(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 015 669 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
22.06.2022 Bulletin 2022/25

(21) Application number: **20896953.5**

(22) Date of filing: **30.04.2020**

(51) International Patent Classification (IPC):
C22C 38/58 (2006.01) ***C22C 38/48*** (2006.01)
C22C 38/46 (2006.01) ***C22C 38/50*** (2006.01)
C22C 38/42 (2006.01) ***C22C 38/44*** (2006.01)
C22C 38/02 (2006.01) ***C22C 38/06*** (2006.01)
C21D 8/02 (2006.01)

(86) International application number:
PCT/CN2020/088281

(87) International publication number:
WO 2021/109439 (10.06.2021 Gazette 2021/23)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **07.12.2019 CN 201911245533**

(71) Applicant: **Jiangyin Xingcheng Special Steel Works Co., Ltd**
Jiangyin, Jiangsu 214434 (CN)

(72) Inventors:
- **JIANG, Changlin**
  Jiangyin, Jiangsu 214434 (CN)
- **LI, Guozhong**
  Jiangyin, Jiangsu 214434 (CN)
- **ZHU, Jianyang**
  Jiangyin, Jiangsu 214434 (CN)
- **LIN, Tao**
  Jiangyin, Jiangsu 214434 (CN)
- **MIAO, Pifeng**
  Jiangyin, Jiangsu 214434 (CN)
- **XU, Weiming**
  Jiangyin, Jiangsu 214434 (CN)
- **XU, Guoqing**
  Jiangyin, Jiangsu 214434 (CN)
- **ZHOU, Haiyan**
  Jiangyin, Jiangsu 214434 (CN)
- **XU, Xiaohong**
  Jiangyin, Jiangsu 214434 (CN)
- **BAI, Yun**
  Jiangyin, Jiangsu 214434 (CN)

(74) Representative: **Huang, Liwei**
Cäcilienstraße 12
40597 Düsseldorf (DE)

(54) HIC-RESISTANT AND LARGE DEFORMATION-RESISTANT PIPELINE STEEL AND PREPARATION METHOD THEREFOR

(57) The invention relates to a pipeline steel with both HIC resistance and resistance to a large deformation . The alloy constituents are C: 0.015-0.039%, Si: 0.15-0.35%, Mn: 1.6-1.9%, S: ≤ 0.002%, P: ≤ 0.012%, Al: 0.02 -0.045%, Cr: 0.15-0.35%, 0.05 ≤ Nb + V + Ti ≤ 0.1%, Nb, V and Ti are not 0, Ni: 0.15-0.50%, Cu: 0.01-0.25%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.01-0.20%, The balance is Fe and unavoidable impurity elements, with single-phase bainite structure, and the grain size of bainite is above grade 11.5. The transverse yield ratio of the product is Rt0.5 / Rm ≤ 0.78, - 20 °C Charpy impact energy ≥ 350J, - 20 °C drop weight shear area SA% ≥ 90%; Longitudinal uniform elongation Uel ≥ 11%, longitudinal yield ratio ≤ 0.77; Longitudinal stress ratio Rt1.5/Rt0.5≥1.18, Rt2.0/Rt1.0≥1.1; HIC resistance: soaking in a solution according to NACE TM0284-2004 A for 96 hours, crack length rate%: 0, crack width rate%: 0 and crack sensitivity rate%: 0.

EP 4 015 669 A1

Description

Technical field

[0001] The invention belongs to the technical field of iron-based alloys, in particular to a pipeline steel.

Background art

[0002] Pipeline transportation is the most economical and reasonable transportation mode of oil and natural gas. The long transmission pipeline not only needs to pass through different temperature areas, but also needs to pass through the stratum movement areas caused by natural disasters such as earthquake tundra, debris flow and landslide. Therefore, in addition to meeting the requirements of high strength and high toughness, the pipeline also needs to have relatively high anti deformation ability to adapt to the transmission geological environment.

[0003] Large deformation resistant pipeline steel is one of the most challenging research fields in the development of pipeline steel, which requires pipeline steel to have higher compression and tensile strain resistance. A large number of studies have proved that in addition to the basic strength plasticity performance parameters, such as yield strength, tensile strength and elongation, the main indexes that can measure its resistance to large deformation are "uniform plastic deformation elongation Ue ≥ 10%, yield strength ratio Rt0.5 / Rm ≤ 0.80", etc.

