

(19)



(11)

EP 4 015 669 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:

07.05.2025 Bulletin 2025/19

(21) Application number: **20896953.5**

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

(51) International Patent Classification (IPC):

C22C 38/04 ^(2006.01) **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)
C21D 9/46 ^(2006.01) **C21D 1/02** ^(2006.01)
C21D 1/19 ^(2006.01) **C21D 1/60** ^(2006.01)
C21D 1/613 ^(2006.01)

(52) Cooperative Patent Classification (CPC):

C22C 38/02; C21D 1/02; C21D 1/19; C21D 1/60;
C21D 1/613; C21D 8/0205; C21D 8/0226;
C21D 8/0236; C21D 8/0263; C21D 9/46;
C22C 38/04; C22C 38/42; C22C 38/44;
C22C 38/46; C22C 38/48;

(Cont.)

(86) International application number:

PCT/CN2020/088281

(87) International publication number:

WO 2021/109439 (10.06.2021 Gazette 2021/23)

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

HITZEBESTÄNDIGER UND STARK VERFORMUNGSBESTÄNDIGER ROHRLEITUNGSSTAHL UND HERSTELLUNGSVERFAHREN DAFÜR

ACIER DE CANALISATION RÉSISTANT AUX HIC ET RÉSISTANT AUX DÉFORMATIONS IMPORTANTES ET SON PROCÉDÉ DE PRÉPARATION

(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

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

(43) Date of publication of application:

22.06.2022 Bulletin 2022/25

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EP 4 015 669 B1

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(52) Cooperative Patent Classification (CPC): (Cont.)
C22C 38/50; C22C 38/58; C21D 2211/002

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 $U_e \geq 10\%$, yield strength ratio $R_{t0.5} / R_m \leq 0.80$ ", 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. Further prior art is disclosed in CN104451446A.

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: $\leq 0.002\%$, P: $\leq 0.012\%$, Al: 0.02-0.045%, Cr: 0.15-0.35%, $0.05 \leq Nb + V + Ti \leq 0.1\%$, Nb, V and Ti are not 0, Ni: 0.15-0.50%, Cu: 0.01-0.25%, Ca: $\leq 0.002\%$, N: $\leq 0.0046\%$, 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 $R_{t0.5}$: 490 - 550MPa, transverse tensile strength R_m : ≥ 710 MPa, transverse yield ratio $R_{t0.5} / R_m \leq 0.78$, - 20 °C Charpy impact energy ≥ 350 J, - 20 °C drop weight shear area $SA\% \geq 90\%$; Longitudinal yield strength 460-530MPa; Longitudinal tensile strength ≥ 690 MPa, longitudinal uniform elongation $U_{el} \geq 11\%$, longitudinal yield ratio ≤ 0.77 ; Longitudinal stress ratio $R_{t1.5}/R_{t0.5} \geq 1.18$, $R_{t2.0}/R_{t1.0} \geq 1.1$; 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 $\leq 0.039\%$, 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 (Al_T) 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 $V = a \cdot H$, H is the steel plate thickness mm, $a = 0.05-0.08 \text{ m} / (\text{s} \cdot \text{mm})$;

[0012] In the cooling system, the billet is directly quenched, air cooled to A_{r3} 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 $\leq$ 0.002%, P $\leq$ 0.012%, Al: 0.03%, Cr: 0.35%, Nb + V + Ti: 0.06%, Ni: 0.50%, Cu: 0.15%, Ca: $\leq$ 0.002%, N: $\leq$ 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 $\geq$ 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 $\geq$ 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 Ar₃ 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 $\leq$ 0.002%, P $\leq$ 0.012%, Al: 0.03%, Cr: 0.25%, Nb + V + Ti: 0.06%, Ni: 0.25%, Cu: 0.15%, Ca: $\leq$ 0.002%, N: $\leq$ 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 $\geq$ 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 $\geq$ 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 Ar₃ 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, SA₅₀ (- 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 $\leq$ 0.002%, P $\leq$ 0.012%, Al: 0.03%, Cr: 0.25%, Nb+V+Ti: 0.08%, Ni: 0.3%, Cu: 0.12%, Ca: $\leq$ 0.002%, N: $\leq$ 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 $\geq$ 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 $\geq$ 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 Ar₃ 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, SA₅₀ (-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 $\leq$ 0.002%, P $\leq$ 0.012%, Al: 0.03%, Cr: 0.25%, Nb + V + Ti: 0.10%, Ni: 0.45%, Cu: 0.25%, Ca: $\leq$ 0.002%, N: $\leq$ 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 $\geq$ 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 $\geq$ 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 Ar₃

