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(54) **SMELTING METHOD OF HIGH-NITROGEN AND HIGH- CHROMIUM PLASTIC MOLD STEEL AND AND HEAT TREATMENT THEREOF**

VERFAHREN ZUM SCHMELZEN VON KUNSTSTOFFFORMSTAHL MIT HOHEM STICKSTOFF- UND HOHEM CHROMGEHALT UND WÄRMEBEHANDLUNG DESSELBEN

PROCÉDÉ DE FUSION D'ACIER POUR MOULE PLASTIQUE À HAUTE TENEUR EN AZOTE ET EN CHROME ET TRAITEMENT THERMIQUE DE CELUI-CI

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EP 3 889 285 B1

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Description**Field of the Invention**

5 **[0001]** The present invention relates to the field of metal materials, in particular to a high-nitrogen and high-chromium plastic mold steel and a smelting method and a heat treatment method thereof.

Background of the invention

10 **[0002]** With the rapid development of the plastic mold industry, higher corrosion resistance is required for plastic mold steel in addition to high strength and toughness, especially in the production of plastic products made of PVC, fluoroplastics and flame retardant ABS. Hydrogen chloride, hydrogen fluoride and sulfur dioxide decomposed from plastics in a molten state have a strong corrosive effect on mold cavities.

15 **[0003]** In order to meet the above service conditions, plastic mold steel 3Cr17NiMo has been developed in China. The steel is developed on the basis of comprehensive analysis of the advantages and disadvantages of S136 steel from Sweden and 1.2316 steel from Germany, and is widely applied in the production of PVC and other plastic products with a strong corrosive effect.

20 **[0004]** JP H11 335782 A discloses a plastic mold steel comprising, by weight, C: 0.15 to 0.45%, Si: 1.0% or less, Mn: 2.0% or less, Cr: 13 to 25%, Ni: 4.0% or less, Mo: 3.0% or less, and N: 0.05 to 0.20%, provided that C + N: less than 0.50%, the balance has an alloy composition consisting of unavoidable impurities and Fe.

25 **[0005]** US 2018/0179618 A1 relates to a powder metallurgy wear and corrosion resistance alloy including chemical components by mass percent of: C: 2.36%-3.30%, W: 0.1%-1.0%, Mo: $\leq$ 1.8%, Cr: 12.6%-18.0%, V: 6.0%-12.5%, Nb: 0.5%-2.1%, Co: 0.1%-0.5%, Si: 1.0%, Mn: 0.2%-1.0%, N: 0.05%-0.35%, with balance iron and impurities; wherein a carbide component of the powder metallurgy wear and corrosion resistance alloy is an MX carbide and a M_7C_3 carbide, wherein the MX carbide has a NaCl type face-centered cubic lattice structure; an M element of the MX carbide comprises V and Nb, and an X element of the MX carbide comprises C and N and a method for preparing the alloy.

30 **[0006]** EP 0 688 883 A1 relates to a martensitic heat-resisting steel excellent in HAZ (heat-affected zone)-softening resistance and used in a high temperature and high pressure environment. The steel is produced by adding titanium, zirconium, tantalum and hafnium to a molten steel having the above-specified chemical composition during the period from 10 minutes before the completion of refining to the completion of refining, then casting and working the refined steel, subjecting the worked steel to solution heat-treatment suspending the cooling step at 950 to 1000°C, and holding the steel thus treated at that temperature for 5-60 minutes. JP 2017 150045 A describes a martensitic stainless steel which contains 0.15-0.40 mass% of C, 1.0 mass% or less of Si, 2.0 mass% or less of Mn, 0.60 mass% or less of Ni, 12.0-17.0 mass% of Cr, 2.0 mass% or less of Mo, 0.1-1.5 mass% of Cu and 0.07-0.15 mass% of N. The balance is Fe with inevitable impurities.

35 **[0007]** However, with the increasing demand for plastic products in the market and cost problems resulting from fierce competition, it is required that plastic molds have higher corrosion resistance to meet the long life of plastic mold cavities.

