(12) STANDARD PATENT (11) Application No. AU 2021218136 B2
(19) AUSTRALIAN PATENT OFFICE

(54) Title
PEARLITE STEEL RAIL WITH RAIL HEAD HARDENED LAYER HAVING UNIFORM HARDNESS GRADIENT AND PREPARATION METHOD THEREOF

(51) International Patent Classification(s)
C21D 9/04 (2006.01) ***C22C 38/04*** (2006.01)
C21D 1/02 (2006.01) ***C22C 38/44*** (2006.01)
C21D 6/00 (2006.01) ***C22C 38/46*** (2006.01)
C22C 38/02 (2006.01)

(21) Application No: **2021218136** (22) Date of Filing: **2021.08.19**

(30) Priority Data

(31) Number	(32) Date	(33) Country
202011119410.X	**2020.10.19**	**CN**

(43) Publication Date: **2022.05.05**
(43) Publication Journal Date: **2022.05.05**
(44) Accepted Journal Date: **2023.02.02**

(71) Applicant(s)
PanGang Group Panzhihua Iron & Steel Research Institute Co., Ltd.

(72) Inventor(s)
LI, Ruoxi;DENG, Yong;YUAN, Jun;YANG, Dawei

(74) Agent / Attorney
Michael Buck IP, PO Box 78, Red Hill, QLD, 4059, AU

(56) Related Art
CN 104561816 A
CN 111485174 A

2021218136 19 Aug 2021

Abstract

The present disclosure relates to the technical field of steel rail production, and discloses a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient and a preparation method thereof. The method comprises the successively performed steps of smelting with a revolving furnace or an electric furnace, refining with a LF furnace, RH or VD vacuum treatment, continuous casting to obtain steel billets, subjecting the steel billets to rolling, heat treatment and processing the steel rail, wherein the heat treatment is a multi-stage cooling process, and the chemical components of the steel rail are controlled, the steel rail comprises: at least one of 0.65-0.85% of C, 0.1-1% of Si, 0.1-1.5% of Mn, less than or equal to 0.03% of P, less than or equal to 0.03% of S, 0.01-0.2% of Cr, 0.005-0.15% of Ni, 0.001-0.3% of Mo and 0.002-0.2% of V, and the balance of Fe and inevitable impurities. The rail head part of the steel rail manufactured with the method has a deep hardened layer with a depth more than 25mm, and has an uniform hardness gradient.

To be published with FIG. 1.

2021218136 19 Aug 2021

Accompanying Drawings

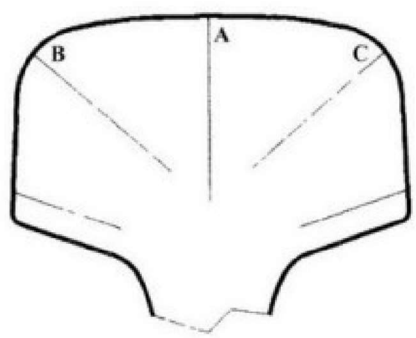

FIG. 1

2021218136 19 Aug 2021

PEARLITE STEEL RAIL WITH RAIL HEAD HARDENED LAYER HAVING UNIFORM HARDNESS GRADIENT AND PREPARATION METHOD THEREOF

FIELD

[0001] The present disclosure relates to the technical field of steel rail production, in particular to a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient and a preparation method thereof.

BACKGROUND

[0002] The railway industry of China is operating in a high-speed development stage, the existing passenger-cargo mixed transportation lines gradually reduce the operation of passenger trains along with an increase of the dedicated passenger transport lines, its operation has transformed into taking freight transportation as the dominant service, in the meanwhile, the dedicated freight transportation lines have also developed towards the trend of heavy load, the overall trend of the freight transportation lines is a development towards the directions of high freight volume, heavy axle and high traffic density. The trend has put higher requirements on the service performance and service life of the steel rails on the line, the high efficiency and safety of the railway freight transportation can be ensured only by

2021218136 19 Aug 2021

improving the quality and performance of the steel rails.

[0003] At present, in order to improve the service performance and service life of the steel rail, the main solution of the passenger-cargo mixed transportation line and the dedicated freight transportation line is to adopt a heat-treated pearlite steel rail with high performance, the higher wear resistance and contact fatigue resistance is obtained by improving the strength and hardness of the steel rail thereof, so as to reduce the abrasion speed of the steel rail and the occurrence of damages such as surface cracks, peeling and chipping.

