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(54) NON-ORIENTED ELECTRIC STEEL PLATE WITHOUT CORRUGATED FAULT AND PRODUCTION METHOD THEREOF

(57) A non-oriented electrical steel sheet without corrugated defect and a manufacturing method thereof is provided, the weight percentage of the chemical composition of the non-oriented electrical steel sheet is that C is no more than 0.005%, Si is 1.2-2.2%, Mn is 0.2-0.4%, P is no more than 0.2%, S is no more than 0.005%, Al is 0.2-0.6%, N is no more than 0.005%, O is no more than 0.005%, and a balance substantially being Fe, a slab can be obtained by hot metal preprocessing, smelting with converter, RH refining, and continuous casting and pouring, wherein a secondary cooling water amount is controlled, the water flowrate of cooling water is controlled to 100-190 1/min, the average superheat of liquid steel in the continuous casting process is controlled to 10-45°C ,the slab is heated and hot rolled; wherein the furnace tap temperature of the slab is 1050-1150 °C , the temperature difference between random two points in the length direction when the slab is heated, is lower than 25 °C , the hot rolling process includes a rough rolling process and a planishing process, the entry temperature in the planishing process is no lower than 970 °C ; the finished non-oriented electrical steel sheet is obtained by acid pickling, cold rolling, annealing and coating. No corrugated defect can be accomplished by controlling the cooling speed of the slab in continuous casting and pouring process, the temperature difference in the length direction of the slab in the heating furnace, and by controlling the temperature drop before planishing the slab.

EP 2 623 626 A1

Description

Technical Field

[0001] The present invention relates to a non-oriented electrical steel sheet and a manufacturing method thereof, especially to a middle steel grade non-oriented electrical steel sheet without corrugated defect, which has an excellent magnetism, and a manufacturing method thereof.

Description of the Prior Art

[0002] For a non-oriented electrical steel sheet having a high extent of silicon, in the surface of a finished strip, accidented waves, similar to corrugations, appear in a direction of rolling, which is generally called "corrugated defect". This defect will reduce a stacking coefficient of the finished strip notably, making the magnetism of the finished strip worse and the electrical resistance between insulating film layers decreased, thus reducing the service performance and life of terminal production. Therefore, almost all of users have a definite demand that a finished strip having corrugated defects is not allowed.

[0003] The mechanism of the generation of the corrugated defects may be explained as follows: the equiaxed crystal ratio in the slab is low, whereas the columnar crystal is gross and growing. The growing direction of the columnar crystal <001>, which is the normal direction of (001), is the direction in which the heat flux gradient is the largest. In such a hot rolling process, the gross columnar crystal can not thoroughly break due to dynamic recovery and slow re-crystallization. However, the slab columnar crystals are easy to grow in the direction of heat flux, and form gross columnar crystals having a certain orienting relation, resulting in inhomogeneous deformations in a rolling process, the center in sheet thickness is fiber texture primarily after hot rolling process, and austenite and ferrite have no phase transition in subsequent process, and will not re-crystallize in the following cold rolling and annealing process, which does not make the homogeneity of the texture eliminated, and leaving behind to the finished product, finally forming accidented corrugated defects.

[0004] The conventional methods for treating corrugated defects are mainly as follows: by utilizing electromagnetic stirring, the equiaxed crystal ratio in the slab may be improved, for example, in Japanese Patent Application Laid-open No. 49-39526; by adding the contents of carbon and manganese into steel, the phase transiting temperature in hot rolling process may be reduced, for example, in Japanese Patent Application Laid-open No. 48-49617, Chinese Patent Application CN10127519, CN1548569 and CN101139681 etc.; by utilizing low temperature pouring, the equiaxed crystal ratio in the slab may be improved, for example, in Japanese Patent Application Laid-open No. 53-14609 and No. 2-192853; by increasing furnace tap temperature of the slab, adjusting heating-up speed of the slab, controlling end-rolling temperature in a planishing process, and controlling the degree of reduction of the first and the last pass in the hot rolling process, the strip may re-crystallize sufficiently, for example, in Japanese Patent Application Laid-open No. 49-27420, No. 49-38813, No. 53-2332, No. 61-69923, Chinese Patent Application CN 1611616 and CN1548569; and by utilizing a normalized process, the strip may re-crystallize sufficiently, for example, in Japanese Patent Application Laid-open No. 61-127817, etc.

[0005] The above-mentioned methods may be used solely or simultaneously depending on technology, cost and the demands on the magnetism of the finished product and surface. These methods have characteristics and requirements described below, respectively.

[0006] By utilizing electromagnetic stirring, the equiaxed crystal ratio in the slab may be improved. This method utilizes electromagnetic stirring, the columnar crystals may break under electromagnetic force, and therefore, the effect thereof is the most effective. This method will remarkably reduce the columnar crystal ratio in the slab and improve the equiaxed crystal ratio in the slab, especially when utilizing electromagnetic stirring twice or more, and will effectively prohibit a secondary columnar crystal in the central area as well. The main disadvantage of this method is that the stirring effect depends on the content of silicon in steel and the electromagnetic stirring number. As to the steel grade that has a low content of silicon, after primary electromagnetic stirring, the equiaxed crystal in the slab is relatively easy to conglomerate, grow, and form a gross columnar crystal once again, therefore, it is necessary to utilize electromagnetic stirring twice or more and control the solidification effect of liquid steel strictly. Also, the manufacturing cost of the electromagnetic stirring is high.