Summary of the Invention

40 **[0008]** The present invention is set out in the appended set of claims, wherein the drawings and respective description relate to advantageous embodiments thereof. The technical problem to be solved by the present invention is to provide a smelting method of the high-nitrogen and high-chromium plastic mold steel. According to a first aspect of the present invention, the smelting method comprises the following steps:

- 45
- A. smelting: smelting an IF steel in an electric furnace until the IF steel is completely melted;
 - B. refining: pouring the completely melted molten steel into an LF furnace for slagging and alloying;
 - C. nitriding: blowing nitrogen for nitrogen alloying; and
 - D. tapping: tapping and casting into ingots after nitrogen blowing, wherein

50 the tapping control temperature of the molten steel is 1540 - 1560°C in step D, the high-nitrogen and high-chromium plastic mold steel comprises the following chemical components by mass: 0.25 - 0.35% of C, 0.45 - 0.8% of Si, 0.4 - 0.7% of Mn, 16.5 - 17.5% of Cr, 0.1 - 0.3% of Ni, 0.1 - 0.5% of Mo, 0.06 - 0.10% of N, and the rest of Fe and inevitable impurity elements and

55 the impurity elements comprise Al $\leq$ 0.02%, P $\leq$ 0.025%, S $\leq$ 0.005%, O $\leq$ 0.003% and H $\leq$ 0.0002%.

[0009] In a further embodiment, the step D of the smelting method of the high-nitrogen and high-chromium plastic mold steel further comprises forging or rolling into 180 - 250 mm thick flat steel after casting into ingots.

[0010] In a preferred embodiment, in the step A of the smelting method of the high-nitrogen and high-chromium plastic mold steel, the IF steel is an IF steel billet or IF steel scrap.

[0011] In another embodiment, in the step A of the smelting method of the high-nitrogen and high-chromium plastic mold steel, the smelting temperature is 1630 - 1650°C. The pressure in the furnace is 1 standard atmospheric pressure.

[0012] Preferably, in the step C of the smelting method of the high-nitrogen and high-chromium plastic mold steel, the nitrogen blowing time is 10 - 20min.

[0013] The second technical problem to be solved by the present invention is to provide a heat treatment method of the high-nitrogen and high-chromium plastic mold steel. Therefore, a second aspect of the present invention is a heat treatment method comprising the following steps:

A. spheroidizing annealing: heating the flat steel below 500°C obtained by the smelting method of the high-nitrogen and high-chromium plastic mold steel according to the first aspect, wherein step D further comprises forging or rolling into 180 - 250 mm thick flat steel after casting into ingots, to 940 - 960°C and holding 8 - 12 h, then cooling to 760 - 780°C and holding 7 - 10 h, cooling below 500°C, discharging and air-cooling to room temperature;

B. isothermal quenching-tempering: heating the flat steel below 450°C obtained in the step A to 810 - 830°C and holding 5 - 8 h, and then heating to 1030 - 1060°C and holding 1 - 1.5 h; then putting the heated flat steel in a salt bath for salt bath treatment, taking the treated flat steel out for tempering at 550 - 650°C, discharging and air-cooling to room temperature, wherein

in step B the salt bath consists of NH_4NO_2 and KNO_3 which are mixed at a mass ratio of 1:1.5 - 2.0 and the temperature of the salt bath is 210 - 230°C.

[0014] In a preferred embodiment, in the step A of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the heating rate for heating to 940 - 960°C is 90 - 100°C/h.

[0015] In a preferred embodiment, in the step A of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the cooling rate for cooling to 760 - 780°C is 40 - 50°C/h.

[0016] In a more preferred embodiment, in the step A of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the cooling rate for cooling below 500°C is 40 - 50°C/h.

[0017] In a preferred embodiment, in the step B of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the heating rate for heating to 810 - 830°C is 90 - 100°C/h.

[0018] In another preferred embodiment, in the step B of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the heating rate for heating to 1030 - 1060°C is 90 - 100°C/h.

[0019] In one embodiment, in the step B of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the salt bath treatment lasts for 15 - 20min.

[0020] In another embodiment, in the step B of the heat treatment method of the high-nitrogen and high-chromium plastic mold steel, the tempering at 550 - 650°C lasts for 5 - 8h.

[0021] The present invention puts forward the design idea of adding N for alloying and reducing the use of Mo, and nitrogen alloying is achieved directly by blowing nitrogen to provide excellent corrosion resistance, together with the heat treatment process of spheroidizing annealing-isothermal quenching-tempering.