[0004] In recent years, the means for enhancing hardness of the pearlite steel rail by the steel rail manufactures at home and abroad mainly comprises the steps of carrying out an accelerated cooling on a rail head of the steel rail by an off-line or on-line heat treatment mode, so as to refine the pearlite structure of a part of the rail head of the steel rail and obtain higher strength and hardness by means of refining the crystal grains, the related patent technologies are specified as follows:

[0005] CN110468632 has a tile of invention "Rail for straight-curve transition section and a production method of rail", it discloses that the rail is provided with three hardness zones from a rail head to a rail head corner area, wherein the three hardness zones have different hardness, the first hardness zone has a lowest hardness, the second hardness zone has high hardness, and the third hardness zone has the highest hardness, the steel rail

2021218136 19 Aug 2021

having different hardness in each area is obtained by using different accelerated cooling strengths during the on-line heat treatment, so as to improve the service life and safety factor of the steel rail in the straight-curve transition section. However, the characteristic of different hardness in each area of the rail head in the steel rail obtained in the patent is only distributed from the surface to a shallow hardened layer, and the abrasion condition of the steel rail after a long-term use is still not optimistic.

[0006] CN104060075 has a title of invention “Heat treatment method for improving depth of hardened layer of steel rail”, it discloses a steel rail heat treatment method for increasing depth of hardened layer of steel rail by using rolling waste heat in an online heat treatment mode to perform multistage accelerated cooling on the steel rail, the heat treatment method comprises the steps of naturally cooling the steel rail after finish rolling until the center temperature of a rail head tread is 660-730°C, then carrying out two accelerated cooling stages with different cooling speeds, subjecting the steel rail to an air cooling to room temperature, such that the rail head part can obtain a deep hardened layer with a thickness exceeding 25mm, the position which is 25mm below the surface layer of a rail head has the hardness value equal to that of the surface layer of the rail head, a wear test is performed to prove that the wear resistance of the steel rail in a continuous wear process under long-term service can be improved. However, the patent does not consider that there is a large hardness

2021218136 19 Aug 2021

difference between the high hardness area and the unhardened area during the actual service period of the steel rail, the rail part with a large hardness difference is prone to generate defects such as cracks under the impact of train wheels during its service life in the line, the defects will impose an adverse influence on the safe service of the steel rail.

[0007] CN102220545 has a title of invention "High-carbon and high-strength heat treated steel rail with high wear resistance and plasticity and manufacturing method thereof", it discloses a high-carbon and high-strength heat treated steel rail meeting the use requirements of heavy load railways, the steel rail comprises the following chemical components in percentage by weight: C：0.80%～1.20%、Si：0.20%～1.20%、Mn：0.20%～1.60%、Cr：0.15%～1.20%、V：0.01%～0.20%、Ti：0.002%～0.050%、P≤0.030%、S≤0.030%、Al≤0.010%、N≤0.0100%and the balance of iron and inevitable impurities; carrying out online heat treatment after rolling, carrying out an accelerated cooling on the rail head and the rail bottom to 400-500°C, and then carrying out air cooling to room temperature. The tensile strength of the rail head of the steel rail produced by the patent is more than 1,330MPa, the hardness of the rail head is more than 380HB, and the depth of a hardened layer is more than 25 mm. However, the steel rail produced by the patent has high content of alloy elements such as Cr and Ti, high production cost and poor welding performance of the steel rail, the accelerated cooling process and equipment used herein are complex, thus it is difficult to promote the process.

[0008] In the relevant patents for improving hardness of the pearlite steel rail at present, a part of patents can improve the hardness of a surface layer or an internal hardened layer of the steel rail, but there is a certain gap between the obtained steel and the actual application requirement of the rail line; although some of the steel rails disclosed in some patents have a deep hardened layer in the rail head, both the chemical components and the production process of the steel rails are complex, which is not conducive to popularization and application of said patents.

SUMMARY

[0009] The present disclosure aims to solve the problems in the prior art concerning a large hardness difference between the high hardness area and the unhardened area during the actual service period of the steel rail, the rail part with a large hardness difference is prone to generate cracks under the impact of train wheels during its service life in the line, high production cost, the complex production process of the steel rails, and poor welding performance of the steel rail, and provides a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient and a preparation method thereof.