[0007] By adding the contents of carbon and manganese into steel, the phase transiting temperature in hot rolling process may be reduced. This method is mainly conducted by adding the contents of carbon and manganese in steel, a phase transition occurs to the slab in the heating up and hot rolling process, accelerating dynamic recovery and re-crystallization, so as to eliminate gross deformation crystal grains. The main disadvantage of this method is that it is necessary to decarburize in annealing process, which is easy to produce inner oxide layer and inner nitration layer, making the magnetism of steel worse.

[0008] By utilizing low temperature pouring, the equiaxed crystal ratio in the slab may be improved. This method decreases the columnar crystal ratio in the slab and improves the ratio that the equiaxed crystal accounts for mainly by reducing the superheat of the liquid steel in the pouring process. The main disadvantage of this method is that it is demanded that the superheat scope of the liquid steel is very low, which is hard to control effectively, and which affects the normal control in the continuous casting process.

[0009] By increasing furnace tap temperature of the slab, adjusting heating-up speed of the slab, controlling end-rolling temperature in a planishing process, and controlling the degrees of reduction of the first and the last pass in the hot rolling process, the strip may re-crystallize sufficiently. This method is mainly conducted by increasing the furnace tap temperature of the slab, adjusting the heating-up speed of the slab, controlling the end-rolling temperature in a planishing process, and controlling the degrees of reduction of the first and the last pass in the hot rolling process, the gross columnar crystals in the slab may break, so as to prohibit the development of the gross deformation crystal grains as well as to make the strip re-crystallized sufficiently. The main disadvantage of this method is that increasing the furnace tap temperature of the slab will make the impurities such as MnS, AIN etc., solutionized intensively, thus make the magnetism of the finished strip worse. Meanwhile, in order to ensure the re-crystallization effect of the strip, the contents of impurity elements such as S, N etc., in steel are strictly demanded. Also, improving the degrees of reduction of the first and the last pass in the hot rolling process is restricted by self-capability of a rolling mill.

[0010] By utilizing the normalized process, the strip may re-crystallize sufficiently. When the single cold rolling method is utilized, the steel grade that has a high content of silicon needs to carry out the normalized process, one of the objects is to increase the re-crystallizing ratio in the hot rolling sheet, so as to avoid the generation of the corrugated defects. The main disadvantage of this method is that the manufacturing cost is very high, which is not applied in low or middle steel grade silicon steel of which the additional value is relatively low.

Disclosure of the Invention

[0011] The object of the present invention is to provide a non-oriented electrical steel sheet without the corrugated defect and a manufacturing method thereof. The manufacture of a middle steel grade non-oriented electrical steel sheet without corrugated defect can be accomplished, which has advantages of easy operation, low cost, energy conservation and environmental protection, and excellent magnetism, by strictly controlling the cooling speed of the slab in continuous casting and pouring process, the temperature difference in the length direction of the slab in the heating furnace, and by controlling the temperature drop before planishing the slab. Meanwhile, the casting speed of the slab in continuous casting and pouring process is normal, so that the relatively high superheat of the liquid steel can be maintained, and the relatively low furnace tap temperature of the slab, and normal end-rolling temperature and coiling temperature etc., can be maintained in the hot rolling and steel reheating process, so that the strip in the hot rolling process does not need to carry out a normalized process.

[0012] In order to obtain the above-described object, the technical solution of the present invention is that

a middle steel grade non-oriented electrical steel sheet without the corrugated defect, wherein the weight percentage of the chemical composition thereof is that C is no more than 0.005%, Si is 1.2-2.2%, Mn is 0.2-0.4%, P is no more than 0.2%, S is no more than 0.005%, Al is 0.2-0.6%, N is no more than 0.005%, O is no more than 0.005%, and a balance substantially being Fe and inevitable impurities.

[0013] In the sub-designs of the present invention,

[0014] C is no more than 0.005%.C is an element for strongly inhibiting the growth of crystal grains, which is easy to result in the increase of iron loss of a strip, producing the serious magnetic aging. Meanwhile, C may further widen γ phase, and increase the transition amount between α phase and γ phase when in the normalized process, so as to reduce Acl point notably, and to fine crystallizing structure. Therefore, C is necessary to be controlled to no more than 0.005%.

[0015] Si is 1.2%-2.2%.Si is an effective element for increasing the electrical resistivity of the steel. If the content of Si is lower than 1.2%, the electromagnetic performance of the steel is not good, whereas if the content of Si is higher than 2.2%, phase change will not occur in the hot rolling process, and the cold-working performance is not good.

[0016] Al is 0.2%-0.6%.Al is an effective element for increasing the electrical resistivity of the steel. If the content of Al is lower than 0.2%, the electromagnetic performance is not stable, whereas if the content of Al is higher than 0.6%, the smelting and pouring process will become difficult, thus increasing the manufacturing cost.