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 $R_{t0.5}$: 485MPa; Tensile strength R_m : 710MPa, transverse yield ratio $R_{t0.5}/R_m=0.68$; Longitudinal yield strength 475MPa, -20 °C Charpy impact energy=420J, SA% (-20 °C)=85%; Longitudinal tensile strength R_m : 695MPa longitudinal uniform elongation $U_{el}=12.5\%$; Longitudinal yield ratio = 0.68; Longitudinal $R_{t1.5}/R_{t0.5}=1.23$, $R_{t2.0}/R_{t1.0}=1.17$, 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: $\leq 0.002\%$, P: $\leq 0.012\%$, Al: 0.02-0.045%, Cr: 0.15-0.35%, $0.05 \leq Nb + V + Ti \leq 0.1\%$, Nb, V and Ti are not 0, Ni: 0.15-0.50%, Cu: 0.01-0.25%, Ca: $\leq 0.002\%$, N: $\leq 0.0046\%$, Mo: 0.01-0.20%, and the balance is Fe and unavoidable impurity elements;

wherein the pipeline steel has a bainite single-phase structure, and the grain size of bainite is grade 11.5 to grade 12;

wherein transverse yield strength of the pipeline steel is $R_{t0.5}$: 490-550MPa, transverse tensile strength R_m : ≥ 710 MPa, transverse yield ratio $R_{t0.5}/R_m \leq 0.78$, -20 °C Charpy impact energy ≥ 350 J, -20 °C drop weight shear area SA% $\geq 90\%$; longitudinal yield strength 460-530MPa; longitudinal tensile strength ≥ 690 MPa, longitudinal uniform elongation $U_{el} \geq 11\%$, longitudinal yield ratio ≤ 0.77 ; longitudinal stress ratio $R_{t1.5}/R_{t0.5} \geq 1.18$, $R_{t2.0}/R_{t1.0} \geq 1.1$;

and the HIC resistance of the pipeline steel: 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.

2. A production method for pipeline steel with both HIC resistance and resistance to a large deformation according to claim 1, wherein 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 $\geq 19\%$;

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 $\geq 70\%$; after rolling, the steel plate is sent to a cooling system through a 45m-95m long roller table at a conveying speed of $V=a \cdot H$. 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 $280^\circ C$, 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 .

3. The production method of pipeline steel with both HIC resistance and resistance to a large deformation according to claim 2, wherein ACC water cooling is adopted for rapid cooling in the cooling system.

Patentansprüche

1. Rohrleitungsstahl mit sowohl Hitzebestand als auch Bestand gegen eine starke Verformung, der **dadurch gekennzeichnet ist, dass** die Legierungsbestandteile wie folgt sind: C: 0,015-0,039 %, Si: 0,15-0,35 %, Mn: 1,6-1,9 %, S: $\leq 0,002$ %, P: $\leq 0,012$ %, Al: 0,02-0,045 %, Cr: 0,15-0,35 %, $0,05 \leq Nb + V + Ti \leq 0,1$ %, wobei Nb, V und Ti nicht 0 sind, Ni: 0,15-0,50 %, Cu: 0,01-0,25 %, Ca: $\leq 0,002$ %, N: $\leq 0,0046$ %, Mo: 0,01-0,20 %, und wobei der Rest Fe und unvermeidbare Unreinheitselemente sind;

wobei der Rohrleitungsstahl eine einphasige Bainitstruktur aufweist und die Korngröße von Bainit Grad 11,5 bis Grad 12 ist;

wobei Querstreckfestigkeit des Rohrleitungsstahls $Rt_{0,5}$: 490-550 MPa, Querkzugfestigkeit R_m : ≥ 710 MPa, Querstreckverhältnis $Rt_{0,5}/R_m \leq 0,78$, $-20^\circ C$ Kerbschlagenergie $\geq 350 J$, $-20^\circ C$ Fallgewichtsscherfläche $SA\% \geq 90$ %; Längsstreckfestigkeit 460-530 MPa; Längszugfestigkeit ≥ 690 MPa, Längsgleichmaßdehnung $U_{el} \geq 11$ %, Längsertragsverhältnis $\leq 0,77$; Längsspannungsverhältnis $Rt_{1,5}/Rt_{0,5} \geq 1,18$, $Rt_{2,0}/Rt_{1,0} \geq 1,1$ ist;

und der Hitzebestand des Rohrleitungsstahls: nach Einweichen in einer Lösung gemäß NACE TM0284-2004 A für 96 Stunden ist die Risslängenrate % 0, ist die Rissbreitenrate % 0 und ist die Rissempfindlichkeitsrate % 0.