[0010] In order to achieve the above objects, a first aspect of the present disclosure provides method for preparing a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient, the method comprises the successively performed steps of smelting with a revolving furnace or an electric furnace, refining with a LF furnace, RH or VD vacuum treatment, continuous casting to obtain steel billets, subjecting the steel billets to rolling, heat treatment and machining the steel rail;

[0011] wherein the heat treatment is a multi-stage cooling process, and specifically comprises the following steps:

[0012] (1) first stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling is within a range of 760-900°C, subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head to an accelerated cooling treatment for 50-150 seconds at a cooling rate of 2-6°C/s;

[0013] (2) second stage cooling: subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail obtained after step (1) to an accelerated cooling treatment for 20-60 seconds at a cooling rate of 1-5°C/s;

[0014] (3) third stage cooling: subjecting the cooled steel rail obtained after step (2) to an air cooling to room temperature;

[0015] controlling the chemical components of the steel rail, the steel rail

2021218136 19 Aug 2021

comprises the following chemical components in percentage by weight: at least one of 0.65-0.85% of C, 0.1-1% of Si, 0.1-1.5% of Mn, less than or equal to 0.03% of P, less than or equal to 0.03% of S, 0.01-0.2% of Cr, 0.005-0.15% of Ni, 0.001-0.3% of Mo and 0.002-0.2% of V, and the balance of Fe and inevitable impurities.

[0016] Preferably, the steel rail comprises the following chemical components in percentage by weight: at least one of 0.68-0.82% of C, 0.2-0.7% of Si, 0.6-1.2% of Mn, less than or equal to 0.025% of P, less than or equal to 0.02% of S, 0.05-0.15% of Cr, 0.005-0.1% of Ni, 0.001-0.2% of Mo and 0.02-0.1% of V, and the balance of Fe and inevitable impurities.

[0017] Preferably, a cooling medium used in the heat treatment is water mist and/or compressed air.

[0018] Preferably, the continuous casting is a bloom billet protection continuous casting.

[0019] Preferably, the steel billet is descaled by using high pressure water before subjecting the steel billet to rolling.

[0020] Preferably, the rolling is carried out in an universal rolling mill.

[0021] Preferably, the air cooling is performed on a walking beam cooling bed.

[0022] Preferably, the processing course comprises: straightening the steel rails by using a horizontal and vertical composite straightening machine.

[0023] A second aspect of the present disclosure provides a pearlite steel

2021218136 19 Aug 2021

rail with a rail head hardened layer having an uniform hardness gradient prepared with the aforementioned method, wherein the running surface of the steel rail has a Brinell hardness within a range of 360-400 HB; the rail head part of the steel rail has a hardened layer with a depth more than 25mm, and when an inner depth of the rail head increases for every 5mm, the Brinell hardness of the hardened layer decreases by 3 ~ 6 HB.

[0024] Preferably, the steel rail has a tensile strength larger than 1,200MPa and an elongation rate greater than or equal to 10%.

[0025] The present disclosure adopts the methods of controlling the chemical components of the steel rail and the heat treatment process, the manufactured and produced pearlite steel rail has an uniform hardness gradient without the need of adding a plurality of micro-alloy elements, the running surface of the steel rail has a Brinell hardness within a range of 360-400 HB; the rail head part of the steel rail has a deep hardened layer with a depth more than 25mm, and deep hardened layer has an uniform hardness gradient, when an inner depth of the rail head increases for every 5mm, the Brinell hardness of the hardened layer decreases by 3-6 HB on average, the deep hardened layer can be matched with the abrasion process and the work hardening of the steel rail during the long-term service, thereby reduce the abrasion speed of the steel rail and the occurrence of surface defects such as cracks, peeling and chipping of the steel rail, improve the service performance and the service life of the steel rail,

2021218136 19 Aug 2021

enhance the safety of train operation, and the preparation method is simple and easy to operate.

BRIEF DESCRITION OF THE DRAWING

[0026] FIG. 1 is a schematic diagram of the section hardness measurement position of the rail head in the test example.

DETAILED DESCRPITION

[0027] The following content describes in detail the specific embodiments of the present disclosure with reference to the drawing. It should be understood that the specific embodiments detailed herein only serve to explain and illustrate the present disclosure, instead of imposing a limitation thereto.

[0028] The terminals and any value of the ranges disclosed herein are not limited to the precise ranges or values, such ranges or values shall be comprehended as comprising the values adjacent to the ranges or values. As for numerical ranges, the endpoint values of the various ranges, the endpoint values and the individual point values of the various ranges, and the individual point values may be combined with one another to produce one or more new numerical ranges, which should be deemed have been specifically disclosed herein.

