United States Patent Office 3,253,909 Patented May 31, 1966

3,253,909

PROCESSING SILICON STEEL

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No Drawing. Filed Nov. 10, 1964, Ser. No. 410,302
4 Claims. (Cl. 75—129)

The invention relates to a method of refining steel which is suitable for use in the production of grain oriented silicon steel, and in particular is directed to a method of refining the steel in its molten state in order to obtain the desired chemistry, which steel is suitable for the production of grain oriented silicon steel.

Silicon steels as such have been known for quite some time, and grain oriented silicon steels have been in commercial use for at least the past thirty years. Perhaps the greatest research endeavor during the last decade has been concerned with the method of producing grain oriented silicon steels by variations in the processing of the material, both at the hot rolled stage and at the cold rolled stage. Signficant in this respect are the patent to Littmann, 2,599,340, and more recently the patent to Crede et al., 2,867,557. With the advent of the L-D process on a commercial basis, research emphasis has now shifted to the rapid production of grain oriented silicon steels wherein the steels are refined employing the L-D process, as typified by Patent 3,030,203, issued April 17, 1962, in the name of G. E. Hilliard. While various reasons have been advanced for employing the L-D process in the manufacture of steel suitable for use in the production of grain oriented silicon steels, nevertheless this process has not supplanted the open hearth nor the electric furnace as the largest suppliers of metal from which grain oriented silicon steel is manufactured. The method of the present invention can be utilized, no matter where the steel is initially refined, so long as during the meltdown or refining of the steel oxygen is employed to reduce the carbon content to the desired low level.

An object of the present invention is to provide a method for processing steel which is suitable for use in the manufacture of grain oriented silicon steel.

Another object of the present invention is to provide a method for refining steel to obtain the desired chemical composition which can thereafter be adjusted to produce a steel suitable for use in the manufacture of grain oriented silicon steel.

A further object of the present invention is to provide a method whereby the steel can be decarburized to low carbon levels and thereafter alloyed with silicon to produce a steel suitable for use in the production of grain oriented silicon steel.

Other objects of the present invention will become apparent to those skilled in the art when read in conjunction with the following description.

In its broader aspects, the method of the present invention contemplates a process in which steel is refined to a given carbon content, following which the steel is vacuum decarburized. The vacuum decarburization is sequentially followed by the adjustment of the oxygen of the bath, after which the molten metal bath is treated by the addition of an alloying component in order to produce a steel having a silicon content between about 2.5% and about 4% silicon. The molten metal is thereafter cast and may then be employed in the production of grain oriented silicon steel by, for example, either the method of the Crede et al. patent or the Littmann et al. patent.

The method of the present invention contemplates that each of the steps be performed in sequence, and the initial step in the method of the present invention is concerned with the manner in which the steel is produced. Molten

metal is obtained in either the conventional open hearth or in the L-D vessel and the carbon content is adjusted by lancing the heat with oxygen. Preferably, oxygen is added to the melt until the carbon content is within the range between about 0.06% and about 0.08%. While up to about .12% carbon can be tolerated, that is, the steel can be later decarburized to the desired low level through the method of the present invention, nonetheless it is preferred to have a carbon content of about .08% as the starting material for the method of the present invention. Typically, the melt will also contain about 0.03% manganese, about 0.01% silicon, and about 0.02% sulfur at this time. At this point it should be noted that the method of the present invention employs a starting material having a much higher carbon content than is normally present in the starting materials in the now commercially applied processes. As a result thereof, it is apparent that economies are involved in tapping the melts at higher carbon contents since less time in the furnace is required, higher metallic yield from the furnace charge is obtained, and in addition a consequential advantage is also realized in minimizing the refractory problem involved in refining heats to exceedingly low carbon contents in an open hearth furnace, that is, a carbon content of less than 0.03%.