2. Produktionsverfahren für Rohrleitungsstahl mit sowohl Hitzebestand als auch Bestand gegen eine starke Verformung nach Anspruch 1, wobei ein Stranggussblock 3-4 Stunden auf $1120-1160^\circ C$ erhitzt, aus dem Ofen entfernt, durch Hochdruckwasser entzündet und dann in zwei Stufen gewalzt wird:

die erste Stufe Walzen in Rekristallisationszonen ist, wobei die Startwalztemperatur $1110-1150^\circ C$ ist und nach dem Walzen von mehreren Durchgängen die finale Walztemperatur $1030-1080^\circ C$ ist, wobei eine Verformungsrate von zwei Durchgängen ≥ 19 % ist;

die zweite Stufe Walzen in Nichtrekristallisationszonen ist, wobei die Startwalztemperatur $830-900^\circ C$ ist, die finale Walztemperatur $750-840^\circ C$ ist und die Gesamtverformungsrate des Walzens in der zweiten Stufe ≥ 70 % ist;

nach dem Walzen die Stahlplatte zu einem Kühlsystem durch einen 45 m-95 m langen Walztisch mit einer Fördergeschwindigkeit von $V=a \cdot H$ geschickt wird, wobei H Dicke von Stahl mm ist, $a=0,05-0,08$ m/(s*mm);

in dem Kühlsystem, zuerst direktes Abschrecken in Wasser, dann Luftkühlen auf Ar_3 -Temperatur und dann schnelles Abkühlen, und eine finale Kühltemperatur gesteuert wird, um niedriger als $280^\circ C$ zu sein, Richten, wenn die Stahlplatte noch warm ist, und schließlich Luftkühlen auf Raumtemperatur, um Rohrleitungsstahl Grad X80 mit sowohl Hitzebestand als auch Bestand gegen eine starke Verformung zu erhalten.

3. Produktionsverfahren für Rohrleitungsstahl mit sowohl Hitzebestand als auch Bestand gegen eine starke Verformung nach Anspruch 2, wobei ACC-Wasserkühlung für schnelle Kühlung in dem Kühlsystem angenommen wird.

Revendications

1. Acier de canalisation présentant à la fois une résistance aux HIC et une résistance à une déformation importante, qui est **caractérisé en ce que** les constituants de l'alliage sont C : 0,015 à 0,039 %, Si : 0,15 à 0,35 %, Mn : 1,6 à 1,9 %, S : $\leq 0,002$ %, P : $\leq 0,012$ %, Al : 0,02 à 0,045 %, Cr : 0,15 à 0,35 %, $0,05 \leq Nb + V + Ti \leq 0,1$ %, Nb, V et Ti ne sont pas égaux à 0, Ni : 0,15 à 0,50 %, Cu : 0,01 à 0,25 %, Ca : $\leq 0,002$ %, N : $\leq 0,0046$ %, Mo : 0,01 à 0,20 % et le reste étant Fe et des éléments d'impureté inévitables ;

l'acier de canalisation comportant une structure monophase de bainite, et la granulométrie de la bainite étant de grade 11,5 à grade 12 ;

une limite d'élasticité transversale de l'acier de canalisation étant $Rt_{0,5}$: 490 à 550 MPa, une résistance à la

traction transversale $R_m \geq 710$ MPa, un rapport d'élasticité transversale $R_{t0,5} / R_m \leq 0,78$, une énergie au choc Charpy à $20^\circ\text{C} \geq 350$ J, un pourcentage de surface de cisaillement par masse tombante $SA\% \text{ à } 20^\circ\text{C} \geq 90\%$; une limite d'élasticité longitudinale 460 à 530 MPa ; une résistance à la traction longitudinale ≥ 690 MPa, un allongement longitudinal uniforme $U_{el} \geq 11\%$, un rapport d'élasticité longitudinale $\leq 0,77$; un rapport de

contrainte longitudinale $R_{t1,5}/R_{t0,5} \geq 1,18$, $R_{t2,0}/R_{t1,0} \geq 1,1$;
et la résistance aux HIC de l'acier de canalisation étant comme suit : après trempage dans une solution selon NACE TM0284-2004 A pendant 96 heures, le taux de longueur de fissure est de 0 %, le taux de largeur de fissure est de 0 % et le taux de sensibilité de fissure est de 0 %.