[0029] A first aspect of the present disclosure provides a method for

2021218136 19 Aug 2021

preparing a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient, the method comprises the successively performed steps of smelting with a revolving furnace or an electric furnace, refining with a LF furnace, RH or VD vacuum treatment, continuous casting to obtain steel billets, subjecting the steel billets to rolling, heat treatment and processing;

[0030] wherein the heat treatment is a multi-stage cooling process, and specifically comprises the following steps:

[0031] (1) first stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling is within a range of 760-900°C, subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field corner of the rail head and two rail head corners of the rail head to an accelerated cooling treatment for 50-150 seconds at a cooling rate of 2-6°C/s;

[0032] (2) second stage cooling: subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail obtained after step (1) to an accelerated cooling treatment for 20-60 seconds at a cooling rate of 1-5°C/s;

[0033] (3) third stage cooling: subjecting the cooled steel rail obtained after step (2) to an air cooling to room temperature;

[0034] controlling the chemical components of the steel rail, the steel rail

2021218136 19 Aug 2021

comprises the following chemical components in percentage by weight: at least one of 0.65-0.85% of C, 0.1-1% of Si, 0.1-1.5% of Mn, less than or equal to 0.03% of P, less than or equal to 0.03% of S, 0.01-0.2% of Cr, 0.005-0.15% of Ni, 0.001-0.3% of Mo and 0.002-0.2% of V, and the balance of Fe and inevitable impurities.

[0035] The reasons for limiting the content of the main chemical elements of the steel rail according to the present disclosure are described in detail below:

[0036] Carbon (C) is the most important and cheapest element for obtaining desirable comprehensive mechanical property of the pearlite steel rail and promoting pearlite transformation of the steel rail. When the content of C is less than 0.65%, the proper strength, hardness and the wear resistance of the steel rail cannot be ensured under the production process disclosed by the present disclosure; when the content of C is more than 0.85%, the steel rail has excessive strength parameter, too low toughness and plasticity and excessively high proportion of carbide under the production process of the present application, thereby affecting the fatigue performance of the steel rail and having an adverse effect on the safe use of the steel rail; thus the carbon content in the present disclosure is limited within a range of 0.65-0.85%.

[0037] The main functions of Silicon (Si) in steel reside in suppressing the formation of cementite and being used as a solid solution strengthening element, increasing hardness of the ferrite matrix, and improving the strength and hardness of steel. When the content of Si is less than 0.10%, the solid solution amount is low, so that the strengthening effect is not obvious; when the Si content is more than 1.00%, the steel is prone to generate a local segregation, the toughness and plasticity of steel will be reduced, the safe use of the steel rail is adversely affected. Therefore, the Si content in the present disclosure is defined within a range of 0.10-1.00%.

[0038] Manganese (Mn) is indispensable for improving the strength of ferrite and austenite in steel. When the Mn content is less than 0.10%, it can hardly achieve the effect of increasing the hardness of carbide thereby increasing the strength and hardness of steel; when the content of Mn is more than 1.50%, it will coarsen the crystal grain size, and obviously lower the toughness and plasticity of steel; in addition, Mn has a significant influence on the diffusion of C in steel, an abnormal structure such as bainite or martensite may be generated in the Mn segregation region, and the welding performance of the steel rail is affected. Therefore, the Mn content in the present disclosure is defined within a range of 0.10-1.50%.

[0039] Chromium (Cr) is used as a carbide forming element, can form various carbides with carbon in steel; moreover, Cr can be used for uniformly distributing carbide in steel, reducing the size of carbide and improving the wear resistance of the steel rail. When the Cr content is less than 0.01%, the hardness and the proportion of the formed carbide are

2021218136 19 Aug 2021

lower; when the Cr content is more than 0.20%, the hardenability of the steel rail is too high, the steel rail is prone to generate harmful bainite and martensite structures, the steel rail cannot be ensured to be a pearlite structure, and the safe use of the steel rail is adversely affected. Therefore, the Cr content in the present disclosure is limited to a range of 0.01-0.20%.

[0040] Phosphorus (P) and sulfur (S) are impurity elements which cannot be completely removed from the steel rail. P will perform segregation at the grain boundary of the steel rail structure, so that the toughness of the steel rail is seriously reduced; S is easy to form MnS inclusions in steel, which is harmful to the wear resistance and contact fatigue resistance of the steel rail. Therefore, the content of P in the present disclosure shall be controlled below 0.030%; the content of S shall be controlled below 0.030%.

[0041] The main role of Nickel (Ni) in steel is a solid solution strengthening element, increasing the ferrite matrix hardness to improve the strength and hardness of pearlite steel rails. When the Ni content is less than 0.005%, its effect is small, and cannot produce the solid solution strengthening effect; when the Ni content is more than 0.15%, the toughness of the ferrite phase in the steel will be decreased, resulting in a reduction in the fatigue resistance of the steel rail. Therefore, the N content in the present disclosure is limited to a range of 0.005-0.15%.

