

# **PRODUCTION METHOD FOR IMPROVING Z-DIRECTION PERFORMANCE OF HEAVY HOT-ROLLED H-SECTION STEEL, AND HEAVY HOT-ROLLED H-SECTION STEEL**

5   **[0001]**   This application claims priority to Chinese Patent Application No. 202311556112.0, titled “PRODUCTION METHOD FOR IMPROVING Z-DIRECTION PERFORMANCE OF HEAVY HOT-ROLLED H-SECTION STEEL, AND HEAVY HOT-ROLLED H-SECTION STEEL”, filed on November 21, 2023 with the China National Intellectual Property Administration, which is incorporated herein by reference in its entirety.

## **FIELD**

**[0002]**   The present disclosure relates to the technical field of H-section steels, and in particular to a production method for improving Z-direction performance of heavy hot-rolled H-section steel and heavy hot-rolled H-section steel.

## **BACKGROUND**

**[0003]**   H-section steel is a new type of economical construction steel. Its cross-sectional shape is economically rational, offering excellent mechanical properties. During rolling, elongation at each point on the cross-section is relatively uniform and the internal stress is  
20   low. It is widely used in high-rise buildings, large venues and major energy projects at home and abroad. However, such buildings have high requirements for various properties of steel due to structural design and mechanical requirements. The Z-direction performance of steel is one of the important properties to ensure the stability and safety of building steel structures.

**[0004]**   To achieve heavy hot-rolled H-section steels with high strength and Z-direction  
25   performance, a certain amount of alloys such as Nb, V, Ti and Als are generally added. The continuous casting process of such high-performance beam blanks with complex microalloying is quite different from that of ordinary carbon steel, and it is even more difficult to ensure the actual quality of continuously cast beam blanks. There is currently no actual

production of large cross-section, high-performance Z-direction beam blanks on domestic shaped continuous caster.

[0005] Chinese patent CN110788293A discloses a continuous casting process for beam blank for high weathering hot-rolled H-section steels. The process parameters of the secondary cooling mode in the continuous casting process include: a specific water amount is 0.5L/kg to 0.55L/kg, the water distribution ratio of zone 1A, zone 1B and zone 2 is 50% to 55%: 25% to 27%: 20% to 25%. In the zone 1A, the inner arc is the same with the outer arc, and the water amount on both sides is 50% of the total water amount of the inner and outer arcs. In the zone 1B, the water amount of the inner arc is 68% to 72% of that of the outer arc, and the water amount on both sides is 65% to 69% of the total water amount of the inner and outer arcs. In the zone 2, the water amount of the inner arc of is 60% of that of the outer arc, and the water amount on both sides is the same as the total water amount of the inner and outer arcs. This patent successfully developed the beam blank for high weathering hot-rolled H-section steels for high weathering heavy-duty trains using the continuously cast beam blanks. However, this patent does not focus on the Z-direction performance of H-section steels.

[0006] Chinese Patent CN113564480A discloses a heavy hot-rolled H-section steel with Z-direction performance and its production method. The main elements are: C, Si, Mn, Nb, Ti, N, B, Als, with the balance being iron and inevitable impurities. The production method includes the following steps: hot metal pretreatment → converter smelting → argon blowing refining → RH → full protective casting of beam blanks → stack slow cooling → rolling → air cooling after rolling. The patent regulates the precipitation amount of second-phase particles by means of combined strengthening via phase transformation + precipitation + grain refinement through reasonable component ratio and process control, and through the process of rough rolling + universal rolling + air cooling after rolling process, to obtain a granular bainite content of 10% to 20% after rolling, so that the heavy hot-rolled H-section steels with a flange thickness below 80mm have excellent strength and toughness and Z-direction performance, with the Z-direction performance reaching 65% to 80. The patent mainly controls the Z-direction performance from the aspect of rolling process, and does not mention how to control the Z-direction performance of finished products in the continuous casting process stage.

[0007] Chinese Patent CN109897928A discloses a method for manufacturing large-thickness steel plate with core anti-lamellar tearing performance produced from continuous casting slabs. In the production method of the large-thickness steel plate of the patent, the type of the continuous casting slab is selected according to the steel plate thickness and steel grade. After primary smelting in a converter, the ladle furnace (LF) refining and RH vacuum refining processes are strictly controlled to produce high-cleanliness molten steel, and then a special continuous steel casting process is controlled to obtain continuous casting slabs with central porosity and central segregation meeting the requirements. The continuous casting slabs are produced into steel plates with good anti-lamellar tearing performance through controlled rolling and controlled cooling, and then reach the final performance through heat treatment. In the patent, the thickness of the steel plate reaches > 80mm to 150mm, the anti-lamellar tearing performance is excellent, the reduction of area in the Z-direction (thickness direction) tensile test at 1/2 thickness position is >35%, and it can be widely used in the construction of steel structures such as large bridges and high-rise buildings. However, the patent is aimed at slabs and is not applicable to beam blanks with complex cross-sectional shapes.