Brief Description of the Drawings

[0022]

Fig. 1 shows a metallographic structure after spheroidizing annealing according to example 1;

Fig. 2 shows a metallographic structure after tempering according to example 1;

Fig. 3 shows a metallographic structure after spheroidizing annealing according to example 2;

Fig. 4 shows a metallographic structure after tempering according to example 2;

Fig. 5 shows physical comparison of salt spray corrosion; in which, a is the conventional 3Cr17NiMo, b1 is a product in example 1 of the present invention, b2 is a product in example 2 of the present invention, Fig. A shows the result after corrosion for 1h, and Fig. B shows the result after corrosion for 24h.

Detailed Description of the Preferred Embodiments

[0023] The high-nitrogen and high-chromium plastic mold steel of the present invention comprises the following chemical components by mass: 0.25 - 0.35% of C, 0.45 - 0.8% of Si, 0.4 - 0.7% of Mn, 16.5 - 17.5% of Cr, 0.1 - 0.3% of Ni, 0.1 - 0.5% of Mo, 0.06 - 0.10% of N, and the rest of Fe and inevitable impurity elements.

[0024] Preferably, in the high-nitrogen and high-chromium plastic mold steel, the other impurity elements comprise Al $\leq 0.02\%$, P $\leq 0.025\%$, S $\leq 0.005\%$, O $\leq 0.003\%$ and H $\leq 0.0002\%$.

[0025] The chemical elements are: C, Si, Mn, Cr, N, Fe, Ni, Al, P, S, O and H.

[0026] According to the smelting method of the high-nitrogen and high-chromium plastic mold steel, the smelting process mainly comprises the following steps:

- 5 (1) selecting an IF steel billet or IF steel scrap based on the above chemical components, and smelting in an electric furnace at a smelting temperature of 1630 - 1650°C and pressure in the furnace of 1 standard atmospheric pressure;
- (2) pouring the molten steel into an LF furnace after the metal material in the electric furnace is completely melted, starting to blow argon, and adding a slagging agent made up of lime, fluorite, lime sand and aluminum oxide 5 - 10min later;
- 10 (3) adding a prepared carburant and an alloy successively after slagging and desulfurization, and inserting an electrode bar for heating and smelting;
- (4) taking samples and fine-tuning components of the alloy based on test results 15 - 30min later;
- (5) stopping blowing argon, blowing high-purity nitrogen instead for 10 - 20min, and adjusting the pressure based on the rolling state at the liquid level;
- 15 (6) at the end of blowing nitrogen, taking samples, fine-tuning the nitrogen blowing time based on component results and adjusting the temperature of the molten steel at 1540 - 1560°C; and
- (7) tapping, casting into ingots, and forging or rolling into finished products.

[0027] The heat treatment method of the high-nitrogen and high-chromium plastic mold steel mainly comprises the following steps:

- A. spheroidizing annealing: placing the flat steel below 500°C obtained by the smelting method of the high-nitrogen and high-chromium plastic mold steel according to the present invention, wherein step D further comprises forging or rolling into 180 - 250 mm thick flat steel after casting into ingots, heating to 940 - 960°C at a rate of 90 - 100°C/h and holding for 8 - 12h, then cooling to 760 - 780°C at a cooling rate of 40 - 50°C/h and holding for 7 - 10h, and finally cooling to ≤500°C at a cooling rate of 40 - 50°C/h, discharging and air-cooling to room temperature; and
- 25 B. isothermal quenching-tempering: putting the mold steel subject to spheroidizing annealing into a quenching furnace at a temperature lower than 450°C, heating to 810 - 830°C at a rate of 90 - 100°C/h and holding for 5 - 8h, keeping heating to 1030 - 1060°C at a rate of 90 - 100°C/h and holding for 1-1.5h, and placing the heated mold steel quickly into a 210 - 230°C salt bath consisting of NH₄NO₂ and KNO₃ which are mixed at a mass ratio of 1:1.5, and holding for 15 - 20min; then taking out the steel subject to salt bath treatment quickly, putting the steel into a tempering furnace heated to 550 - 650°C and holding for 5 - 8h, discharging and air-cooling to room temperature.

[0028] In order to completely release residual stress during deformation, the temperature of the flat steel put into the annealing furnace is controlled below 500°C in the step A.