[0042] The primary functions of Molybdenum (Mo) in steel reside in

2021218136 19 Aug 2021

improving the equilibrium transformation temperature of pearlite steel, increasing the supercooling degree and enhancing the effect of refining the pearlite lamella subjected to an accelerated cooling, so as to improve hardness of the steel rail. When the Mo content is less than 0.001%, the effect of improving the supercooling degree is small, it cannot make contribution to improving hardness of the steel rail; when the Mo content is more than 0.30%, it results in a decrease in the phase transition rate of the pearlite structure, and it is prone to produce a martensite structure which adversely affects the toughness and plasticity of the steel rail. As a result, the Mo content in the present disclosure is defined within a range of 0.001-0.30%.

[0043] Vanadium (V) is a precipitation strengthening element in pearlite steel, forms carbonitride in the cooling process of the steel rail, and improves the strength and hardness of the steel rail, thereby enhancing wear resistance of the steel rail. When the content of V is less than 0.002%, the precipitation strengthening degree is too small to play a desired role; when the content of V is more than 0.20%, its capability of improving the strength and the hardness of the steel rail is reduced, and excessive precipitation strengthening effect may cause excessive precipitated phases in steel and have negative effect on the toughness of the steel rail. Therefore, the V content in the present disclosure is limited within a range of 0.002-0.20%.

2021218136 19 Aug 2021

[0044] In a preferred embodiment, the steel rail comprises the following chemical components in percentage by weight: at least one of 0.68-0.82% of C, 0.2-0.7% of Si, 0.6-1.2% of Mn, less than or equal to 0.025% of P, less than or equal to 0.02% of S, 0.05-0.15% of Cr, 0.005-0.1% of Ni, 0.001-0.2% of Mo and 0.02-0.1% of V, and the balance of Fe and inevitable impurities.

[0045] The inventors of the present disclosure have found through a large amount of researches that:

[0046] (1) In regard to the first stage cooling: when the temperature of the running surface of the steel rail is within a range of 760-900°C, the steel rail shall be subjected to an accelerated cooling at a high temperature stage so as to inhibit precipitation of proeutectoid ferrite or proeutectoid cementite in the steel rail and obtain the steel rail with uniform hardness gradient; in addition, because the starting temperature of the cooling process is high, a larger cooling rate is required to ensure the stable performance of the interior of the rail head, and the cooling rate needs to be controlled within a range of 2.0-6.0°C/s;

[0047] (2) In regard to the second stage cooling: after the steel rail is subjected to the first-stage accelerated cooling for 50-150 seconds, the internal temperature of the rail running surface of the steel rail is still within a range of 500-600°C, the phase change of the steel rail is still performed in the temperature range, if the accelerated cooling is stopped, the heat of

2021218136 19 Aug 2021

the part of steel rail, which is not subjected to the accelerated cooling, can be quickly diffused to the rail head, the phase change cooling rate is reduced, such that the hardness of the final product steel rail is reduced, the hardness gradient is adversely affected, and the effect of a heat treatment process is insufficient; in the meanwhile, it is required to carry out the accelerated cooling of the second stage, and considering that the cooling rate of the central part of the rail head is lower than that of the surface at this time, if the cooling rate is adopted continuously at the same level as that of the first stage, the risk of abnormal structures on the surface is high, and it is difficult to obtain the uniform hardness gradient, so that the cooling intensity and the cooling time shall be reduced to obtain the pearlite steel rail with an uniform hardness gradient.

[0048] (3) In regard to the third stage cooling: after the first two cooling stages are finished, the internal temperature of the rail head of the steel rail shall be within a range of 400-450°C, the phase change of the steel rail has been completed at the moment, there is not obvious significance to continue the accelerated cooling process, the steel rail can be subjected to an air cooling to room temperature to facilitate the subsequent process treatment.

[0049] In a specific embodiment, a first stage accelerated cooling in step (1) may be performed when the temperature of the running surface of the steel rail after the finish final rolling is 760°C, 780°C, 800°C, 820°C, 840°C, 860°C, 880°C, or 900°C.

[0050] In a specific embodiment, the cooling rate of the accelerated cooling in step (1) may be 2°C/s, 3°C/s, 4°C/s, 5°C or 6°C/s.

[0051] In a specific embodiment, the time for the accelerated cooling in step (1) may be 50s, 60s, 70s, 80s, 90s, 100s, 110s, 120s, 130s, 140s or 150 s.

[0052] In a specific embodiment, the cooling rate of the accelerated cooling in step (2) may be 1°C, 2°C, 3°C, 4°C, or 5°C.

[0053] In a specific embodiment, the time for accelerated cooling in step (2) may be 20s, 30s, 40s, 50s or 60s.