## SUMMARY

[0008] The purpose of the present application is to provide a production method for improving the Z-direction performance of heavy hot-rolled H-section steel. By setting the secondary cooling mode of continuous casting for beam blank, defects such as surface transverse cracks of the beam blanks, tensile white spots in finished product and low Z-direction performance are addressed, and a temperature difference between the flange surface and the flange core is controlled within a range of 300°C to 500°C during rolling on a universal mill unit. The strain energy storage and nucleation sites required for subsequent phase transformation and precipitation are provided using strain accumulation, thereby refining the grains and further improving the Z-direction performance.

[0009] The present application further provides a heavy hot-rolled H-section steel produced by the above production method, the heavy hot-rolled H-section steel has a Z-direction performance of 35% to 65% and the cast blank has a good surface quality.

**[0010]** To achieve the above purpose, the technical solution adopted by the present application is as follows.

**[0011]** A production method for improving the Z-direction performance of heavy hot-rolled H-section steel is provided. The production method comprises the following steps: hot metal pretreatment, converter double-slag smelting, LF furnace refining, VD vacuum degassing, continuous casting, slow cooling, hot rolling, cooling;

In the continuous casting step, casting is carried out under a low superheat and a constant casting speed, the superheat is 10°C to 35°C, and the casting speed of the continuous casting of beam blank cross-section is 0.45m/min to 0.95m/min; a specific water amount in secondary cooling is 0.45 L/kg to 0.77L/kg, a foot roller zone is cooled with water, a movable segment, segment 1, segment 2 and segment 3 are cooled by air-water mist cooling; and a water distribution ratio for the foot roller zone, movable segment, segment 1, segment 2 and segment 3 is 25% to 33%: 40% to 45%: 15% to 20%: 7% to 10%: 4.5% to 6%.

**[0012]** In the continuous casting step, a top of the inner arc between segment 3 of a fan-shaped segment of a continuous caster for the beam blank and a withdrawal and straightening roll is insulated with a heat insulation cover.

**[0013]** In the continuous casting step, casting is performed using a submerged entry nozzle with side holes, a casting point is located at a center of a web, and a lower end of the submerged entry nozzle immersed in molten steel has a flat shape.

**[0014]** The beam blank obtained by the continuous casting has the following dimensions: a width of 750 mm to 1300mm, a height of 440 mm to 510 mm, and a flange tip width of 80 mm to 180mm.

**[0015]** For BB5 beam blank type, a constant casting speed of 0.75m/min is adopted; for BB6 beam blank type, a constant casting speed of 0.88m/min is adopted; for BB7 beam blank type, a constant casting speed of 0.55m/min is adopted.

**[0016]** The cross-section of the BB5 beam blank type is 900mm \*450mm \*130mm; the cross-section of the BB6 beam blank type is 1030mm \*440 mm \*80 mm; the cross-section of the BB7 beam blank type is 1300 mm \*510 mm \*180 mm.

**[0017]** In the slow cooling step, stack slow cooling is carried out for 35h to 50h.

**[0018]** In the hot rolling step, a rolling speed of rough rolling is  $\leq 2\text{m/s}$ , and a temperature drop during rough rolling is  $\leq 120^\circ\text{C}$ ; after rough rolling, the blank is fed into the universal mill unit for rolling, the rolling speed is  $\leq 3.0\text{m/s}$ , and a temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

5 **[0019]** During rolling in the universal mill unit, side nozzles at an oscillating roller table of the rolling mill are activated to cool flange ends of the H-section steel, the water pressure is ensured to be not less than 1MPa, and the cooling water pressure of a universal horizontal roll is reduced to  $\leq 0.5\text{MPa}$  to ensure that the temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

10 **[0020]** In the cooling step, after the blank is rolled into finished product and offline, the finished product is first cooled to  $500^\circ\text{C}$  at a rate of  $5^\circ\text{C/s}$  to  $10^\circ\text{C/s}$ , and then placed into a heat preservation pit for slow cooling within a temperature range of  $500^\circ\text{C}$  to  $300^\circ\text{C}$  for more than 24h, with a cooling rate of  $0.1^\circ\text{C/s}$  to  $1.0^\circ\text{C/s}$  in the process.

**[0021]** The present application further provides a heavy hot-rolled H-section steel produced  
15 by the above production method.