[0029] In order to prevent thermal cracks or prevent affecting the production efficiency, the mold steel is heated to 940 - 960°C at a controlled rate of 90 - 100°C/h in the step A.

[0030] In order to ensure the spheroidizing effect, in the step A, the mold steel is cooled to 760 - 780°C at a controlled cooling rate of 40 - 50°C/h and held for 7 - 10h, and then cooled below 500°C at a cooling rate of 40 - 50°C/h.

[0031] In the step A of the present invention, the formation of martensite is avoided by speeding up cooling. In order to prevent cracks during heating, the temperature of the mold steel put into the heating furnace is controlled below 450°C in the step B.

[0032] In order to prevent thermal cracks, in the step B, the mold steel is heated to 810 - 830°C at a controlled rate of 90 - 100°C/h and held for 5 - 8h, and then continuously heated to 1030 - 1060°C at a rate of 90 - 100°C/h and held for 1 - 1.5h.

[0033] In order to obtain the products with excellent mechanical properties and corrosion resistance, the tempering temperature is controlled at 550 - 650°C.

[0034] According to the present invention, users can take the following approaches: spheroidizing annealing in the step A, then processing into the corresponding molds, and isothermal quenching-tempering in the step B; or spheroidizing annealing in the step A, then isothermal quenching-tempering in the step B, and processing into the corresponding molds, based on their own processing capability and requirements for comprehensive mechanical properties and corrosion resistance of finished mold products.

Example 1

[0035] Smelting of a high-nitrogen and high-chromium plastic mold steel in the following steps:

- (1) placing an IF steel billet mainly containing the following elements by mass: 0.002% of C, 0.01% of Si, 0.1% of Mn, 0.012% of P, 0.010% of S, 0.015% of Al, and the rest of Fe and other inevitable impurities into an electric furnace

for primary smelting at a temperature of $1640 \pm 10^\circ\text{C}$;

(2) pouring the molten steel into an LF furnace after the metal material in the electric furnace is completely melted, starting to blow argon, and adding a slagging agent (lime, fluorite, lime sand and aluminum oxide) 5min later;

(3) adding a prepared carburant and an alloy successively after slagging and desulfurization, and inserting an electrode bar for heating and smelting;(4) taking samples and fine-tuning components of the alloy based on test results 30min later;

(5) stopping blowing argon, blowing high-purity nitrogen instead for 15min, and adjusting the pressure based on the rolling state at the liquid level;

(6) at the end of blowing nitrogen, taking samples, fine-tuning the nitrogen blowing time based on the component results and adjusting the temperature of molten steel at $1550 \pm 10^\circ\text{C}$; and

(7) tapping, casting into ingots, then upsetting and stretching for two times into finished products after high-temperature homogenization treatment.

[0036] Heat treatment of a new high-nitrogen and high-chromium plastic mold steel in the following steps:

(1) spheroidizing annealing: putting the mold steel into an annealing furnace at a temperature lower than 500°C , heating the mold steel to $950 \pm 10^\circ\text{C}$ at a rate of 95°C/h and holding for 12h, then cooling the mold steel to 760°C at a cooling rate of 40°C/h and holding for 9h, finally cooling the mold steel to $\leq 500^\circ\text{C}$ at a cooling rate of 45°C/h , discharging and air-cooling to room temperature, with the metallographic structure as shown in Fig. 1.

(2) Isothermal quenching-tempering

[0037] Putting the mold steel subject to spheroidizing annealing into a quenching furnace at a temperature lower than 450°C , heating to 830°C at a rate of 100°C/h and holding for 8h, keeping heating to 1060°C at a rate of 100°C/h and holding for 1.5h, placing the heated mold steel quickly into a 220°C salt bath consisting of NH_4NO_2 and KNO_2 which are mixed at a ratio of 1:1.5, and holding for 20min; then taking out the mold steel subject to salt bath treatment quickly, putting the treated mold steel into a tempering furnace heated to 580°C and holding for 8h, discharging and air-cooling to room temperature, with the metallographic structure as shown in Fig. 2.

[0038] The components and content of the product prepared in Example 1 are shown in Table 1 below.