[0054] In a preferred embodiment, the cooling medium used in the heat treatment is water mist and/or compressed air.

[0055] In a preferred embodiment, the continuous casting is a bloom billet protection continuous casting.

[0056] In a preferred embodiment, the steel billet is descaled by using high pressure water before subjecting the steel billet to rolling.

[0057] In a preferred embodiment, the rolling is carried out in an universal rolling mill.

[0058] In a preferred embodiment, the air cooling is performed on a walking beam cooling bed.

[0059] In a preferred embodiment, the processing course comprises: straightening the steel rails by using a horizontal and vertical composite straightening machine.

[0060] In a specific embodiment, the method for preparing a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient comprises the successively performed steps on low-sulfur molten steel of smelting with a revolving furnace or an electric furnace, refining with a LF furnace, RH or VD vacuum treatment, bloom billet protection continuous casting, heating the steel billet with a heating furnace, descaling the steel billet by using high pressure water before subjecting the steel billet to rolling, carrying out rolling with an universal rolling mill, subjecting the steel rail to an online heat treatment, air cooling with a walking beam cooling bed at room temperature, straightening the steel rails by using a horizontal and vertical composite straightening machine, inspecting specification of the steel rails, treating the steel rails on a processing line, surface inspection, and transporting the steel rails to a warehouse.

[0061] A second aspect of the present disclosure provides a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient prepared with the aforementioned method, wherein the running surface of the steel rail has a Brinell hardness within a range of 360-400 HB; the rail head part of the steel rail has a hardened layer with a depth more than 25mm, and the deep hardened layer has an uniform hardness gradient; when an inner depth of the rail head increases for every 5mm, the Brinell hardness of the hardened layer decreases by 3 ~ 6 HB; namely the Brinell hardness of the hardened layer at an inner depth of 5mm in the rail head is within a range of 355-397HB, the Brinell hardness of the hardened layer at an inner depth of 10mm in the rail head is within a range of 350-393HB, the Brinell hardness of the hardened layer at an inner depth of 15mm in the rail head is within a range of 345-390HB, the Brinell hardness of the hardened layer at an inner depth of 20mm in the rail head is within a range of 340-387HB, the Brinell hardness of the hardened layer at an inner depth of 25mm in the rail head is within a range of 335-383HB.

[0062] Preferably, the steel rail has a tensile strength larger than 1,200MPa and an elongation rate greater than or equal to 10%.

[0063] The present disclosure will be described in detail below with reference to examples, but the scope of the present disclosure is not limited thereto.

[0064] Example 1

[0065] The specific process for preparing the steel rail comprised the following steps:

[0066] smelting with an electric furnace, refining with a LF furnace, RH vacuum treatment, performing a bloom billet protection continuous casting to obtain steel billets, descaling the steel billets by using high pressure water before subjecting the steel billets to rolling, rolling the steel billets in an universal rolling mill, heat treatment and processing of the steel rail were sequentially carried out;

2021218136 19 Aug 2021

[0067] wherein the cooling medium for heat treatment was compressed air, and the heat treatment specifically comprised the following steps:

[0068] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 855°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 150 seconds at a cooling rate of 2.1°C/s;

[0069] (2) Second stage cooling: the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail obtained after step (1) were subjected to an accelerated cooling treatment for 50 seconds at a cooling rate of 1.6°C/s;

[0070] (3) Third stage cooling: the cooled steel rail obtained after step (2) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature;

[0071] The chemical components of the steel rail were as shown in Table 1.

[0072] Example 2

[0073] The specific process for preparing the steel rail comprised the following steps:

[0074] smelting with an electric furnace, refining with a LF furnace, RH

2021218136 19 Aug 2021

vacuum treatment, performing a bloom billet protection continuous casting to obtain steel billets, descaling the steel billets by using high pressure water before subjecting the steel billets to rolling, rolling the steel billets in an universal rolling mill, heat treatment and processing of the steel rail were sequentially carried out;

[0075] wherein the cooling medium for heat treatment was compressed air, and the heat treatment specifically comprised the following steps:

[0076] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 792°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 85 seconds at a cooling rate of 3.9°C/s;

[0077] (2) Second stage cooling: the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail obtained after step (1) were subjected to an accelerated cooling treatment for 35 seconds at a cooling rate of 2.7°C/s;

[0078] (3) Third stage cooling: the cooled steel rail obtained after step (2) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature;

[0079] The chemical components of the steel rail were as shown in Table

1.