**[0022]** The heavy hot-rolled H-section steel comprises the following chemical components by weight percentage: C 0.06% to 0.20%, Si 0.25% to 0.55%, Mn 1.35% to 1.60%, P  $\leq 0.020\%$ , S  $\leq 0.005\%$ , Ni  $\leq 1.5\%$ , V 0.001% to 0.09%, Nb 0.005% to 0.040%, Ti 0.008% to 0.020%, Als 0.006% to 0.035%, N 30ppm to 60ppm, H  $\leq 5.5\text{ppm}$ , with the balance being Fe  
20 and other inevitable impurities. Various steel grades with the chemical composition can be produced into heavy hot-rolled H-section steels with good surface quality of the cast blank and excellent Z-direction performance by the production method provided by the present application.

**[0023]** The heavy hot-rolled H-section steel has a Z-direction performance of 35% to 65%  
25 and the cast blank has a good surface quality .

**[0024]** The production method for improving the Z-direction performance of the heavy hot-rolled H-section steels provided by the present application adopts the production processes of hot metal pretreatment, converter double-slag smelting, LF furnace refining, VD degassing and continuous casting to produce the beam blank, with reasonable working  
30 procedures and low production cost. The VD or LF process is beneficial to reducing the gas

content in steel, minimizing porosity and shrinkage cavities in steel grades, and avoiding the situation where, due to a small compression ratio in the subsequent rolling process, deformation fails to penetrate, thus affecting the Z-direction performance of the finished products. In addition, the double processes of LF furnace refining and VD vacuum degassing ensure that the steel grade has an S content of  $\leq 0.005\%$ , thereby reducing the formation of sulfides in the steel grade and improving the Z-direction performance.

**[0025]** In the continuous casting process, the working casting speed of the continuous casting of the beam blank cross-section is 0.45 m/min to 0.95m/min. In the secondary cooling mode, the foot roller zone is cooled with water, the movable segment, segment 1, segment 2 and segment 3 are cooled by air-water mist cooling, and the specific water amount in secondary cooling is 0.45 L/kg to 0.77L/kg. The water distribution ratio for the foot roller zone, movable segment, segment 1, segment 2 and segment 3 is 25% to 33%: 40% to 45%: 15% to 20%: 7% to 10%: 4.5% to 6%. A certain proportion of specific water amount and the ratio of different sections of secondary cooling water can increase the formation and proportion of equiaxed crystals during the solidification process of super large specification beam blanks, reduce the generation of columnar crystals, and reduce defects such as central porosity and shrinkage cavities. In a case that the specific water amount and ratio are not controlled according to these parameters, excessive columnar crystals may be generated, leading to increase of the defects of central porosity and shrinkage cavities, which in turn deteriorate the Z-direction performance.

**[0026]** In the continuous casting process, a submerged entry nozzle with side holes is used for casting, and a lower end of the submerged entry nozzle immersed in molten steel is designed to have a flat shape. The design is conducive to secondary oxidation of molten steel, controlling the flow state and injection speed of molten steel, promoting the floating of inclusions, and preventing non-metallic inclusions such as mold slag from being involved in the molten steel, thereby avoiding the formation of large and numerous inclusions that would reduce the Z-direction performance.

**[0027]** In the continuous casting process, casting is carried out under a low superheat and a constant casting speed, the superheat is 10°C to 35°C. For BB5 beam blank type, a constant casting speed of 0.75m/min is adopted; for BB6 beam blank type, a constant casting speed of 0.88m/min is adopted; for BB7 beam blank type, a constant casting speed of 0.55m/min is

adopted. A lower superheat can reduce the generation of columnar crystals, increase the generation of equiaxed crystals, and reduce central porosity and shrinkage cavities under the condition of a large compression ratio. In addition, the constant casting speed is conducive to the uniformity of the structure in a length direction of the cast blank, ensuring that the microstructure is relatively uniform throughout the whole blank.

**[0028]** In the continuous casting process, a top of the inner arc between segment 3 of a fan-shaped segment of a continuous caster for the beam blank and a withdrawal and straightening roll is insulated with a heat insulation cover. The heat insulation cover slows down the temperature drop at the ends of the beam blank, so that the withdrawal and straightening process avoids the high-temperature second brittle zone and improves the top crack of the beam blank.

**[0029]** In the hot rolling process, the rolling speed is controlled to be  $\leq 3.0\text{m/s}$  during rolling in the universal mill unit, to increase the deformation penetration and the structure refinement during rolling. The side nozzles at an oscillating roller table of the rolling mill are activated to cool flange ends of the H-section steel, the water pressure is ensured to be not less than 1MPa, and the cooling water pressure of the universal horizontal roll is reduced to  $\leq 0.5\text{MPa}$  to ensure that the temperature difference between the flange surface and the flange core is  $200^{\circ}\text{C}$  to  $500^{\circ}\text{C}$ . The strain accumulation is used to provide the strain energy storage and nucleation sites required for subsequent phase transformation and precipitation, thereby refining the grains and further improving the Z-direction performance.