Table 1 Chemical Components (wt%)

C	Si	Mn	Cr	Ni	Mo	N	Al	P	S	O	H
0.33	0.6	0.65	17.2	0.25	0.2	0.09	0.02	0.021	0.004	0.0028	0.0002

Example 2

[0039] Smelting of a new high-nitrogen and high-chromium plastic mold steel in the following steps:

(1) placing an IF steel billet mainly containing the following elements by mass: 0.0015% of C, 0.011% of Si, 0.12% of Mn, 0.011% of P, 0.010% of S, 0.015% of Al, and the rest of Fe and other inevitable impurities into an electric furnace for primary smelting at a temperature of $1640 \pm 10^\circ\text{C}$;

(2) pouring the molten steel into an LF furnace after the metal material in the electric furnace is completely melted, starting to blow argon, and adding a slagging agent (lime, fluorite, lime sand and aluminum oxide) 5min later;

(3) adding a prepared carburant and an alloy successively after slagging and desulfurization, and inserting an electrode bar for heating and smelting;

(4) taking samples and fine-tuning components of the alloy based on test results 30min later;

(5) stopping blowing argon, blowing high-purity nitrogen instead for 15min, and adjusting the pressure based on the rolling state at the liquid level;

(6) at the end of blowing nitrogen, taking samples, fine-tuning the nitrogen blowing time based on the component results and adjusting the temperature of molten steel at $1550 \pm 10^\circ\text{C}$; and

(7) tapping, casting into ingots, then upsetting and stretching for two times into finished products after high-temperature homogenization treatment.

[0040] Heat treatment of a new high-nitrogen and high-chromium plastic mold steel in the following steps:

(1) spheroidizing annealing: putting the mold steel into an annealing furnace at a temperature lower than 500°C , heating the mold steel to $950 \pm 10^\circ\text{C}$ at a rate of 95°C/h and holding for 12h, then cooling the mold steel to 760°C

at a cooling rate of 40°C/h and holding for 9h, finally cooling the mold steel to $\leq 500^{\circ}\text{C}$ at a cooling rate of 45°C/h, discharging and air-cooling to room temperature, with the metallographic structure as shown in Fig. 3.

(2) Isothermal quenching-tempering

[0041] Putting the mold steel subject to spheroidizing annealing into a quenching furnace at a temperature lower than 450°C, heating to 820°C at a rate of 95°C/h and holding for 8h, keeping heating to 1050°C at a rate of 100°C/h and holding for 1.5h, and placing the heated mold steel quickly into a 230°C salt bath consisting of NH_4NO_2 and KNO_3 which are mixed at a ratio of 1:1.5, and holding for 20min; then taking out the mold steel subject to salt bath treatment quickly, putting the treated mold steel into a tempering furnace heated to 590°C and holding for 8h, discharging and air-cooling to room temperature, with the metallographic structure as shown in Fig. 4.

[0042] The components and content of the product prepared in Example 2 are shown in Table 2 below.

Table 2 Chemical Components (wt%)

C	Si	Mn	Cr	Ni	Mo	N	Al	P	S	O	H
0.31	0.45	0.62	16.9	0.22	0.24	0.08	0.02	0.022	0.004	0.0029	0.0002

[0043] The results of samples prepared in examples 1 and 2 of the present invention and the conventional 3Cr17NiMo under the same salt spray corrosion conditions are shown in Fig. 5. As can be seen from the figure, the conventional 3Cr17NiMo is severely corroded, while the plastic mold steel of the present invention is slightly corroded, indicating that the plastic mold steel of the present invention has better corrosion resistance.

Claims

1. A smelting method of the high-nitrogen and high-chromium plastic mold steel, **characterized by** comprising the following steps:

- A. smelting: smelting an IF steel in an electric furnace until the IF steel is completely melted;
- B. refining: pouring the completely melted molten steel into an LF furnace for slagging and alloying;
- C. nitriding: blowing nitrogen for nitrogen alloying; and
- D. tapping: tapping and casting into ingots after nitrogen blowing, wherein

the tapping control temperature of the molten steel is 1540 - 1560°C in step D, the high-nitrogen and high-chromium plastic mold steel comprises the following chemical components by mass: 0.25 - 0.35% of C, 0.45 - 0.8% of Si, 0.4 - 0.7% of Mn, 16.5 - 17.5% of Cr, 0.1 - 0.3% of Ni, 0.1 - 0.5% of Mo, 0.06 - 0.10% of N, and the rest of Fe and inevitable impurity elements and the impurity elements comprise $\text{Al} \leq 0.02\%$, $\text{P} \leq 0.025\%$, $\text{S} \leq 0.005\%$, $\text{O} \leq 0.003\%$ and $\text{H} \leq 0.0002\%$.