[0017] Mn is 0.2%-0.4%.Like the elements Si and Al, Mn may increase the electrical resistivity of the steel, as well as improve the surface state of the electrical steel, so it is necessary to add no less than 0.2% of Mn. While the content of Mn is higher than 0.4%, the smelting and pouring process will become difficult, thus increasing the manufacturing cost.

[0018] P is no more than 0.2%.Adding some phosphorus into steel can improve the workability of steel sheet, but if the content of phosphorus is more than 0.2%, it instead makes the cold rolling workability of steel plate deteriorated.

[0019] S is no more than 0.005%.If the content of S is more than 0.005%, the deposition amount of sulfide such as MnS, will increase greatly, thus strongly preventing crystal grains growing and making iron loss worse.

[0020] N is no more than 0.005%.If the content of N is more than 0.005%, the deposition amount of nitride such as AIN, will increase greatly, thus strongly preventing crystal grains growing and making iron loss worse.

[0021] O is no more than 0.005%.If the content of O is more than 0.005%, the impurity amount of oxidate such as Al_2O_3, will increase greatly, thus strongly preventing crystal grains growing and making iron loss worse.

[0022] A method for manufacturing a non-oriented electrical steel sheet without corrugated defect of the present invention comprises the following steps:

1) the weight percentage of the chemical composition of non-oriented electrical steel sheet is that C <0.005%, Si is 1.2-2.2%, Mn is 0.2-0.4%, P <0.2%, S <0.005%, Al is 0.2-0.6%, N <0.005%, O <0.005%, and a balance substantially being Fe and inevitable impurities, in accordance with the above chemical composition, a slab is obtained by hot metal preprocessing, smelting with converter, RH refining, and continuous casting and pouring, wherein a secondary cooling water amount is controlled, the water flowrate of cooling water is controlled to 100-190 l/min, the average superheat of liquid steel in the continuous casting process is controlled to 10-45 °C ;

2) the slab is heated and hot rolled;

the furnace tap temperature of the slab is 1050-1150 °C , the temperature difference between the random two points in the length direction when the slab is heated, is lower than 25 °C , the hot rolling process includes a rough rolling process and a planishing process, the entry temperature in the planishing process is no lower than 970 °C ;

3) the finished non-oriented electrical steel sheet is obtained by acid pickling, cold rolling, annealing and coating.

[0023] The middle steel grade non-oriented electrical steel sheet without corrugated defect of the present invention and the manufacturing method thereof comprise the following steps:

The average superheat of liquid steel in the pouring process is controlled to 10-45 °C . In the continuous casting and pouring process, the water flowrate of cooling water is adjusted to 100-190 1/min, so as to improve the equiaxed crystal ratio in the slab, avoiding columnar crystals in the slab gross and growing.

[0024] Relatively low temperature, which affects the surface temperature of the slab so as to make the strip re-crystallized insufficiently, should be avoided. Therefore, the temperature difference between the random two points in the length direction when the slab is heated, is controlled to be lower than 25 °C; the temperature difference between the watermark points of the slab is limited within 25 °C , meanwhile the residence time of the slab in after-firing zone should be no less than 45 min, so as to ensure uniform heating, making the temperatures of both surfaces of the slab close.

[0025] The furnace tap temperature of the slab can be reduced to no higher than 1150 °C , avoiding the impurities such as MnS, AlN etc., solutionized intensively, which thus making the magnetism of the finished strip worse. Hot rolling sheet is rolled to have a thickness of 2.0mm-2.8mm.Before the rough rolling process and the planishing process, hot tops are respectively utilized to thermal insulate the slab and the intermediate billet, the entry temperature in the planishing process is controlled to no lower than 970 °C so as to facilitate sufficient recrystallization, and the end-rolling temperature is controlled to about 850 °C , the coiling temperature is controlled to about 600 °C.

[0026] The hot rolling is rolled to thick strip that has a thickness of 0.5mm, and then is annealed continuously in a dry atmosphere. In the continuous annealing process, the electromagnetic performance of the steel is further improved by warming up the finished strip quickly in a preheating zone, in which the heat-up speed is no less than 1000°C/min, and by controlling the atmosphere mode in furnace.

[0027] Basing on the controlling demand on the composition of the present invention, after the extent of silicon in the steel exceeds 2.2%, when an electromagnetic stirring is not utilized or a slightly electromagnetic stirring is utilized, since the content of silicon is relatively high, the columnar crystal in the slab is growing and gross, and the electromagnetic stirring force is not enough to break the columnar crystals, and a part of the broken columnar crystals will still polymerize and grow once again, so that making the ratio of fine equiaxed crystals in the slab is relatively low while the ratio of gross and growing columnar crystals is relatively high. Therefore, it is necessary to improve electromagnetic stirring intensity so as to control the corrugated defects in the surface of the finished strip.