**[0030]** After the beam blank is rolled into finished product and offline, the finished product is first cooled to  $500^{\circ}\text{C}$  at a rate of  $5^{\circ}\text{C/s}$  to  $10^{\circ}\text{C/s}$  in a high-temperature section, and then slowly cooled for more than 24h in a temperature range of  $500^{\circ}\text{C}$  to  $300^{\circ}\text{C}$ . The purpose is to allow H to escape, so that the H content in steel grades is  $\leq 5.5\text{ppm}$ . A high H content in steel grade may cause white spots to appear in the tensile process, increase the brittleness of steel, and sharply deteriorate the Z-direction performance of steel.

**[0031]** Compared with the conventional technology, the present application has the following beneficial effects:

The production method for improving the Z-direction performance of the heavy hot-rolled H-section steel provided by the present application focuses on the influence of the continuous casting process on the Z-direction performance of the heavy hot-rolled H-section

steel. The Z-direction performance of heavy hot-rolled H-section steels is improved by controlling the process parameters in the continuous casting process, using the submerged entry nozzle with side holes for casting in the continuous casting process, designing the lower end of the submerged entry nozzle immersed in molten steel into the flat shape, and insulating  
5 the top of the inner arc between segment 3 of a fan-shaped segment of a continuous caster for the beam blank and a withdrawal and straightening roll with the heat insulation cover. Combined with the subsequent hot rolling process, it further ensures that the heavy hot-rolled H-section steel has excellent Z-direction performance.

## 10 BRIEF DESCRIPTION OF THE DRAWINGS

[0032] FIG. 1 is a fracture picture of tensile specimens of heavy hot-rolled H-section steels according to Examples 1 to 8.

[0033] FIG. 2 is a schematic diagram of a flange of the beam blank of the heavy hot-rolled H-section steel according to Example 1 without transverse crack defect.

15 [0034] FIG. 3 is a schematic diagram of a flange of the beam blank of the heavy hot-rolled H-section steel in Comparative example 1 without transverse crack defect.

[0035] FIG. 4 is a schematic diagram of a flange of the beam blank of the heavy hot-rolled H-section steel in Comparative example 3 without transverse crack defect.

20 [0036] FIG. 5 is a schematic diagram of a flange of the beam blank of the heavy hot-rolled H-section steel in Comparative example 4 without transverse crack defect.

## DETAILED DESCRIPTION OF EMBODIMENTS

[0037] A production method for improving the Z-direction performance of heavy hot-rolled H-section steels is provided by the present application, and the production method comprises  
25 the following steps: hot metal pretreatment, converter double-slag smelting, LF furnace refining, VD vacuum degassing, continuous casting, slow cooling, hot rolling, cooling;

In the continuous casting step, casting is carried out under a low superheat and a constant casting speed, the superheat is 10°C to 35°C, and the casting speed of the continuous casting of beam blank cross-section is 0.45m/min to 0.95m/min; a specific water amount in

secondary cooling is 0.45 L/kg to 0.77L/kg, a foot roller zone is cooled with water, and a movable segment, segment 1, segment 2 and segment 3 are cooled by air-water mist cooling; and a water distribution ratio for the foot roller zone, movable segment, segment 1, segment 2 and segment 3 is 25% to 33%: 40% to 45%: 15% to 20%: 7% to 10%: 4.5% to 6%.

5   **[0038]** In the continuous casting step, a top of the inner arc between segment 3 of a fan-shaped segment of a continuous caster for the beam blank and a withdrawal and straightening roll is insulated with a heat insulation cover.

**[0039]** In the continuous casting step, casting is performed using a submerged entry nozzle with side holes, a casting point is located at a center of a web, and a lower end of the submerged entry nozzle immersed in molten steel has a flat shape.

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**[0040]** The beam blank obtained by the continuous casting has the following dimensions: a width of 750 mm to 1300mm, a height of 440 mm to 510 mm, and a flange tip width of 80 mm to 180mm.

**[0041]** For BB5 beam blank type, a constant casting speed of 0.75m/min is adopted; for BB6 beam blank type, a constant casting speed of 0.88m/min is adopted; and for BB7 beam blank type, a constant casting speed of 0.55m/min is adopted.

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**[0042]** The cross-section of the BB5 beam blank type is 900mm \*450mm \*130mm, the cross-section of the BB6 beam blank type is 1030mm \*440 mm \*80 mm, and the cross-section of the BB7 beam blank type is 1300 mm \*510 mm \*180 mm.

20   **[0043]** In the slow cooling step, stack slow cooling is carried out for 35h to 50h.