[0004] For the requirement of "resistance to a large deformation ", pipeline steels disclosed in patent documents such as application No. CN2009100760066.8, CN201210327206 and CN2009100760066.8 involve obtaining ferrite + bainite dual phase structure by relaxation and other methods, which has good resistance to a large deformation characteristics. However, because the structure is two-phase structure, see Fig. 2. Moreover, the two-phase structure has obvious strip along the rolling direction, so the HIC resistance is not ideal. The two-phase structure is easy to accumulate hydrogen at boundary, and the strip structure can also induce hydrogen accumulation. For the pipeline steel with two-phase structure of ferrite + bainite, the HIC resistance is tested according to the corresponding NACE standards. The steel plate has many HIC cracks along different directions of thickness, and the HIC resistance is not ideal.

Detailed description of the invention

[0005] Aiming at the above prior art, the invention provides a pipeline steel with both HIC resistance and resistance to a large deformation and a production method thereof, which can adapt to the product development of pipeline steel plate of Grade X80 and below. The pipeline steel not only has the characteristics of resistance to a large deformation such as low yield strength ratio, high uniform elongation and high stress ratio, but also shows good HIC resistance.

[0006] The technical scheme adopted by the invention to solve the above problems is: a pipeline steel with both HIC resistance and resistance to a large deformation, which is characterized in that the alloy constituents adopted are C: 0.015-0.039%, Si: 0.15-0.35%, Mn: 1.6-1.9%, S: ≤ 0.002%, P: ≤ 0.012%, Al: 0.02- 0.045%, Cr: 0.15-0.35%, 0.05 ≤ Nb + V + Ti ≤ 0.1%, Nb, V and Ti are not 0, Ni: 0.15-0.50%, Cu: 0.01-0.25%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.01-0.20%, and the balance is Fe and unavoidable impurity elements.

[0007] The content of Nb is determined as per the content of C and niobium carbide, and the content of Ti is determined as per the stoichiometric ratio of Ti / N of 3.42.

[0008] Further, the product is bainite single-phase structure, and the grain size of bainite is grade 11.5 to grade 12.

[0009] The transverse yield strength of the product of the invention Rt0.5: 490 - 550MPa, transverse tensile strength Rm: ≥ 710MPa, transverse yield ratio Rt0.5 / Rm ≤ 0.78, - 20 °C Charpy impact energy ≥ 350J, - 20 °C drop weight shear area SA% ≥ 90%;Longitudinal yield strength 460-530MPa; Longitudinal tensile strength ≥ 690MPa, longitudinal uniform elongation Uel ≥ 11%, longitudinal yield ratio ≤ 0.77; Longitudinal stress ratio Rt1.5/Rt0.5≥1.18, Rt2.0/Rt1.0≥1.1; And the HIC resistance of the product: after soaking in a solution according to NACE TM0284-2004 A for 96 hours, the crack length rate %: 0, the crack width rate %: 0, and the crack sensitivity rate %: 0.

[0010] The design basis for chemical constituents of the pipeline steel of the invention are as follows:

C: It is the most economical and basic strengthening element in steel. The strength of steel can be significantly improved through solid solution and precipitation, but it will have an adverse impact on the toughness, ductility and welding performance of steel. Therefore, the development trend of pipeline steel is to continuously reduce the C content. Considering the characteristics of large deformation resistant steel structure, in order to ensure the acquisition of specific bainite structure, it is necessary to control C within an appropriate range. In the invention, the content of C is controlled at ≤ 0.039%, preferably 0.015-0.039%.

Si:It is a deoxidizing element in steel, which improves the strength of steel in the form of solid solution strengthening, and is conducive to the corrosion resistance of steel. When the Si content is low, the deoxidation effect is poor, and when the Si content is high, the toughness will be reduced. The Si content of the invention is controlled to be

0.15-0.35%.

Mn: improving the strength of steel through solid solution strengthening is the most important element in pipeline steel to make up for the strength loss caused by the reduction of C content. Mn is also the element to expand γ phase zone, reduce $\gamma \rightarrow \alpha$ phase transformation temperature of steel. Mn is helpful to obtain fine phase transformation products, improve the toughness of steel and reduce the ductile brittle transition temperature. Mn is also an element to improve the hardenability of steel. The Mn content in the invention is designed to be in the range of 1.6-1.9%.