[0028] In the present invention, when the content of silicon is less than 2.2%, the content of silicon does not affect the growth of the columnar crystal as greatly as the cooling speed of the slab, therefore, the water flowrate of cooling water in the continuous casting process can be adjusted to reduce the heat flux gradient of the slab in the growing direction of the columnar crystal, so that the ratio of gross and growing columnar crystals can be reduced effectively. Further, considering the temperature of the slab at the location where the slab contacts the roller table is relatively low in the slab heating process, which affects the re-crystallization of the fiber texture in the interior of the slab, not making the homogeneity of the texture eliminated and leaving behind to the finished product, therefore, it is necessary to strictly control the temperature of the watermark point of the slab. The main reason on improving the entry temperature in the planishing process is to facilitate the break and elimination of the columnar crystals in the rolling process and improve the re-crystallization ratio of the fiber texture in the hot rolling strip.

[0029] Also, since the content of silicon is no more than 1.2%, the phase change from γ phase to α phase in the hot rolling process is sufficient, the corrugated defects will not occur in the surface of the subsequent finished product.

[0030] Also, if two or three pairs of electromagnetic stirring rolls are utilized, the columnar crystals in the slab may be broken due to highly electromagnetic stirring force, as possible as to transit to fine equiaxed crystals, so as to improve the equiaxed crystal ratio in the slab greatly; or the phase change from γ phase to α phase happens in the interior of the slab by increasing the furnace tap temperature of the slab in the heat process greatly, meanwhile the re-crystallization of the slab is improved by utilizing high temperature status to enlarge the re-crystallizing structure in the interior of the slab. Except for the great increasement in the aspect of equipment investment and energy consumption, it is more important that the electromagnetic stirring technology is hard to match the superheat of the liquid steel precisely, if the superheat of the liquid steel is controlled improperly, the controlling effect of the electromagnetic stirring is not stable, which is hard to obtain the expecting effect; and by increasing the furnace tap temperature of the slab, the heating load distribution in the heating furnace will forward, making high temperature time zone relatively long, which affects the magnetism of the finished strip. This method is easy to result in mass defect at the edge of the strip with respect to high-silicon steel grade.

[0031] Under the condition of the special chemical composition of the present invention, the water flowrate of cooling water in the continuous casting process can be adjusted to reduce the heat flux gradient of the slab in the growing direction of the columnar crystal, so that the ratio of gross and growing columnar crystals can be reduced effectively. It is more important that this method is substantially affected by the change in the superheat of the liquid steel, so the range of application is relatively wide. Meanwhile, the adjustment on the water flowrate of cooling water is very simple and controllable, so the difficulty in implementation is low, the stability is good. Further, the equipment load may be reduced by utilizing lower furnace tap temperature of the slab, avoiding the deposition of fine impurities in the steel and affecting the magnetism of final product. If the lower temperature is used to heat the slab, the temperature at the watermark points in the slab may be adjusted to increase re-crystallizing ratio of the fiber texture of the slab in the hot rolling process, and to improve the homogeneity of the texture of the slab in the hot rolling strip, which facilitates to the corrugated defects in the surface of the finished strip.

Brief Description of Drawings

[0032]

Fig. 1 is a schematic view of the relation between the water flowrate of the cooling water and the equiaxed crystal ratio in the slab.

Fig. 2 is a schematic view of the relation between the entry temperature in the hot rolling and planishing process and the incidence of the corrugated defects in a finished product.

Fig. 3 is a schematic view of the relation between the furnace tap temperature of the slab and the magnetism of the finished product.

Fig. 4 is a picture of a metallographic structure of a strip in hot rolling process corresponding to a watermark point temperature of 20 °C.

Fig. 5 is a picture of a metallographic structure of a strip in hot rolling process corresponding to a watermark point temperature of 35 °C.

Detailed Description of the Invention

[0033] Hereinafter, the present invention will be described in connection with the embodiments and drawings.

First Embodiment

[0034] The chemical composition of the tundish liquid steel in the continuous casting process is controlled as follows: C is 0.001%, Si is 1.22%, Mn is 0.25%, P is 0.02%, S is 0.003%, Al is 0.33%, N is 0.001%, O is 0.004%, and a balance substantially being Fe and inevitable impurities. The average superheat of the liquid steel is 34.6 °C, the casting speed is 1.07m/min, the water flowrate of the cooling water is 185 l/min, the temperature drop speed of the slab is 11.6min/°C, the surface temperature of the slab at the outlet of a caster is 710 °C and the equiaxed crystal ratio is 43%.In the heating furnace, the temperature difference between the watermark points is 22 °C, the residence time in after-firing zone of the slab is 46 minutes. The rolling process will be carried out after heating for 3h at 1125°C, the temperature at the inlet in planishing process is 978 °C, the end-rolling temperature is 856 °C and the coiling temperature is 567 °C .The hot rolling sheet is rolled to 0.5mm thickness of strip with the single cold rolling method, and then is annealed continuously in a dry atmosphere. Corrugated defects are not generated in the surface of the finished strip, the iron loss is 4.743 W/kg, and the magnetic induction is 1.727T.