The steel is preferably tapped from the furnace where the carbon content is within the range of between about .06% and .08%. After tapping the heat into a ladle, for example, in a 15-ton heat the tap into the ladle may take about 2½ minutes, the ladle is transported to a vacuum degassing chamber where any of the known vacuum degassing techniques may be employed in order to decarburize the steel. In this respect, the entire ladle may be placed within a vacuum chamber and the vacuum drawn in order to decarburize the steel; that is, at reduced atmospheric pressure the dissolved oxygen will react with the dissolved carbon contained in the steel and liberate carbon monoxide gas which is drawn off by the evacuation system. As an alternative, the steel can be placed in a pony ladle and may be stream degassed into a vacuum chamber wherein a teeming ladle is placed, such stream degassing being effective for producing the same reaction. Both batch and stream degassing are effective for also removing hydrogen which is detrimental to the magnetic characteristics of the grain oriented silicon steel which can be produced from the steel which is subject to the process of the present invention. Irrespective of the particular mechanism which is employed in vacuum treating the material, it is sufficient so long as the steel is subjected to a vacuum of less than about 1 mm. of mercury. Extended periods of time at the subatmospheric pressure are unnecessary since it has been found that prolonged treatment is not significantly more beneficial than treatment for, say, up to about 15 minutes while subjected to said vacuum conditions. In practice, 15 tons have been decarburized after seven minutes, the decarburization being effective for reducing the carbon content from about 0.22% to 0.002%. Other experiments have indicated that in less than ten minutes 15 tons of steel can be decarburized from 0.056% to 0.0031%. It is to be noted, however, that the starting material in these instances has been less than about 0.06% carbon. Where, however, higher carbon contents are present in the starting material, that is, carbon contents up to about .12%, it may be necessary to add additional oxygen to that already contained as a dissolved component within the molten metal bath, and such oxygen may be introduced by any of the well-known methods in order to obtain decarburization to a value of less than about 0.03% carbon at the end of the vacuum treatment. Success has been had where the vacuum chamber employed has been about ten feet high and about eleven feet three inches in diameter, which

was sufficient to accommodate a teeming ladle containing 15 tons of molten meal.

Following the subjection of the molten metal to the vacuum conditions, it has been found necessary to recharge oxygen into the molten metal bath where the steel is employed in the production of grain oriented silicon steel. Initially, the molten metal bath had a dissolved oxygen content of between about 0.09% and 0.12%; however, during the vacuum treatment the amount of oxygen which remained dissolved in the bath was drastically reduced by reason of its reaction with the dissolved carbon and the formation of carbon monoxide. Since the oxygen plays an indirect role in the development of the final texture of the grain oriented silicon steel, it has been found necessary to recharge oxygen into the molten metal. This is usually accomplished by adding oxygen in the form of mill scale, ore, gas or any other compatible form to the melt to obtain a final oxygen content of between about 0.07% and about 0.12%. This amount of oxygen must be supplied to the bath prior to the addition of any silicon thereto in order to obtain the proper conditions for the formation of the deoxidation product having a proper particle size. That is to say, if the particle size of the deoxidation product is too small, the fine particles do inhibit secondary grain growth. As a result, a substantially equiaxed structure is obtained which is characterized by the lack of a preferred orientation exhibiting poor magnetic characteristics. Where, on the other hnad, a suitable oxygen content is present within the steel, it has been found that the deoxidation product which results from the addition of silicon in order to obtain a silicon content within the steel of about 3.25%, has a large particle size, and these particles can grow and coalesce with the result that the preferred secondary grain growth required for cube-on-edge texture development is not impaired. Consequently, it is necessary to finally adjust the oxygen content of the steel to obtain a dissolved oxygen content of between about 0.07% and about 0.12%. When the steel has an oxygen content within the desired range and a correspondingly low carbon content, ferrosilicon or silicon in any other suitable form may be added to the molten metal bath in order to obtain the desired silicon level within the range of between about 2.5% and about 4%. While the preferred analysis of the silicon is between about 2.9% and 3.5%, reproducible results are readily obtained when about 3.25% silicon is present within the steel as cast.