Al: mainly for nitrogen fixation and deoxidation. AlN formed by the bonding of Al and N can effectively refine the grain, but too high content will damage the toughness of the steel and deteriorate the hot workability. Therefore, the invention controls its content (Alt) in the range of 0.02-0.045%.

Cr: It is a ferrite forming element. At the same time, Cr can also improve the hardenability of steel. The invention controls Cr at 0.15-0.35%.

Nb: It is an element with obvious effect on grain refinement. The $\gamma \rightarrow \alpha$ phase transformation of steel can be delayed by solution drag of Nb. During the hot rolling process, Nb (C, N) strain induced precipitation can hinder the recovery and recrystallization of austenite. After rapid cooling, the deformed austenite rolled in the non-recrystallized zone forms fine phase transformation products during phase transformation, so as to improve the strength and toughness of steel. The invention determines the Nb content through the content of C, and the content of Nb and C is determined according to the relationship of 1:1.

V: It has high precipitation strengthening and weak grain refinement. When Nb, V and Ti are used in combination, V mainly plays the role of precipitation strengthening.

Ti: It is an element which can strongly solidify N element. The stoichiometric ratio of Ti / N is 3.42. Using about 0.02% Ti can fix the N below 60ppm in the steel, and TiN precipitates can be formed during billet continuous casting. This fine precipitates can effectively prevent the growth of austenite grains during billet heating and help to improve the solid solubility of Nb in austenite. At the same time, it can improve the impact toughness of welding heat affected zone, which is an indispensable element in pipeline steel.

Mo: It can suppress formation of ferrite during $\gamma \rightarrow \alpha$ phase transformation. It plays an important role in controlling phase transformation and improving the hardenability of steel. The invention controls Mo in the range of 0.01-0.20%.

S, P: It is an unavoidable impurity element in pipeline steel, which is easy to form segregation, inclusions and other defects, which will have an adverse impact on the toughness and hot workability of the steel plate, and its content should be reduced as far as possible. Adding an appropriate amount of Ca can change the long strip sulfide inclusion in the pipeline steel into spherical CaS inclusion, and significantly reduce the segregation of sulfur at the grain boundary. Ca is very beneficial to reduce the brittleness of the pipeline steel and improve the hot crack resistance of the pipeline steel during casting, but adding too much calcium will increase the inclusions in the pipeline steel, which is unfavorable to the improvement of toughness. The invention controls P $\leq$ 0.012%, S $\leq$ 0.002% and Ca $\leq$ 0.002%, so that the pipeline steel can obtain better toughness.

Cu, Ni: The strength of steel can be improved through solid solution strengthening. On the one hand, the addition of Ni can improve the toughness of steel and improve the thermal brittleness easily caused by Cu in steel. On the other hand, the addition of Ni can improve the hardenability. The invention controls Cu at 0.01-0.25%; Ni is controlled at 0.15-0.50%.

N: It is an impurity element harmful to toughness. In order to obtain excellent low-temperature toughness, the invention controls its content in steel $\leq$ 0.0046%.

[0011] The production method of pipeline steel with both HIC resistance and resistance to a large deformation in the application: first smelt the molten steel conforming to the chemical constituents design, cast the continuous casting billet with the chemical constituents consistent with the chemical constituents of the finished steel plate, heat the continuous casting billet to 1120-1160 °C for 3-4 hours, and then discharge the furnace; After descaling with high-pressure water, two-stage rolling is carried out: the first stage is recrystallization zone rolling, and the start rolling temperature is 1110-1150 °C. After multi pass rolling, the final rolling temperature is controlled at 1030-1080 °C, and the rolling deformation rate of two passes of rough rolling is controlled to be $\geq$ 19%; The second stage is rolled in the non-recrystallization zone. The start rolling temperature is 830-900 °C, the final rolling temperature is controlled at 750-840 °C, and the rolling cumulative deformation rate in the second stage is $\geq$ 70%; After rolling, according to the change of austenite microstructure, the steel plate is sent to the cooling system through a 45m-95m long roller table at a conveying speed of V = a * H, H is the steel plate thickness mm, a = 0.05-0.08m / (s * mm);

[0012] In the cooling system, the billet is directly quenched, air cooled to Ar_3 temperature after direct quenching, and then cooled rapidly. The final cooling temperature is controlled below 280 °C, straightened with temperature, and finally air cooled to room temperature to obtain X80 pipeline steel plate with both HIC and resistance to a large deformation.