**[0044]** In the hot rolling step, a rolling speed of rough rolling is  $\leq 2\text{m/s}$ , and a temperature drop during rough rolling is  $\leq 120^\circ\text{C}$ ; after rough rolling, the beam blank is fed into the universal mill unit for rolling, the rolling speed is  $\leq 3.0\text{m/s}$ , and a temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

25   **[0045]** During rolling on the universal mill, side nozzles at an oscillating roller table of the rolling mill are activated to cool flange ends of the H-section steel, the water pressure is ensured to be not less than 1MPa, and the cooling water pressure of the universal horizontal roll is reduced to  $\leq 0.5\text{MPa}$  to ensure that the temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

**[0046]** In the cooling step, after the beam blank is rolled into finished product and offline, the finished product is first cooled to 500°C at a rate of 5°C/s to 10°C/s, and then placed into a heat preservation pit for slow cooling within a temperature range of 500°C to 300°C for more than 24h, with a cooling rate of 0.1°C/s to 1.0°C/s in the process.

5 **[0047]** The heavy hot-rolled H-section steel comprises the following chemical components by weight percentage: C 0.06% to 0.20%, Si 0.25% to 0.55%, Mn 1.35% to 1.60%, P  $\leq 0.020\%$ , S  $\leq 0.005\%$ , Ni  $\leq 1.5\%$ , V 0.001% to 0.09%, Nb 0.005% to 0.040%, Ti 0.008% to 0.020%, Als 0.006% to 0.035%, N 30ppm to 60ppm, H  $\leq 5.5\text{ppm}$ , with the balance being Fe and other inevitable impurities.

10 **[0048]** The present application is described in detail below in conjunction with examples.

**[0049]** The steel grades and weight percentages of chemical components of the heavy hot-rolled H-section steels produced in each Example and Comparative example are shown in Table 1.

**[0050]** Table 1

|           | Steel grade | C   | Si  | Mn  | P    | S    | Als  | Nb   | V    | Ti   | N     | H      |
|-----------|-------------|-----|-----|-----|------|------|------|------|------|------|-------|--------|
| Example 1 | Q390GJC     | 0.1 | 0.4 | 1.4 | 0.02 | 0.00 | 0.00 | 0.04 | 0.04 | 0.01 | 40ppm | 5ppm   |
|           | Z15         | 7   | 0   | 5   | 0    | 5    | 6    | 0    | 0    | 5    |       |        |
| Example 2 | Q390GJC     | 0.1 | 0.4 | 1.5 | 0.01 | 0.00 | 0.01 | 0.03 | 0.04 | 0.02 | 45ppm | 4ppm   |
|           | Z15         | 8   | 0   | 5   | 5    | 5    | 0    | 5    | 5    | 0    |       |        |
| Example 3 | S355J0Z1    | 0.1 | 0.2 | 1.4 | 0.01 | 0.00 | 0.00 | 0.04 | 0.00 | 0.01 | 40ppm | 4ppm   |
|           | 5           | 7   | 5   | 5   | 5    | 5    | 6    | 0    | 2    | 5    |       |        |
| Example 4 | S355J0Z1    | 0.1 | 0.2 | 140 | 0.01 | 0.00 | 0.01 | 0.00 | 0.04 | 0.00 | 55ppm | 3ppm   |
|           | 5           | 9   | 5   |     | 5    | 5    | 0    | 5    | 5    | 8    |       |        |
| Example 5 | A992        | 0.1 | 0.3 | 1.4 | 0.01 | 0.00 | 0.00 | 0.03 | 0.05 | 0.01 | 30ppm | 2.5ppm |
|           |             | 6   | 5   | 6   | 3    | 4    | 5    | 5    | 5    | 8    |       |        |
| Example 6 | A992        | 0.1 | 0.3 | 1.5 | 0.01 | 0.00 | 0.01 | 0.03 | 0.06 | 0.01 | 35ppm | 3ppm   |
|           |             | 5   | 0   | 0   | 0    | 1    | 0    | 0    | 0    | 5    |       |        |
| Example 7 | Q355BZ1     | 0.1 | 0.4 | 1.3 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.01 | 43ppm | 3.5pp  |