Second Embodiment

[0035] The chemical composition of the tundish liquid steel in the continuous casting process is controlled as follows: C is 0.002%, Si is 1.42%, Mn is 0.30%, P is 0.06%, S is 0.002%, Al is 0.25%, N is 0.002%, O is 0.002%, and a balance substantially being Fe and inevitable impurities. The average superheat of the liquid steel is 31.4 °C, the casting speed is 1.04m/min, the water flowrate of the cooling water is 175 l/min, the temperature drop speed of the slab is 9.6 min/°C, the surface temperature of the slab at the outlet of a caster is 680 °C and the equiaxed crystal ratio is 57%.In the heating furnace, the temperature difference between the watermark points is 22 °C, the residence time in after-firing zone of the slab is 48 minutes. The rolling process will be carried out after heating for 3h at 1135 °C, the temperature at the inlet in planishing process is 973 °C, the end-rolling temperature is 853 °C and the coiling temperature is 563 °C.The hot rolling sheet is rolled to 0.5mm thickness of strip with the single cold rolling method, and then is annealed continuously in a dry atmosphere. Corrugated defects are not generated in the surface of the finished strip, the iron loss is 3.130 W/kg, and the magnetic induction is 1.741 T.

Third Embodiment

[0036] The chemical composition of the tundish liquid steel in the continuous casting process is controlled as follows: C is 0.002%, Si is 1.49%, Mn is 0.49%, P is 0.02%, S is 0.003%, Al is 0.59%, N is 0.001%, O is 0.002%, and a balance substantially being Fe and inevitable impurities. The average superheat of the liquid steel is 28.7 °C , the casting speed is 0.99m/min, the water flowrate of the cooling water is 189 l/min, the temperature drop speed of the slab is 8.7 min/°C, the surface temperature of the slab at the outlet of a caster is 660°C and the equiaxed crystal ratio is 63%.In the heating furnace, the temperature difference between the watermark points is 24 °C, the residence time in after-firing zone of the slab is 53 minutes. The rolling process will be carried out after heating for 3h at 1102°C, the temperature at the inlet in planishing process is 983 °C, the end-rolling temperature is 854 °C and the coiling temperature is 575 °C.The hot rolling sheet is rolled to 0.5mm thickness of strip with the single cold rolling method, and then is annealed continuously in a dry atmosphere. Corrugated defects are not generated in the surface of the finished strip, the iron loss is 3.559 W/kg, and the magnetic induction is 1.737T.

Fourth Embodiment

[0037] The chemical composition of the tundish liquid steel in the continuous casting process is controlled as follows: C is 0.001%, Si is 2.12%, Mn is 0.25%, P is 0.01%, S is 0.002%, Al is 0.36%, N is 0.001%, O is 0.004%, and a balance substantially being Fe and inevitable impurities. The average superheat of the liquid steel is 31.2°C, the casting speed is 0.95m/min, the water flowrate of the cooling water is 173 l/min, the temperature drop speed of the slab is 13.2 min/°C, the surface temperature of the slab at the outlet of a caster is 680°C and the equiaxed crystal ratio is 59%. In the heating furnace, the temperature difference between the watermark points is 20 °C, the residence time in after-firing zone of the slab is 48 minutes. The rolling process will be carried out after heating for 3h at 1097°C , the temperature at the inlet in planishing process is 972°C, the end-rolling temperature is 844°C and the coiling temperature is 583°C . The hot rolling sheet is rolled to 0.5mm thickness of strip with the single cold rolling method, and then is annealed continuously in a dry atmosphere. Corrugated defects are not generated in the surface of the finished strip, the iron loss is 2.833 W/kg, and the magnetic induction is 1.726T.

Comparative Example

[0038] The chemical composition of the tundish liquid steel in the continuous casting process is controlled as follows: C is 0.001%, Si is 1.47%, Mn is 0.32%, P is 0.02%, S is 0.003%, Al is 0.25%, N is 0.002%, O is 0.002%, and a balance substantially being Fe and inevitable impurities. The average superheat of the liquid steel is 28.9°C, the casting speed is 1.03m/min, the water flowrate of the cooling water is 257 l/min, the temperature drop speed of the slab is 17.4 min/°C, the surface temperature of the slab at the outlet of a caster is 580°C and the equiaxed crystal ratio is 28%. In the heating furnace, the temperature difference between the watermark points is 37 °C , the residence time in after-firing zone of the slab is 41 minutes. The rolling process will be carried out after heating for 3h at 1153°C, the temperature at the inlet in planishing process is 947°C, the end-rolling temperature is 847°C and the coiling temperature is 567°C . The hot rolling sheet is rolled to 0.5mm thickness of strip with the single cold rolling method, and then is annealed continuously in a dry atmosphere. The percentage of the generation of corrugated defects in the surface of the finished strip is as high as no less than 90%, the iron loss is 3.273 W/kg, and the magnetic induction is 1.736T.

[0039] Fig. 1 shows the relation between the water flowrate of the cooling water and the equiaxed crystal ratio in the slab. As seen in Fig.1, on the premise of not utilizing an electromagnetic stirring, by decreasing the water flowrate of the cooling water and strictly controlling it to no more than 190 1/min, the equiaxed crystal ratio in the slab is improved remarkably. In the embodiments, the equiaxed crystal ratio in the slab may be controlled when the superheat of the liquid steel is relatively high. In the fourth embodiment of these embodiments, when the water flowrate of the cooling water is 173 1/m, the equiaxed crystal ratio in the slab is up to 59%, in the comparative example, when the water flowrate of the cooling water is 257 1/min, the equiaxed crystal ratio in the slab is only 28%. Also, in the third embodiment, the control of the equiaxed crystal ratio in the slab is better, up to 63%.