[0013] The conveying speed of billet roller table after rolling shall take into account the microstructure dislocation movement of steel plate after sufficient deformation of austenite to obtain microstructure with different dislocation density at different grain positions, so as to provide growth conditions for obtaining very fine bainite structure.

[0014] Compared with the prior art, the invention has the advantages that according to the HIC resistance principle and hydrogen trap theory, in order to achieve good HIC resistance performance, it is prefer to have a relatively single and uniform structure. While according to the resistance to a large deformation principle, the structure needs to have excellent cooperative deformation ability in deformation in order to have excellent resistance to a large deformation ability. It is confirmed by research, some low carbon bainites have the ability to combine these two properties. According to the deformation principle, the bainite needs to be very small in order to give play to the good cooperative deformation effect between grains in the deformation process, so as to obtain excellent resistance to a large deformation . In order to obtain this very fine bainite, it is necessary to design the constituents and process. The pipeline steel developed by the invention has a uniform microstructure of very fine bainite, and the microstructure grain size reaches more than grade 11.5. Compared with the two-phase structure, H is not easy to aggregate, so it shows good HIC resistance.

Description of the Attached Drawings

[0015]

Figure 1 is the organization diagram of X80 grade pipeline steel plate with HIC and resistance to a large deformation in the embodiment of the invention;
Figure 2 shows the near surface microstructure of X80 pipeline steel obtained by conventional relaxation air cooling.

Detailed description of embodiments

[0016] The invention is described in further detail below in combination with the embodiments of the attached drawings. The embodiments described below with reference to the attached drawings are exemplary and are intended to explain the invention and cannot be understood as limitations on the invention.
[0017] The following embodiments take pipeline steel of X80 steel grade as an example. The performance and production difficulty of steel grades below X80 steel grade, such as X70 and X60, are lower than those of X80, so they are not listed one by one in this application.

Embodiment 1

[0018] The continuous casting billet with thickness no more than 370mm is produced by continuously casting the molten steel consistent with the chemical constituents of the prepared pipeline steel plate through the continuous casting machine. The chemical constituents of the obtained continuous casting billet includes: C: 0.015%, Si: 0.28%, Mn: 1.6%, S ≤ 0.002%, P ≤ 0.012%, Al: 0.03%, Cr: 0.35%, Nb + V + Ti: 0.06%, Ni: 0.50%, Cu: 0.15%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.13%. The balance is Fe and unavoidable impurity elements.
[0019] The continuous casting billet is heated to 1150 °C for 3.5 hours, discharged from the furnace, descaled by 20MPa high-pressure water, and then rolled in two stages: The first stage is rolled in the recrystallization zone, the start rolling temperature is 1150 °C, and rolled in seven passes, in which the deformation rate of two passes is ≥ 19%.The final rolling temperature is 1050 °C, and the thickness of the intermediate billet obtained after rolling in the recrystallization zone is 90mm; The second stage is rolled in the non-recrystallization zone. The start rolling temperature is 850 °C, the final rolling temperature is 810 °C, the cumulative deformation rate of rolling in the non-recrystallization zone is ≥ 70%, and the thickness of the finished pipeline steel plate is 22mm;After rolling, the steel plate is sent to the cooling system through a 60m long roller table at the conveying speed of 1. 1m/s. First, it is directly quenched in water, then air cooled to Ar_3 temperature after water is discharged, then is cooled rapidly by ACC, the final cooling temperature is 250 °C, and finally air cooled to room temperature. The microstructure of the obtained pipeline steel is very fine bainite with grain size of 11.5. The microstructure morphology in the thickness direction is shown in Fig. 1. Compared with X80 pipeline steel in the ferrite + bainite dual phase structure, as prepared by conventional relaxation air cooling shown in Fig. 2, the microstructure is more uniform and the bainite grain is finer. After testing, the strength and plasticity indexes are as follows: transverse yield strength Rt0.5: 540MPa; Tensile strength Rm: 740MPa, transverse yield ratio Rt0.5/Rm=0.76; Longitudinal yield strength 510MPa, - 20 °C Charpy impact energy = 450J, SA% (- 20 °C) = 90%; Longitudinal tensile strength Rm: 730MPa longitudinal uniform elongation Uel = 11%; Longitudinal yield ratio = 0.70; Longitudinal Rt1.5/Rt0.5=1.25, Rt2.0/Rt1.0 = 1.16.The HIC resistance test results are shown in Table 1.