[0080] Example 3

[0081] The specific process for preparing the steel rail comprised the following steps:

[0082] smelting with an electric furnace, refining with a LF furnace, RH vacuum treatment, performing a bloom billet protection continuous casting to obtain steel billets, descaling the steel billets by using high pressure water before subjecting the steel billets to rolling, rolling the steel billets in an universal rolling mill, heat treatment and processing of the steel rail were sequentially carried out;

[0083] wherein the cooling medium for heat treatment was compressed air and water mist, and the heat treatment specifically comprised the following steps:

[0084] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 846°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 150 seconds at a cooling rate of 5.6°C/s;

[0085] (2) Second stage cooling: the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail

2021218136 19 Aug 2021

obtained after step (1) were subjected to an accelerated cooling treatment for 25 seconds at a cooling rate of 4°C/s;

[0086] (3) Third stage cooling: the cooled steel rail obtained after step (2) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature;

[0087] The chemical components of the steel rail were as shown in Table 1.

[0088] Example 4

[0089] The steel rail was prepared according to the same method in Example 1, except that the chemical components of the steel rail were different, as shown in Table 1.

[0090] Example 5

[0091] The steel rail was prepared according to the same method in Example 2, except that the starting temperature of the accelerated cooling in step (1) is 760°C.

[0092] Comparative Example 1

[0093] The steel rail was prepared according to the same method in Example 1, except that the heat treatment specifically comprised the following steps:

[0094] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 860°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face

2021218136 19 Aug 2021

and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 210 seconds at a cooling rate of 1.8°C/s;

[0095] (2) Third stage cooling: the cooled steel rail obtained after step (1) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature.

[0096] Comparative Example 2

[0097] The steel rail was prepared according to the same method in Example 2, except that the heat treatment specifically comprised the following steps:

[0098] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 775°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 190 seconds at a cooling rate of 2°C/s;

[0099] (2) Third stage cooling: the cooled steel rail obtained after step (1) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature.

[00100] Comparative Example 3

[00101] The steel rail was prepared according to the same method in Example 3, except that the heat treatment specifically comprised the following steps:

[00102] (1) First stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling was 838°C, the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head were subjected to an accelerated cooling treatment for 170 seconds at a cooling rate of 2.4°C/s;

[00103] (2) Third stage cooling: the cooled steel rail obtained after step (1) was placed on a walking beam cooling bed and subjected to an air cooling to room temperature.

[00104] Table 1

	Example 1	Example 2	Example 3	Example 4
C(%)	0.78	0.76	0.8	0.81
Si(%)	0.47	0.5	0.46	0.55
Mn(%)	1.11	1.13	1.08	0.74
Cr(%)	0.12	0.1	0.14	0.08
P(%)	0.012	0.02	0.01	0.012
S(%)	0.014	0.008	0.013	0.004
Ni(%)	-	-	0.02	0.01
Mo(%)	-	0.01	-	-
V(%)	0.01	-	-	-
Fe +	Balance	Balance	Balance	Balance

2021218136 19 Aug 2021

inevitable impurities (%)				

[00105] Test Example

[00106] The tensile properties and the section hardness of the rail head of the Examples and Comparative Examples were tested according to the HBW 2.5/187.5 test force scheme of the Standard CB/T231.1-2018 “Brinell hardness Test of Metal Material, Part I: Test Method”, wherein the measurement position of section hardness of the rail head were shown in FIG. 1, the Brinell hardness measurement was carried out on three lines A, B and C, the distance between measurement points of hardness was 5mm, the first point was 5mm away from the rail surface, and the measurement depth was up to 25 mm. The results were shown in Table 2.

[00107] Table 2

Numbers	Fracture section hardness /HB						Tensile strength /MPa	Elongation rate /%	Hardness of rail running surface /HB
	Sites	5mm	10mm	15mm	20mm	25mm			
Example 1	A	360	357	351	348	344	1237	10.5	366
	B	362	357	355	351	347			
	C	360	363	357	353	350			
Example 2	A	379	374	369	363	359	1290	10.0	379
	B	378	367	365	356	351			
	C	380	373	369	364	357			
Example 3	A	382	379	373	369	362	1287	10.0	383
	B	381	375	376	367	364			
	C	386	383	378	375	367			
Comparative	A	358	365	364	351	341	1228	10.5	362
	B	351	359	350	336	328			

Example 1	C	362	364	359	347	339			
Comparative Example 2	A	373	374	375	363	361	1281	10.5	375
	B	368	376	368	357	350			
	C	369	377	369	364	359			
Comparative Example 3	A	373	380	369	372	367	1274	10.5	381
	B	374	374	370	367	356			
	C	373	386	380	375	366			

[00108] The detection results in Table 2 demonstrates that the Brinell hardness of the running surface of the steel rail prepared with the method of the present disclosure is within a range of 360-400HB, the rail head part of the steel rail is provided with a deep hardened layer with a depth more than 25mm, the deep hardened layer of the steel rail has a more uniform hardness gradient than the steel rail prepared in the Comparative Examples.