[0040] Fig. 2 shows the relation between the entry temperature in the hot rolling and planishing process and the incidence of the corrugated defects in a finished product. It is indicated in accordance with the statistical results that by increasing the entry temperature in the hot rolling and planishing process and up to more than 970°C, because the re-crystallizing ratio of the fiber texture of the slab in the hot rolling process is increased remarkably, the incidence of the corrugated defects in the finished strip may be reduced greatly. In the comparative example, the entry temperatures in the hot rolling and planishing process of most of strips are less than 970°C, the percentage of the generation of corrugated defects in the surface of the finished strip is as high as no less than 90%. In several embodiments, most of the entry temperatures in the hot rolling and planishing process of strips are more than 970°C, corrugated defects are not generated in the surface of the finished strip, respectively.

[0041] Fig. 3 shows the relation between the furnace tap temperature of the slab and the magnetism of the finished product. The higher the furnace tap temperature of the slab is, the worse the magnetism of the finished product is.

[0042] Figs. 4 and 5 are metallographic structures of strips in hot rolling process corresponding to different watermark point temperatures. The watermark point temperatures are all less than 25 °C in the first to fourth embodiments, so re-crystallizing structures of the strips in the hot rolling process are very homogeneous, the fiber textures disappear completely, whereas in the comparative example, the temperature at the watermark point is as high as 37 °C, the fiber texture of the strip in the hot rolling process is clear, which is hard to re-crystallized in the period of the subsequent cold rolling and annealing process, not being able to destroy the homogeneity of the structures and leaving behind to the finished product, finally forming accidented corrugated defects.

Claims

1. A non-oriented electrical steel sheet without corrugated defect, wherein the weight percentage of the chemical composition thereof is that C <0.005%, Si is 1.2-2.2%, Mn is 0.2-0.4%, P <0.2%, S <0.005%, Al is 0.2-0.6%, N <0.005%, O <0.005%, and a balance substantially being Fe and inevitable impurities.

2. A method for manufacturing a non-oriented electrical steel sheet without corrugated defect of Claim 1, comprising the following steps:

   1) the weight percentage of the chemical composition of non-oriented electrical steel sheet is that C <0.005%, Si is 1.2-2.2%, Mn is 0.2-0.4%, P <0.2%, S <0.005%, Al is 0.2-0.6%, N <0.005%, O <0.005%, and a balance substantially being Fe and inevitable impurities, in accordance with the above chemical composition, a slab is obtained by hot metal preprocessing, smelting with converter, RH refining, and continuous casting and pouring, wherein a secondary cooling water amount is controlled, the water flowrate of cooling water is controlled to 100-190 1/min, the average superheat of liquid steel in the continuous casting process is controlled to 10-45°C;
   2) the slab is heated and hot rolled;
   wherein the furnace tap temperature of the slab is 1050-1150°C, the temperature difference between the random two points in the length direction when the slab is heated, is lower than 25°C, the hot rolling process includes a rough rolling process and a planishing process, the entry temperature in the planishing process is no lower than 970 °C ;
   3) the finished non-oriented electrical steel sheet is obtained by acid pickling, cold rolling, annealing and coating.

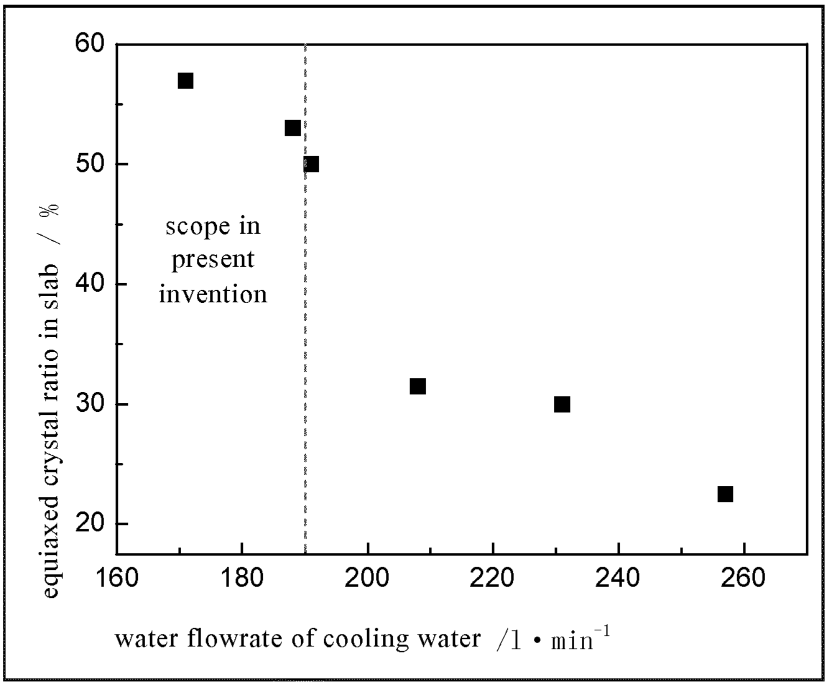
60
50
40
30
20
160
180
200
220
240
260
scope in present invention
equiaxed crystal ratio in slab / %
water flowrate of cooling water /l • min-1