Embodiment 2

[0020] The continuous casting billet with thickness no more than 370mm is produced by continuously casting the molten steel consistent with the chemical constituents of the prepared pipeline steel plate through the continuous casting machine. The chemical constituents of the obtained continuous casting billet includes: C: 0.03%, Si: 0.30%, Mn: 1.6%, S≤ 0.002%, P ≤ 0.012%, Al: 0.03%, Cr: 0.25%, Nb + V + Ti: 0.06%, Ni: 0.25%, Cu: 0.15%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.13%. The balance is Fe and unavoidable impurity elements.

[0021] The continuous casting billet is heated to 1150 °C for 3.5 hours, discharged from the furnace, descaled by 20MPa high-pressure water, and then rolled in two stages: The first stage is rolled in the recrystallization zone, the start rolling temperature is 1150 °C, and rolled in seven passes, in which the deformation rate of two passes is ≥ 19%.The final rolling temperature is 1050 °C, and the thickness of the intermediate billet obtained after rolling in the recrystallization zone is 90mm;The second stage is rolled in the non-recrystallization zone. The start rolling temperature is 850 °C, the final rolling temperature is 810 °C, the cumulative deformation rate of rolling in the non-recrystallization zone is ≥ 70%, and the thickness of the finished pipeline steel plate is 22mm;After rolling, the steel plate is sent to the cooling system through a 60m long roller table at the conveying speed of 1.1m/s. First, it is directly quenched in water, then air cooled to Ar_3 temperature after water is discharged, then is cooled rapidly by ACC, the final cooling temperature is 250 °C, and finally air cooled to room temperature. The microstructure of the obtained pipeline steel is very fine bainite with grain size of 11.5. The microstructure morphology in the thickness direction is shown in Fig. 1. Compared with X80 pipeline steel in the ferrite + bainite dual phase structure, as prepared by conventional relaxation air cooling shown in Fig. 2, the microstructure is more uniform and the bainite grain is finer. After testing, the strength and plasticity indexes are as follows: transverse yield strength Rt0.5: 535MPa; Tensile strength Rm: 735MPa, transverse yield ratio Rt0.5/Rm=0.76; Longitudinal yield strength 500MPa, - 20 °C Charpy impact energy = 450J, SA% (- 20 °C) = 90%; Longitudinal tensile strength Rm: 730MPa longitudinal uniform elongation Uel = 12%; Longitudinal yield ratio = 0.68; Longitudinal Rt1.5/Rt0.5=1.27, Rt2.0/Rt1.0 = 1.17, the HIC resistance test results are shown in Table 1.

Embodiment 3

[0022] The continuous casting billet with thickness no more than 370mm is produced by continuously casting the molten steel consistent with the chemical constituents of the prepared pipeline steel plate through the continuous casting machine. The chemical constituents of the obtained continuous casting billet includes: C: 0.033%, Si: 0.25%, Mn: 1.8%, S≤0.002%, P≤0.012%, Al: 0.03%, Cr: 0.25%, Nb+V+Ti: 0.08%, Ni: 0.3%, Cu: 0.12%, Ca: ≤0.002%, N: ≤0.0046%, Mo: 0.20%. The balance is Fe and unavoidable impurity elements.