The method of the present invention, when employing the steps in the sequence set forth hereinbefore, is effective for producing a product which can be successfully employed in the production of grain oriented silicon steels. Advantages are obtained through the use of this process in that regardless of which method of hot rolling and cold rolling-heat treatment process is employed, the steel, when processed according to the method of the present invention, will produce substantially equivalent magnetic characteristics. However, great advantage is obtained in that certain of the magnetic characteristics are improved through the elimination of detrimental amounts of hydrogen which can adversely affect these magnetic characteristics. In addition, obvious economies are obtained since the steel can be tapped at high carbon contents, thereby reducing furnace time as well as refractory wear, less oxygen is consumed during manufacture, and higher metallic yields are obtained. As thus produced to about .014" gauge, the steel, when manufactured employing the process of the present invention and processed to the form of grain oriented silicon steels, will exhibit a watt loss of about .66 watt per pound when measured at 15 kilogausses and at a frequency of 60 cycles per second, as well as a permeability of about 1800 when measured at 10 oersteds. It is to be understood that in the method

of the present invention other alloying additions may be made at the same time that the silicon content is increased in the molten metal to obtain a silicon content of about 3.25%, such alloying additions including the adjustment of the manganese content to about 0.065% and the adjustment of the sulfur content to about 0.020%.

The method of the present invention thus effects obvious economies and utilizes normal mill equipment without employing extraordinary personal technology in order to produce a steel having the desired properties and which is suitable for use in the production of grain oriented silicon steels.

We claim:

1. In the process of producing steel suitable for use in the production of grain oriented silicon steel, the steps comprising, refining the molten metal to obtain a carbon content of less than 0.10%, subjecting the molten metal to a vacuum of less than 1 mm. of mercury, introducing oxygen to the vacuum treated molten metal to obtain a dissolved oxygen content of between 0.07% and about 0.12%, adding silicon to produce a steel having about 3.25% silicon therein, and thereafter casting the steel.

2. In the process of producing steel suitable for use in the production of grain oriented silicon steel, the steps comprising, refining the molten metal to obtain a carbon content of less than 0.10%, subjecting the molten metal to a vacuum of less than 1 mm. of mercury to remove the carbon content of the molten metal to less than 0.005%, removing the molten metal from the vacuum influence, introducing oxygen to the vacuum treated decarburized molten metal to obtain a dissolved oxygen content of between 0.07% and about 0.12%, adding silicon to produce a steel having about 3.25% silicon therein, and thereafter casting the steel.

3. In the process of producing steel suitable for use in the production of grain oriented silicon steel, the steps comprising, refining molten metal to obtain a steel containing an analysis of less than 0.10% carbon, about 0.01% silicon, about 0.03% manganese, about 0.020% sulfur and the balance essentially iron, subjecting the molten metal to a vacuum within the range 50 and 500 microns to remove the hydrogen and decarburize the molten metal, removing the molten metal from the vacuum, introducing oxygen to the vacuum treated molten metal to obtain a dissolved oxygen content of between 0.07% and about 0.12%, adding silicon to produce a steel having about 3.25% silicon therein, and thereafter casting the steel.

4. In the process of producing steel suitable for use in the production of grain oriented silicon steel, the steps comprising, refining molten metal to obtain a steel containing less than 0.10% carbon, about 0.01% silicon, about 0.03% manganese, about 0.02% sulfur and the balance essentially iron, removing the hydrogen contained in the molten metal and decarburizing the molten metal by subjecting the molten metal to a vacuum of less than 1 mm. of mercury, removing the molten metal from the vacuum, introducing oxygen to the vacuum treated molten metal to obtain a dissolved oxygen content of between 0.07% and about 0.12%, adding silicon to produce a steel having about 3.25% silicon therein, and thereafter casting the steel.

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