Fig. 1

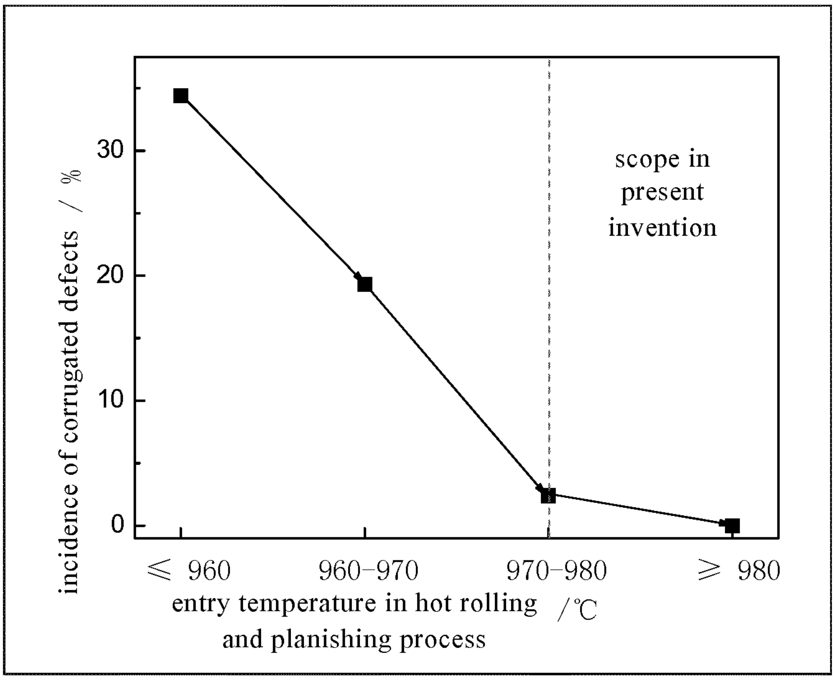
30
20
10
0
≤ 960
960-970
970-980
≥ 980
scope in present invention
incidence of corrugated defects / %
entry temperature in hot rolling and planishing process /℃

Fig. 2

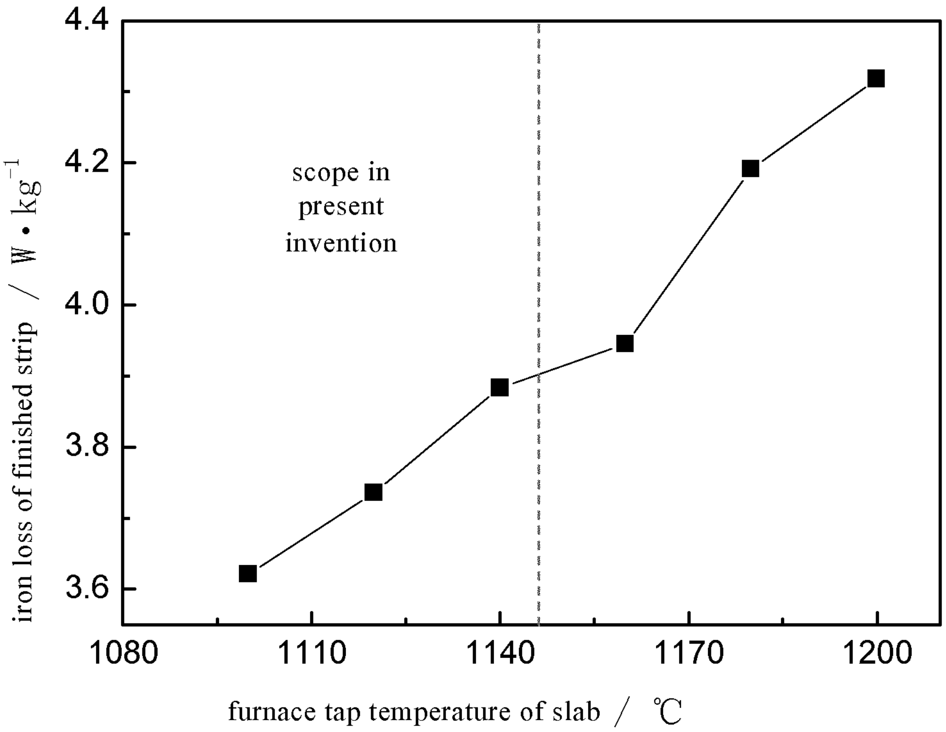
4.4
4.2
4.0
3.8
3.6
iron loss of finished strip / W • kg^{-1}
scope in
present
invention
1080
1110
1140
1170
1200
furnace tap temperature of slab / ℃