[0023] The continuous casting billet is heated to 1150 °C for 3.0 hours, discharged from the furnace, descaled by 20MPa high-pressure water, and then rolled in two stages: The first stage is rolled in the recrystallization zone, the start rolling temperature is 1150 °C, and rolled in five passes, in which the deformation rate of two passes is ≥ 17%. The final rolling temperature is 1030 °C, and the thickness of the intermediate billet obtained after rolling in the recrystallization zone is 95mm; The second stage is rolled in the non-recrystallization zone. The start rolling temperature is 850 °C, the final rolling temperature is 830 °C, the cumulative deformation rate of rolling in the non-recrystallization zone is ≥ 60%, and the thickness of the finished pipeline steel plate is 26.4mm;After rolling, the steel plate is sent to the cooling system through a 60m long roller table at the conveying speed of 1.55m/s. First, it is directly quenched in water, then air cooled to Ar_3 temperature after water is discharged, then is cooled rapidly by ACC, the final cooling temperature is 270 °C, and finally air cooled to room temperature. The microstructure of the obtained pipeline steel is very fine bainite. After testing, the strength and plasticity indexes are as follows: Transverse yield strength Rt0.5: 510MPa; Tensile strength RM: 705MPa, Transverse yield ratio Rt0.5/Rm=0.72; Longitudinal yield strength 505MPa, - 20 °C Charpy impact energy=380J, SA% (-20 °C)=96%; Longitudinal tensile strength Rm: 700MPa longitudinal uniform elongation Uel=12.5%; Longitudinal yield ratio = 0.72; Longitudinal Rt1.5/Rt0.5=1.22, Rt2.0/Rt1.0=1.18, the HIC resistance test results are shown in Table 1.

Embodiment 4

[0024] The continuous casting billet with a thickness of no more than 370mm is produced by continuously casting the molten steel consistent with the chemical constituents of the prepared pipeline steel plate through the continuous casting machine. The chemical constituents of the obtained continuous casting billet includes: C: 0.039%, Si: 0.25%, Mn: 1.85%, S ≤ 0.002%, P ≤ 0.012%, Al: 0.03%, Cr: 0.25%, Nb + V + Ti: 0.10%, Ni: 0.45%, Cu: 0.25%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.20%. The balance is Fe and unavoidable impurity elements.

[0025] The continuous casting billet is heated to 1160 °C for 4.0 hours, discharged from the furnace, descaled by 20MPa high-pressure water, and then rolled in two stages: The first stage is rolled in the recrystallization zone, the start rolling temperature is 1140 °C, and rolled in five passes, in which the deformation rate of two passes is ≥ 17%. The final rolling temperature is 1050 °C, and the thickness of the intermediate billet obtained after rolling in the recrystallization zone is 110mm; The second stage is rolled in the non-recrystallization zone. The start rolling temperature is 870 °C, the final rolling temperature is 840 °C, the cumulative deformation rate of rolling in the non-recrystallization zone is ≥ 60%, and the thickness of the finished pipeline steel plate is 33mm; After rolling, the steel plate is sent to the cooling system through a 85m long roller table at the conveying speed of 2.0m/s. First, it is directly quenched in water, then air cooled to Ar_3 temperature after water is discharged, then is cooled rapidly by ACC, the final cooling temperature is 280 °C, and finally air cooled to room temperature. The microstructure of the obtained pipeline steel is very fine bainite. After testing, the strength and plasticity indexes are as follows: Transverse yield strength Rt0.5: 485MPa; Tensile strength Rm: 710MPa, transverse yield ratio Rt0.5/Rm=0.68; Longitudinal yield strength 475MPa, - 20 °C Charpy impact energy=420J, SA% (- 20 °C)=85%; Longitudinal tensile strength Rm: 695MPa longitudinal uniform elongation Uel=12.5%; Longitudinal yield ratio = 0.68; Longitudinal Rt1.5/Rt0.5=1.23, Rt2.0/Rt1.0=1.17, The HIC resistance test results are shown in Table 1.

Table 1 HIC Resistance of X80 Pipeline Steel in Each Embodiment

Embodiment	HIC test standard: soak in a solution according to NACE TM0284-2004 A for 96 hours		
	Crack length rate%	Crack width ratio%	Crack sensitivity%
1	0	0	0
	0	0	0
	0	0	0
2	0	0	0
	0	0	0
	0	0	0
3	0	0	0
	0	0	0
	0	0	0
4	0	0	0
	0	0	0
	0	0	0

Claims

1. A pipeline steel with both HIC resistance and resistance to a large deformation, which is **characterized in that** the alloy constituents are C: 0.015-0.039%, Si: 0.15-0.35%, Mn: 1.6-1.9%, S: ≤ 0.002%, P: ≤ 0.012%, Al: 0.02-0.045%, Cr: 0.15-0.35%, 0.05 ≤ Nb + V + Ti ≤ 0.1%, Nb, V and Ti are not 0, Ni: 0.15-0.50%, Cu: 0.01-0.25%, Ca: ≤ 0.002%, N: ≤ 0.0046%, Mo: 0.01-0.20%, and the balance is Fe and unavoidable impurity elements.

