3 . Niobium is added usually at the same time as the aluminum to form a refining grain size effect which when combined with the aluminum produces the necessary fine grain. Less aluminum is present than if the effect is to be obtained by aluminum alone, and hence there is less available in the steel for forming Al_2O_3 ; the steel is therefore cleaner. We substitute a proportioned amount of niobium (Cb) for some of the aluminum to obtain the necessary grain size and, in fact, a better grain size than obtained by the use of aluminum alone.

On the other hand, we discovered that the presence of a slight effective amount of niobium when introduced simultaneously with the aluminum has an oxide-forming-inhibiting action on the aluminum, such that the aluminum goes into the melt mostly as a metal that produces a fine grain size and incidentally raises its coarsening temperature by about 100° F. The silicon and other conventional deoxidizers added to the melt are free to carry out their normal actions and purposes without hindrance, while our Al-Cb ferrous metal alloy can function as a grain refiner. As a result, the aluminum is made innocuous from the standpoint of its normally inherent disadvantageous characteristic in the melt from the standpoint of forming an oxide while its good and more favorable characteristics are more effectively retained and utilized.

For the purpose of such a composition utilization, we find that it is advantageous to make up the elements of our composition in package form, so that such package can be directly and easily introduced into the melt in requisite quantity units. In this connection, such elements may be provided in the form of an alloy or preferably, in the form of a compact or briquette and, as an optimum, added to the metal in the ladle. It may be added to the metal in the mold or in the requisite total amount to the metal in the ladle or the mold.

Our composition for trade purposes is marketed as CA-3. It may be made up using about 25 to 50% aluminum metal and about 75 to 50% of ferro-niobium. As an optimum, it may be in the form of an alloy or briquette containing essentially about 40% aluminum metal and about 60% ferro-niobium. The aluminum content which is utilized for grain conditioning, may be within a range having a maximum of about 50% by weight; when the aluminum exceeds this amount, the appearance of Al_2O_3 begins to show in the microetch. Although the aluminum content may be as low as about 25% by weight, we have found that for best results, from the standpoint of fineness of grain, that an optimum is about 40%. Ferro-niobium usually contains by weight about 50% to 60% niobium metal, up to 8% silicon and up to a maximum of about 40% carbon, with the balance iron. A 60% by weight content of ferro-niobium will provide around 36 to 40% by weight of niobium in the composition of the briquette. A good working range of niobium is about 30 to 50% with about 36% being the optimum. Ferro-niobium is a convenient source for the niobium, although iron, alloying and other compatible suitable metals may be added to our composition separately to provide the requisite weights; the remainder or balance will be principally or essentially iron, however.

Although we have tested the addition of niobium in amounts up to 60 or 70%, we find that such amounts are in excess of requirements and do not give any further improvement in results. We have also tested the use of vanadium separately or in combination with our composition, but find that the resultant steel tends to be less clean and there is a tendency for some difficulty in heat treatments. Although minor percentages of silicon are not harmful in our composition, best results as to cleanliness are obtained when the greater proportion of the silicon is added to the melt ahead of our composition. By using a package, such as represented by a briquette of a given weight size of one pound, we have found it relatively easy to control the analysis and to make a product that is easily handled by the steel maker.

We have employed our composition as an addition to the melt in the ladle for steel and ferrous metal alloys produced, both by open hearth and oxygen furnace methods, and have been able to produce carbon and alloy steels of any desired types on a regular production heat basis that have met every test as to cleanliness and grain size, and without the need for vacuum degassing or electric furnace melting practice. Our composition is added to the melt on the basis of about one pound to a ton of the ferrous melt. By way of example, we have produced a grade 1050 steel in an open hearth furnace wherein the charge was 308,880 pounds, the ore constituted 6%, the scrap 46% and the molten metal 48%. The heat was worked with the ore and had a normal carbon drop blocked at .46% carbon. The heat was tapped at 2860° F. and ladle additions of 650 pounds of ferro-manganese, of 1000 pounds of 50% ferro-silicon and of 170 pounds of our composition were made. The tapped metal represented 351,000 pounds and shows an analysis of .52% C, 1.20% Mn, .017% P, .023% S and .27% Si. Ingots produced from such heat were used in the making of 169 crankshafts with no rejections. Such a melt was also produced in a basic oxygen furnace and was utilized in making crankshafts without any rejections.

Bearing steels, alloy steels, such as 4027, 8820 and 2630, all were made using our composition, showing extraordinary and excellent results. We found that we can produce high quality steels employing our invention at a cost of about \$2 per ton as compared to about \$11 per ton for electric furnace melting with vacuum processing.