Fig. 3

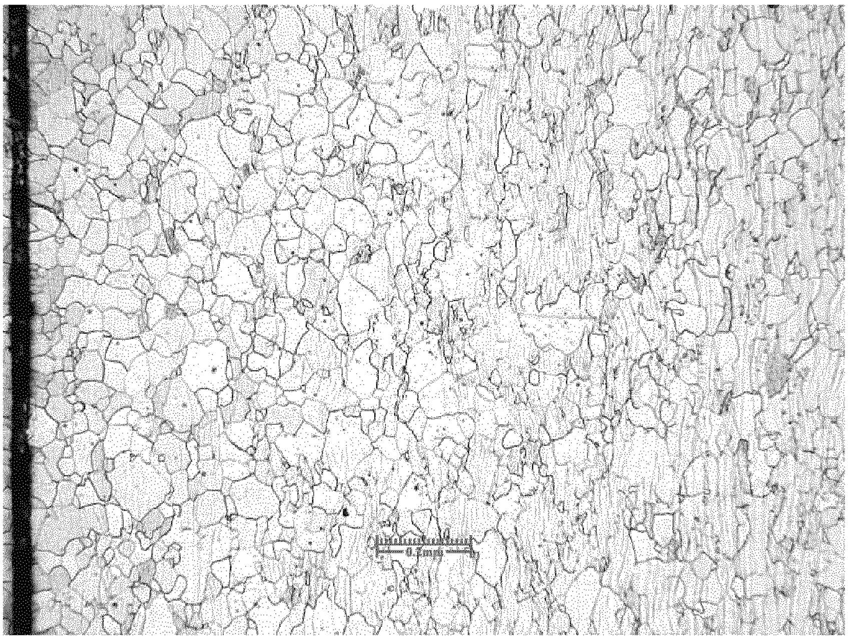

Fig. 4

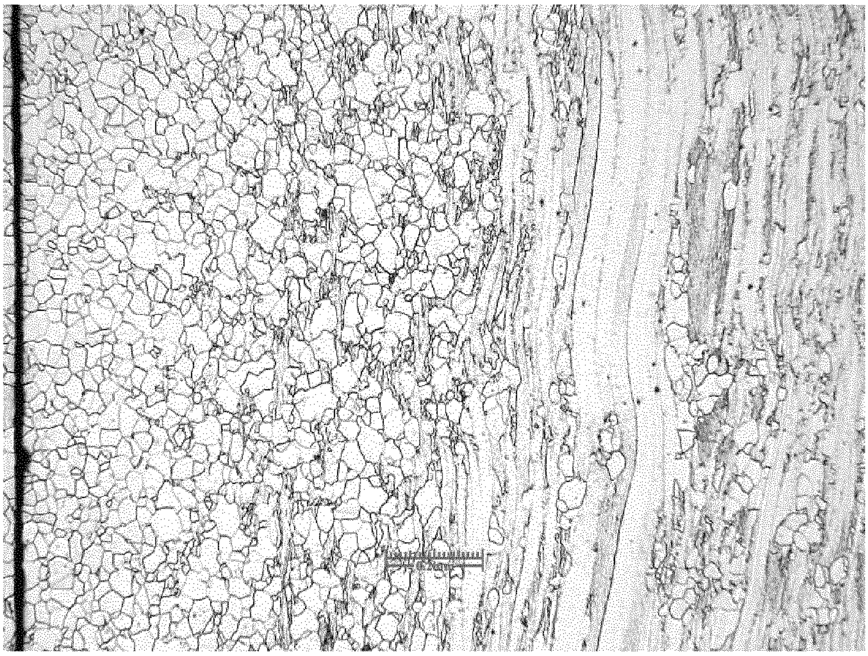

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No. PCT/CN2011/072766

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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)

IPC：C21D 8, C22C 38

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)

CNPAT, CNKI, WPI, EPODOC, non directional，silicon steel，non oriented，electric+ steel, magnetic steel, corrugated faul, cooling water, degree of superheat, carbon , c, silicon, si, manganese, mn, aluminium, aluminum, al

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN1611616A(BAOSHAN IRON & STEEL CO LTD)04 May 2005（04.05.2005） Description, pages 1-2, example 2	1-2
X	CN1796015A(BAOSHAN IRON & STEEL CO LTD)05 Jul. 2006（05.07.2006）Description, page 1, example 3	1-2
X	CN1887512A(BAOSHAN IRON & STEEL CO LTD)03 Jan.2007（03.01.2007）table 1-3	1-2
X	WO2006068399A1（POSCO et al.）29 Jun. 2006（29.06.2006）table 1-2	1-2
X	CN100999050A(BAOSHAN IRON & STEEL CO LTD)18 Jul. 2007（18.07.2007） table 1-3	1-2

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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
04 Jul.2011(04.07.2011)	**21 Jul. 2011 (21.07.2011)**

Name and mailing address of the ISA/CN
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/072766

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO03097884A1(THYSSEN KRUPP STAHL AG et al.)27 Nov. 2003(27.11.2003) whole document	1-2

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/072766

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CN1796015A	05.07.2006	none	
CN1887512A	03.01.2007	CN100446919C	31.12.2008
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/072766

Continuation of:second sheet A.CLASSIFICATION OF SUBJECT MATTER：
C22C38/06 (2006.01)i
C21D8/12 (2006.01)i
C21D8/02 (2006.01)i

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REFERENCES CITED IN THE DESCRIPTION

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- JP 61069923 A **[0004]**
- CN 1611616 **[0004]**
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