2. The pipeline steel with both HIC resistance and resistance to a large deformation according to claim 1, which is **characterized in that** the product has a bainite single-phase structure, and the grain size of bainite is grade 11.5 to grade 12.

3. The pipeline steel with both HIC resistance and resistance to a large deformation according to claim 1, which is **characterized in that** the transverse yield strength of the product is Rt0.5: 490-550MPa, transverse tensile strength Rm: ≥ 710MPa, transverse yield ratio Rt0.5 / Rm ≤ 0.78, - 20 °C Charpy impact energy ≥ 350J, - 20 °C drop weight shear area SA% ≥ 90%; longitudinal yield strength 460-530MPa; longitudinal tensile strength ≥ 690MPa, longitudinal uniform elongation Uel ≥ 11%, longitudinal yield ratio ≤ 0.77; longitudinal stress ratio Rt1.5/Rt0.5≥1.18, Rt2.0/Rt1.0≥1.1;
and the HIC resistance of the product: after soaking in a solution according to NACE TM0284-2004 A for 96 hours, the crack length rate % is 0, the crack width rate % is 0, and the crack sensitivity rate % is 0.

4. A production method for pipeline steel with both HIC resistance and resistance to a large deformation according to any one of claims 1-3, which is **characterized by**:
a continuous casting billet is heated to 1120-1160°C for 3-4 hours, removed out of the furnace, descaled by high-pressure water, and then rolled in two stages:

the first stage is rolling in recrystallization zones, wherein the start rolling temperature is 1110-1150 °C, and after rolling of several passes, the final rolling temperature is 1030-1080°C, wherein a deformation rate of two passes is ≥19%;

the second stage is rolling in non-recrystallization zones, wherein the start rolling temperature is 830-900 °C, the final rolling temperature is 750-840°C, and the total deformation rate of rolling in the second stage is ≥ 70%; after rolling, the steel plate is sent to a cooling system at a conveying speed of V=a*H. wherein H is thickness of steel mm, a= 0.05-0.08 m/(s*mm) ;
in the cooling system, firstly directly quenching in water, then air cooling to Ar_3 temperature, and then rapidly cooling, and a final cooling temperature is controlled to be lower than 280 °C, straightening when the steel plate is still warm, and finally air cooling to room temperature, to obtain X80 grade pipeline steel with both HIC resistance and resistance to a large deformation .

5. The production method of pipeline steel with both HIC resistance and resistance to a large deformation according to claim 4, which is **characterized in that** ACC water cooling is adopted for rapid cooling in the cooling system.