It is well recognized in the art that if the temperature of a steel is raised above a certain value during working, there is a tendency to coarsen its grain. In this connection, we found that steels produced in accordance with our invention can be raised an additional 100° F. without danger of grain coarsening.

By further way of example, we produced a C-1048, fine grain, hot top silicon killed steel in a 200 ton basic oxygen furnace, employing an all plain carbon scrap-hot metal charge. After the lance was lowered and the ignition started, the usual amounts of burnt lime and spar flux materials were added. The heat was blown with high purity oxygen until the desired end-point carbon and temperature levels were reached, at which point the heat was tapped to a ladle. Calcium, silicon, a recarburizer, 50% ferro-silicon, and high carbon ferro-manganese were added along with our composition or alloy to the metal in the ladle, with our alloy being added on the basis of one pound per ton of melt. Teeming was accomplished in 32 inch by 32 inch BEU molds. The products produced were 4 1/2 inch square, 5 1/2 inch square and 6 inch square billets. The ladle analysis showed about .52% carbon, 1.14% manganese, .011% P, .012% S, .24% Si and .004% Al. The grain size was ASTM 6. Micrographs showed very little, if any, evidence of non-metallic inclusions, as checked by magna flux and sonic tests.

We have found that our composition or compact may be and is preferably made up by utilizing the metals in granular or powdered form and then alloying, compacting or briquetting them to form charging packages.

Although we prefer to use ferro-niobium, since it is readily available, it will be apparent that niobium metal may be used as such in our composition so as to provide a range of about 30 to 50% by weight of the briquette. Major proportions of the composition are represented by iron and aluminum to make up the balance, with incidental impurities. We have found that normal and minor amounts of impurities have no adverse effect on our composition utilization; the silicon content should, as an optimum, be kept down within a maximum of about 10% for best results. Further, our composition may be added to other forms of melts, such as those used in continuous casting, in vacuum degassing and other procedures to assure clean and fine grain ingots.

In continuous casting, there is a necessity for the metal stream to be continuous, with little change in its intensity, otherwise the pressure of the ferro-static head will vary. If such variance is too great, then unfilled sections of the finished billet or bloom will result and the product will be rejected. Such a change in the ferro-static head takes place if the liquid metal stream is reduced in size; this happens if there is a build-up of various solidified materials in the passageway and the nozzle. Because Al_2O_3 is most commonly found in this solidified material, it is necessary to limit the use of aluminum as an addition to the liquid steel. Heretofore, when fine grain steels were to be made, it was necessary to increase the aluminum to 1 to 2 pounds per ton of liquid steel. It is obvious that the high formation of amounts of Al_2O_3 from this practice will soon clog the pouring nozzle. Thus, when fine grain steel is desired by the continuous casting process, our addition may be advantageously used. We get a fine grained steel and no clogging of the passageway or nozzle.

The presence of the controlled amount of niobium in our composition tends to isolate the available amount of aluminum from the standpoint of oxidation and thus, minimize its combination with silicates; also, the niobium has a greater affinity for oxygen pick-up and the characteristic of moving as an oxide rapidly out of the molten metal melt into the slag blanket, before freezing or solidification.

It will be apparent to those skilled in the art that our invention has broad aspects and is not limited to specific applications and mechanism, such as those described, but that various applications, utilizations and adaptations may be made within its scope.

We claim:

1. A method of limiting nonmetallic inclusions in the nature of alumina and alumina silicates and of producing improved fine grain steels and ferrous metal alloys which comprises, providing an iron bearing melt having deox-

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idizers therein, and thereafter introducing a metal composition into such melt at the rate of about one pound of the composition to one ton of the melt which composition comprises: about 25 to 50% by weight of aluminum metal, about 30 to 50% by weight of niobium, and the remainder principally iron with incidental impurities.

2. A method of limiting nonmetallic inclusions in the nature of alumina and alumina silicates and of producing improved fine grain steels and ferrous metal alloys which comprises, providing an iron bearing melt having deoxidizers therein, and thereafter introducing a metal composition into such melt at the rate of about one pound of the composition to one ton of the melt which composition comprises: about 25 to 50% by weight of aluminum metal, and about 75 to 50% by weight of ferro niobium, with incidental impurities.

3. A method as defined in claim 2 wherein the elements of said composition are in granular form and are compacted into a package.

4. A method as defined in claim 2 wherein said composition comprises about 40% by weight of aluminum metal and about 60% by weight of ferro niobium with incidental impurities.

5. A method as defined in claim 2 wherein said composition is added to the iron bearing melt in the ladle, and

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major quantities of silicon are added to the melt before the addition of said composition thereto.

6. A method as defined in claim 2 wherein said composition has a content of about 30 to 50% by weight of niobium.

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