[00109] The above content describes in detail the preferred embodiment of the present disclosure, but the present disclosure is not limited thereto. A variety of simple modifications can be made in regard to the technical solutions of the present disclosure within the scope of the technical concept of the present disclosure, including a combination of individual technical features in any other suitable manner, such simple modifications and combinations thereof shall also be regarded as the content disclosed by the present disclosure, each of them falls into the protection scope of the present disclosure.

2021218136 19 Aug 2021

Claims

1. A method for preparing a pearlite steel rail with a rail head hardened layer having an uniform hardness gradient, the method comprises the successively performed steps of smelting with a revolving furnace or an electric furnace, refining with a LF furnace, RH or VD vacuum treatment, continuous casting to obtain steel billets, subjecting the steel billets to rolling, heat treatment and processing the steel rail;

wherein the heat treatment is a multi-stage cooling process, and specifically comprises the following steps:

(1) first stage cooling: when the temperature of the running surface of the steel rail after the finish final rolling is within a range of 760-900°C, subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head to an accelerated cooling treatment for 50-150 seconds at a cooling rate of 2-6°C/s;

(2) second stage cooling: subjecting the running surface of the steel rail, gauge corner and field corner of the rail head, gauge face and field face of the rail head and two rail head corners of the rail head of the cooled steel rail obtained after step (1) to an accelerated cooling treatment for 20-60 seconds at a cooling rate of 1-5°C/s;

(3) third stage cooling: subjecting the cooled steel rail obtained after step

2021218136 19 Aug 2021

(2) to an air cooling to room temperature;

controlling the chemical components of the steel rail, the steel rail comprises the following chemical components in percentage by weight: at least one of 0.65-0.85% of C, 0.1-1% of Si, 0.1-1.5% of Mn, less than or equal to 0.03% of P, less than or equal to 0.03% of S, 0.01-0.2% of Cr, 0.005-0.15% of Ni, 0.001-0.3% of Mo and 0.002-0.2% of V, and the balance of Fe and inevitable impurities.

2. The method of claim 1, wherein the steel rail comprises the following chemical components in percentage by weight: at least one of 0.68-0.82% of C, 0.2-0.7% of Si, 0.6-1.2% of Mn, less than or equal to 0.025% of P, less than or equal to 0.02% of S, 0.05-0.15% of Cr, 0.005-0.1% of Ni, 0.001-0.2% of Mo and 0.02-0.1% of V, and the balance of Fe and inevitable impurities.

3. The method of claim 1 or 2, wherein the cooling medium used in the heat treatment is water mist and/or compressed air.

4. The method of claim 1 or 2, wherein the continuous casting is a bloom billet protection continuous casting.

5. The method of claim 1 or 2, wherein the steel billet is descaled by using high pressure water before subjecting the steel billet to rolling.

6. The method of claim 1 or 2, wherein the rolling is carried out in an universal rolling mill.

7. The method of claim 1 or 2, wherein the air cooling is performed on a

2021218136 19 Aug 2021

walking beam cooling bed.

8. The method of claim 1 or claim 2, wherein the processing course comprises: straightening the steel rails by using a horizontal and vertical composite straightening machine.

9. A pearlite steel rail with a rail head hardened layer having an uniform hardness gradient prepared with the method of any one of claims 1 to 8, wherein the running surface of the steel rail has a Brinell hardness within a range of 360-400 HB; the rail head part of the steel rail has a hardened layer with a depth more than 25mm, and when an inner depth of the rail head increases for every 5mm, the Brinell hardness of the hardened layer decreases by 3 - 6 HB.

10. The pearlite steel rail of claim 9, wherein the steel rail has a tensile strength larger than 1,200MPa and an elongation rate greater than or equal to 10%.

2021218136 19 Aug 2021

Accompanying Drawings

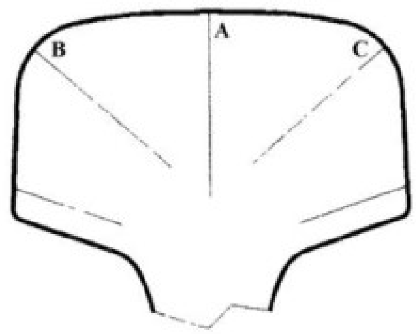

FIG. 1