|                       |                |          |          |          |           |           |           |           |           |           |        |        |
|-----------------------|----------------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|--------|--------|
|                       | 5              | 7        | 5        | 8        | 5         | 2         | 2         | 8         | 2         | 3         |        | m      |
| Example 8             | Q355BZ1<br>5   | 0.1<br>9 | 0.3<br>8 | 1.4<br>0 | 0.01<br>3 | 0.00<br>3 | 0.01<br>3 | 0.02<br>8 | 0.00<br>2 | 0.01<br>2 | 45ppm  | 4.8ppm |
| Comparative example 1 | Q390GJC<br>Z15 | 0.1<br>8 | 0.4<br>0 | 1.5<br>0 | 0.02<br>5 | 0.01<br>5 | 0.00<br>6 | 0.04<br>0 | 0.04<br>0 | 0.01<br>5 | 40ppm  | 10ppm  |
| Comparative example 2 | S355J0Z1<br>5  | 0.1<br>7 | 0.4<br>5 | 1.4<br>0 | 0.01<br>8 | 0.00<br>4 | 0.04<br>0 | 0.04<br>1 | 0.04<br>5 | 0.02<br>0 | 80ppm  | 4ppm   |
| Comparative example 3 | S355J0Z1<br>5  | 0.1<br>9 | 0.3<br>5 | 1.4<br>3 | 0.01<br>6 | 0.00<br>3 | 0.03<br>8 | 0.03<br>9 | 0.03<br>9 | 0.03<br>0 | 60ppm  | 8ppm   |
| Comparative example 4 | A992           | 0.1<br>5 | 0.3<br>0 | 1.5<br>0 | 0.01<br>0 | 0.00<br>1 | 0.01<br>0 | 0.03<br>0 | 0.06<br>0 | 0.04<br>5 | 35ppm  | 10ppm  |
| Comparative example 5 | Q355BZ1<br>5   | 0.1<br>7 | 0.4<br>5 | 1.3<br>8 | 0.00<br>5 | 0.00<br>2 | 0.04<br>5 | 0.03<br>8 | 0.00<br>2 | 0.01<br>3 | 100ppm | 3.5ppm |

**[0051]** The process parameters of the continuous casting section for the heavy hot-rolled H-section steels produced in each Examples and Comparative example are shown in Table 2.

**[0052]** Table 2

|  | Blank type | Superheat °C | Casting speed m/min | Specific water amount L/kg | Cooling water in roller zone /% | Cooling water in movable segment % | Cooling water in segment 1 % | Cooling water in segment 2 % | Cooling water in segment 3 % | Beam blank surface quality |
|--|------------|--------------|---------------------|----------------------------|---------------------------------|------------------------------------|------------------------------|------------------------------|------------------------------|----------------------------|
|--|------------|--------------|---------------------|----------------------------|---------------------------------|------------------------------------|------------------------------|------------------------------|------------------------------|----------------------------|

|                              |     |    |      |      |       | nt<br>% |       |       |       |                      |
|------------------------------|-----|----|------|------|-------|---------|-------|-------|-------|----------------------|
| Example 1                    | BB5 | 30 | 0.75 | 0.45 | 28.1  | 40.02   | 16.20 | 9.12  | 5.8   | Good                 |
| Example 2                    | BB6 | 35 | 0.88 | 0.55 | 30.95 | 40.20   | 15.80 | 8.15  | 4.90  | Good                 |
| Example 3                    | BB5 | 30 | 0.75 | 0.55 | 29.31 | 41.5    | 16.40 | 8.62  | 5.2   | Good                 |
| Example 4                    | BB7 | 32 | 0.55 | 0.70 | 31.85 | 42.8    | 15.64 | 8.18  | 5.31  | Good                 |
| Example 5                    | BB5 | 28 | 0.75 | 0.45 | 28.1  | 43.0    | 16.20 | 9.12  | 4.5   | Good                 |
| Example 6                    | BB6 | 30 | 0.88 | 0.55 | 30.95 | 44.8    | 15.80 | 8.15  | 4.90  | Good                 |
| Example 7                    | BB7 | 29 | 0.55 | 0.70 | 31.85 | 45.0    | 15.64 | 8.18  | 5.31  | Good                 |
| Example 8                    | BB6 | 34 | 0.88 | 0.55 | 30.95 | 43.5    | 15.80 | 8.15  | 4.90  | Good                 |
| Comparati<br>ve<br>example 1 | BB5 | 50 | 0.68 | 1.0  | 30.45 | 38.50   | 16.10 | 8.28  | 6.67  | Transver<br>se crack |
| Comparati<br>ve<br>example 2 | BB5 | 45 | 0.72 | 0.9  | 29.50 | 39.65   | 15.71 | 8.39  | 6.75  | Transver<br>se crack |
| Comparati<br>ve<br>example 3 | BB7 | 30 | 0.48 | 0.50 | 19.80 | 20.10   | 20.10 | 15.38 | 24.62 | Transver<br>se crack |
| Comparati<br>ve<br>example 4 | BB6 | 35 | 0.88 | 1.0  | 30.45 | 38.50   | 16.10 | 8.28  | 6.67  | Good                 |
| Comparati<br>ve<br>example 5 | BB7 | 55 | 0.55 | 0.50 | 30.95 | 40.20   | 15.80 | 8.15  | 4.90  | Good                 |

**[0053]** The process parameters of the slow cooling, hot rolling and cooling sections, and the post-rolling Z-direction tensile properties of the heavy hot-rolled H-section steels produced in each example and comparative example are shown in Table 3.