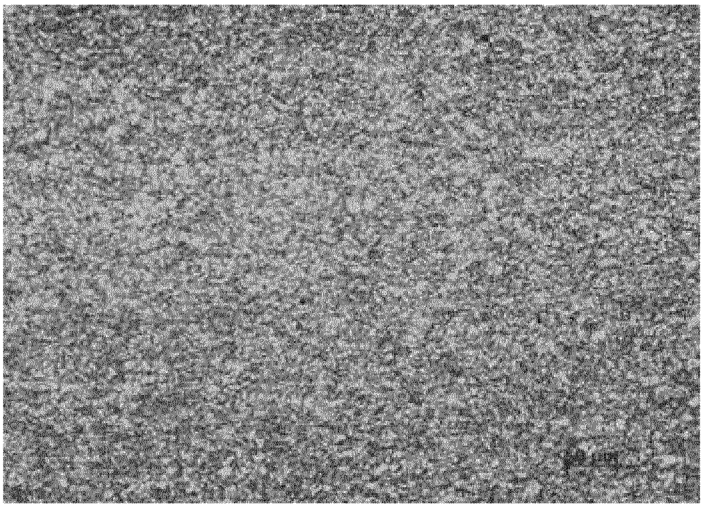

Figure 1

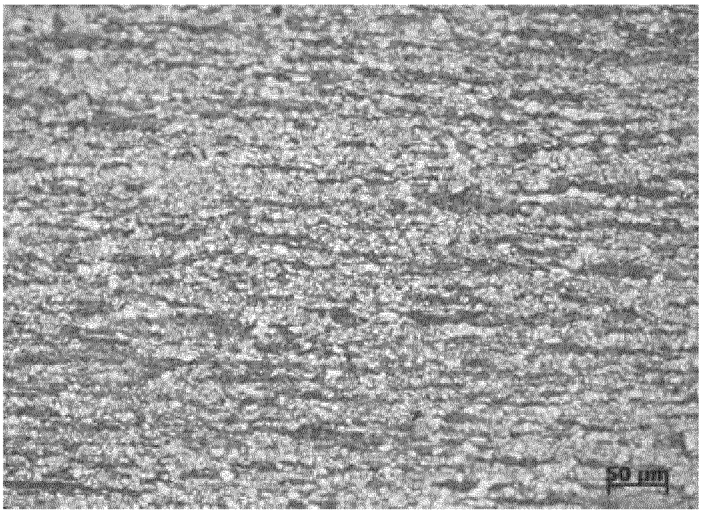

Figure 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/088281

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; C22C 38/48(2006.01)i; C22C 38/46(2006.01)i; C22C 38/50(2006.01)i; C22C 38/42(2006.01)i; C22C 38/44(2006.01)i; C22C 38/02(2006.01)i; C22C 38/06(2006.01)i; C21D 8/02(2006.01)i

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)

C22C 38, C21D

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)

DWPI, SIPOABS, CN-PAT, CNKI: 硅, 锰, 铬, 铌, 钛, 钒, 镍, 钼, 铜, 管, 贝氏体, Si, Silicon, Silicium, Silicone, Mn, Manganese, Manganous, Manganum, Mangan, Cr, Chromium, Chrome, Chrom, Nb, Niobium, Niob, Ti, Titanium, Titanic, V, Vanadium, Ni, Nickel, Mo, Molybdenum, Cu, Copper, pipe+, tube?, bainite

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 110964991 A (JIANGYIN XINGCHENG SPECIAL STEEL WORKS CO., LTD.) 07 April 2020 (2020-04-07) claims 1-5	1-5
Y	CN 104451446 A (WUHAN IRON & STEEL (GROUP) CORPORATION) 25 March 2015 (2015-03-25) description paragraphs 0011-0018, 0043	1-5
Y	CN 107406948 A (JFE STEEL CORPORATION) 28 November 2017 (2017-11-28) description paragraphs 0056, 0069	1-5
X	CN 110284066 A (BAOSTEEL ZHANJIANG IRON AND STEEL CO., LTD.) 27 September 2019 (2019-09-27) claims 1 and 2	1, 2
X	CN 108342655 A (BAOSHAN IRON & STEEL CO., LTD.) 31 July 2018 (2018-07-31) claims 1 and 2	1,
X	JP 2012241267 A (JFE STEEL CORP.) 10 December 2012 (2012-12-10) claims 1 and 2	1,

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "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
28 August 2020	**07 September 2020**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088** **China**	Authorized officer
Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/088281

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2015189984 A (JFE STEEL CORP.) 02 November 2015 (2015-11-02) claims 2, 3	1,
A	CN 108342651 A (SHOUGANG GROUP CO., LTD.) 31 July 2018 (2018-07-31) entire document	1-5
A	CN 102011064 A (CHINA NATIONAL PETROLEUM CORPORATION et al.) 13 April 2011 (2011-04-13) entire document	1-5

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/088281

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 110964991 A	07 April 2020	None	
CN 104451446 A	25 March 2015	CN 104451446 B	25 January 2017
CN 107406948 A	28 November 2017	US 2018051363 A1	22 February 2018
		EP 3276026 A4	18 April 2018
		JP 6256654 B2	10 January 2018
		CN 107406948 B	08 March 2019
		CA 2980424 C	10 March 2020
		KR 20170128574 A	22 November 2017
		CA 2980424 A1	29 September 2016
		KR 102032105 B1	15 October 2019
		EP 3276026 B1	28 August 2019
		JP WO2016152172 A1	15 June 2017
		EP 3276026 A1	31 January 2018
		WO 2016152172 A1	29 September 2016
CN 110284066 A	27 September 2019	None	
CN 108342655 A	31 July 2018	None	
JP 2012241267 A	10 December 2012	JP 5782828 B2	24 September 2015
JP 2015189984 A	02 November 2015	None	
CN 108342651 A	31 July 2018	None	
CN 102011064 A	13 April 2011	CN 102011064 B	19 June 2013

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 2009100760066 **[0004]**
- CN 201210327206 **[0004]**