2. Procédé de production d'un acier de canalisation présentant à la fois une résistance aux HIC et une résistance à une déformation importante selon la revendication 1, une billette de coulée continue étant chauffée entre 1120 et 1160°C pendant 3 à 4 heures, retirée du four, détartrée par de l'eau à haute pression, puis laminée en deux étapes :

la première étape étant un laminage dans des zones de recristallisation, la température de laminage initiale étant comprise entre 1110 et 1150°C et la température de laminage finale, après laminage en plusieurs passes, étant comprise entre 1030 et 1080°C , un taux de déformation de deux passes étant $\geq 19\%$;

la seconde étape étant un laminage dans des zones de non-recristallisation, la température de laminage de départ est comprise entre 830 et 900°C , la température de laminage finale étant comprise entre 750 et 840°C et le taux de déformation total du laminage lors de la seconde étape étant $\geq 70\%$;

après laminage, la tôle d'acier étant envoyée à un système de refroidissement par l'intermédiaire d'un train de rouleaux de 45 m à 95 m de long à une vitesse de transport de $V=a \cdot H$, où H est l'épaisseur de l'acier en mm et $a=0,05$ à $0,08$ m/(s*mm) ;

dans le système de refroidissement, la tôle d'acier étant d'abord directement trempée dans de l'eau, puis refroidie à l'air à la température Ar_3 , puis refroidie rapidement, une température de refroidissement finale étant régulée pour être inférieure à 280°C , puis redressée lorsque la tôle d'acier est encore chaude, et enfin refroidie à l'air à température ambiante, afin d'obtenir un acier de canalisation de qualité X80 présentant à la fois une résistance aux HIC et une résistance à une déformation importante.

3. Procédé de production d'un acier de canalisation présentant à la fois une résistance aux HIC et une résistance à une déformation importante selon la revendication 2, un refroidissement à l'eau ACC étant adopté pour un refroidissement rapide dans le système de refroidissement.

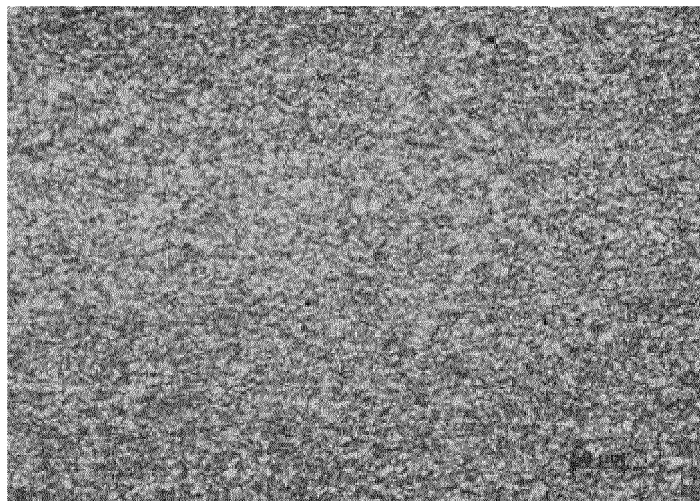


Figure 1

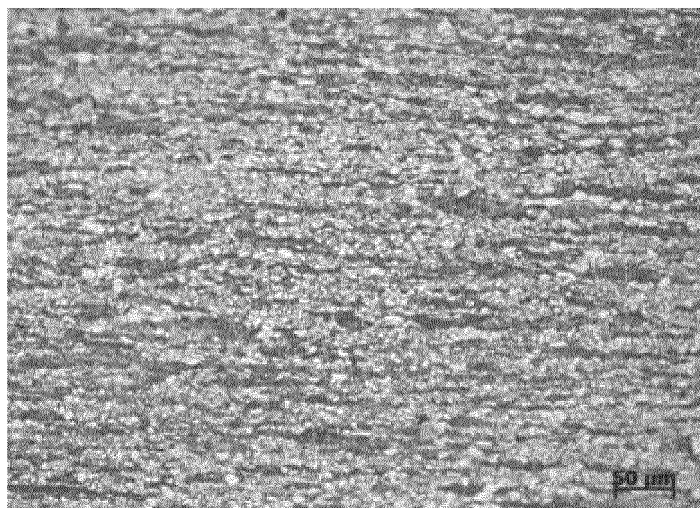


Figure 2

REFERENCES CITED IN THE DESCRIPTION

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