**[0054]** Table 3

|                          |                | Slow cooling<br>time /h | BD<br>section<br>rolling<br>speed<br>m/s | Universal<br>area<br>rolling<br>speed<br>m/s | Temperature<br>difference<br>between<br>flange<br>surface and<br>flange core<br>°C | Cooling rate at<br>high-temperature<br>section above<br>500°C<br>°C /s |
|--------------------------|----------------|-------------------------|------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Example 1                | Q390GJC<br>Z15 | 48                      | 2.0                                      | 0.4                                          | 300                                                                                | 6                                                                      |
| Example 2                | Q390GJC<br>Z15 | 36                      | 1.8                                      | 0.6                                          | 350                                                                                | 8                                                                      |
| Example 3                | S355J0Z15      | 38                      | 1.5                                      | 1.0                                          | 380                                                                                | 7                                                                      |
| Example 4                | S355J0Z15      | 45                      | 1.5                                      | 1.5                                          | 400                                                                                | 10                                                                     |
| Example 5                | A992           | 50                      | 1.8                                      | 2.0                                          | 420                                                                                | 5                                                                      |
| Example 6                | A992           | 48                      | 1.9                                      | 2.5                                          | 440                                                                                | 7                                                                      |
| Example 7                | Q355BZ15       | 40                      | 1.6                                      | 3.0                                          | 450                                                                                | 10                                                                     |
| Example 8                | Q355BZ15       | 43                      | 2.0                                      | 2.6                                          | 480                                                                                | 9                                                                      |
| Comparative<br>example 1 | Q390GJC<br>Z15 | 44                      | 1.5                                      | 1.0                                          | 450                                                                                | 8                                                                      |
| Comparative<br>example 2 | S355J0Z15      | 48                      | 1.2                                      | 1.8                                          | 300                                                                                | 9                                                                      |
| Comparative<br>example 3 | S355J0Z15      | 40                      | 2.0                                      | 2.0                                          | 380                                                                                | 10                                                                     |
| Comparative<br>example 4 | A992           | 50                      | 1.5                                      | 2.5                                          | 200                                                                                | 6                                                                      |
| Comparative<br>example 5 | Q355BZ15       | 50                      | 1.8                                      | 2.8                                          | 260                                                                                | 9                                                                      |
|                          |                | Cooling rate at         | Yield                                    | Tensile                                      | Elongation                                                                         | Post-rolling                                                           |

|                          |                | low-temperature<br>section of<br>500°C to 300°C<br>°C /s | strength<br>/ReL(or<br>ReH)/MPa | /Rm(MPa) | /A(%) | tensile<br>z-direction<br>performance /% |
|--------------------------|----------------|----------------------------------------------------------|---------------------------------|----------|-------|------------------------------------------|
| Example 1                | Q390GJC<br>Z15 | 1                                                        | 452                             | 625      | 29    | 60                                       |
| Example 2                | Q390GJC<br>Z15 | 0.5                                                      | 435                             | 627      | 26.6  | 45                                       |
| Example 3                | S355J0Z15      | 0.9                                                      | 389                             | 580      | 28.9  | 52                                       |
| Example 4                | S355J0Z15      | 1.2                                                      | 395                             | 590      | 30.2  | 38                                       |
| Example 5                | A992           | 0.1                                                      | 378                             | 568      | 24.5  | 60                                       |
| Example 6                | A992           | 0.5                                                      | 388                             | 587      | 25.4  | 58                                       |
| Example 7                | Q355BZ15       | 0.3                                                      | 405                             | 559      | 26.0  | 55                                       |
| Example 8                | Q355BZ15       | 0.6                                                      | 412                             | 602      | 24.8  | 45                                       |
| Comparative<br>example 1 | Q390GJC<br>Z15 | 0.8                                                      | 390                             | 530      | 21.0  | 10                                       |
| Comparative<br>example 2 | S355J0Z15      | 0.9                                                      | 355                             | 490      | 18.0  | 9                                        |
| Comparative<br>example 3 | S355J0Z15      | 0.4                                                      | 359                             | 512      | 19.5  | 8                                        |
| Comparative<br>example 4 | A992           | 0.7                                                      | 362                             | 522      | 21.0  | 10                                       |
| Comparative<br>example 5 | Q355BZ15       | 0.6                                                      | 359                             | 500      | 22.0  | 12                                       |

**[0055]** It can be seen from the above that heavy hot-rolled H-section steels with good cast blank surface quality and excellent Z-direction performance can be produced according to the production method according to the present application. In contrast, in a case that the above process is not controlled in accordance with the requirements of the present application, heavy

hot-rolled H-section steels with good cast blank surface quality and excellent Z-direction performance cannot be produced.

**[0056]** The above detailed description of a production method for improving the Z-direction performance of the heavy hot-rolled H-section steel and the heavy hot-rolled H-section steel with reference to examples is illustrative rather than restrictive, and several examples can be listed according to the limited scope. Therefore, changes and modifications without departing from the general concept of the present application shall fall within the protection scope of the present application.

## CLAIMS

1. A production method for improving Z-direction performance of heavy hot-rolled H-section steel, wherein the production method comprises the following steps: hot metal pretreatment, converter double-slag smelting, LF furnace refining, VD vacuum degassing, continuous casting, slow cooling, hot rolling, cooling;

in the continuous casting step, casting is carried out under a low superheat and a constant casting speed, the superheat is 10°C to 35°C, and the casting speed of the continuous casting of beam blank cross-section is 0.45m/min to 0.95m/min; a specific water amount in secondary cooling is 0.45 L/kg to 0.77L/kg, a foot roller zone is cooled with water, and a movable segment, segment 1, segment 2 and segment 3 are cooled by air-water mist cooling; and a water distribution ratio for the foot roller zone, movable segment, segment 1, segment 2 and segment 3 is 25% to 33%: 40% to 45%: 15% to 20%: 7% to 10%: 4.5% to 6%.

2. The production method according to claim 1, wherein in the continuous casting step, a top of the inner arc between segment 3 of a fan-shaped segment of a continuous caster for the beam blank and a withdrawal and straightening roll is insulated with a heat insulation cover.

3. The production method according to claim 1, wherein in the continuous casting step, casting is performed using a submerged entry nozzle with side holes, a casting point is located at a center of a web, and a lower end of the submerged entry nozzle immersed in molten steel has a flat shape.

4. The production method according to claim 1, wherein the beam blank obtained by the continuous casting has the following dimensions: a width of 750 mm to 1300mm, a height of 440 mm to 510 mm, and a flange tip width of 80 mm to 180mm.

5. The production method according to claim 1, wherein for BB5 beam blank type, a constant casting speed of 0.75m/min is adopted; for BB6 beam blank type, a constant casting speed of 0.88m/min is adopted; for BB7 beam blank type, a constant casting speed of 0.55m/min is adopted.

6. The production method according to claim 1, wherein in the slow cooling step, stack slow cooling is carried out for 35h to 50h.

7. The production method according to any one of claims 1 to 6, wherein in the hot rolling step, a rolling speed of rough rolling is  $\leq 2\text{m/s}$ , and a temperature drop during rough rolling is  $\leq 120^\circ\text{C}$ ; after rough rolling, the blank is fed into the universal mill unit for rolling, the rolling speed is  $\leq 3.0\text{m/s}$ , and a temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

8. The production method according to claim 7, wherein during rolling in the universal mill unit, side nozzles at an oscillating roller table of the rolling mill are activated to cool flange ends of the H-section steel, the water pressure is ensured to be not less than  $1\text{MPa}$ , and the cooling water pressure of a universal horizontal roll is reduced to  $\leq 0.5\text{MPa}$  to ensure that the temperature difference between the flange surface and the flange core is  $200^\circ\text{C}$  to  $500^\circ\text{C}$ .

9. The production method according to any one of claims 1-6, wherein in the cooling step, after the blank is rolled into finished product and offline, the finished product is first cooled to  $500^\circ\text{C}$  at a rate of  $5^\circ\text{C/s}$  to  $10^\circ\text{C/s}$ , and then placed into a heat preservation pit for slow cooling within a temperature range of  $500^\circ\text{C}$  to  $300^\circ\text{C}$  for more than 24h.

10. A heavy hot-rolled H-section steel produced by the production method according to any one of claims 1-9.

11. The heavy hot-rolled H-section steel according to claim 10, wherein the heavy hot-rolled H-section steel comprises the following chemical components by weight percentage: C 0.06% to 0.20%, Si 0.25% to 0.55%, Mn 1.35% to 1.60%, P  $\leq 0.020\%$ , S  $\leq 0.005\%$ , Ni  $\leq 1.5\%$ , V 0.001% to 0.09%, Nb 0.005% to 0.040%, Ti 0.008% to 0.020%, Al 0.006% to 0.035%, N 30ppm to 60ppm, H  $\leq 5.5\text{ppm}$ , with the balance being Fe and other inevitable impurities.

12. The heavy hot-rolled H-section steel according to claim 10, wherein the heavy hot-rolled H-section steel has a Z-direction performance of 35% to 65%, and the cast blank has a good surface quality.