2. The smelting method of the high-nitrogen and high-chromium plastic mold steel according to claim 1, **characterized in that** step D further comprises forging or rolling into 180 - 250 mm thick flat steel after casting into ingots.

3. The smelting method of the high-nitrogen and high-chromium plastic mold steel according to claim 1 or 2, **characterized in that** the smelting temperature is 1630 - 1650°C in step A.

4. The smelting method of the high-nitrogen and high-chromium plastic mold steel according to claim 1 or 2, **characterized in that** the nitrogen blowing time is 10 - 20min in step C.

5. A heat treatment method of the high-nitrogen and high-chromium plastic mold steel, **characterized by** comprising the following steps:

- A. spheroidizing annealing: heating the flat steel below 500°C obtained by the smelting method of the high-nitrogen and high-chromium plastic mold steel according to claim 2 to 940 - 960°C and holding 8 - 12 h, then cooling to 760 - 780°C and holding 7 - 10 h, cooling below 500°C, discharging and air-cooling to room temperature;
- B. isothermal quenching-tempering: heating the flat steel below 450°C obtained in the step A to 810 - 830°C and holding 5 - 8 h, and then heating to 1030 - 1060°C and holding 1 - 1.5 h; then putting the heated flat steel in a salt bath for salt bath treatment, taking the treated flat steel out for tempering at 550 - 650°C, discharging

and air-cooling to room temperature, wherein

in step B the salt bath consists of NH_4NO_2 and KNO_3 which are mixed at a mass ratio of 1:1.5 - 2.0 and the temperature of the salt bath is 210 - 230°C.

6. The heat treatment method of the high-nitrogen and high-chromium plastic mold steel according to claim 5, **characterized in that** in step A, at least any one of the following is satisfied:

the heating rate for heating to 940 - 960°C is 90 - 100°C/h;
the temperature is held at 940 - 960°C for 8-12h;
the cooling rate for cooling to 760 - 780°C is 40 - 50°C/h;
the cooling rate for cooling below 500°C is 40-50°C/h; and
the temperature is held at 760 - 780°C for 7-10h.

7. The heat treatment method of high-nitrogen and high-chromium plastic mold steel according to claim 5, **characterized in that** in step B, at least any one of the following is satisfied:

the heating rate for heating to 810 - 830°C is 90 - 100°C/h;
the temperature is held at 810 - 830°C for 5 - 8h;
the heating rate for heating to 1030 - 1060°C is 90 - 100°C/h;
the temperature is held at 1030 - 1060°C for 1 - 1.5h;
the salt bath consists of NH_4NO_2 and KNO_3 which are mixed at a mass ratio of 1:1.5 - 2.0, preferably at a mass ratio of 1:1.5;
the temperature of the salt bath is 210 - 230°C;
the salt bath treatment lasts for 15 - 20min; and
the tempering at 550 - 650°C lasts for 5 - 8h.

Patentansprüche

1. Verfahren zum Schmelzen von Kunststoffformstahl mit hohem Stickstoff- und hohem Chromgehalt, **dadurch gekennzeichnet, dass** es die folgenden Schritte umfasst:

A. Schmelzen: Schmelzen eines IF-Stahls in einem Elektroofen, bis der IF-Stahl vollständig geschmolzen ist;
B. Raffinieren: Gießen der vollständig geschmolzenen Stahlschmelze in einen LF-Ofen zum Schlacken und Legieren;
C. Nitrieren: Einblasen von Stickstoff zum Stickstofflegieren; und
D. Abstich: Abstechen und Gießen zu Blöcken nach dem Stickstoffeinblasen, wobei

die Abstichregelungstemperatur der Stahlschmelze in Schritt D 1540 - 1560°C beträgt,
der Kunststoffformstahl mit hohem Stickstoff- und hohem Chromgehalt die folgenden chemischen Massenbestandteile aufweist: 0,25 - 0,35 % C, 0,45 - 0,8 % Si, 0,4 - 0,7 % Mn, 16,5 - 17,5 % Cr, 0,1 - 0,3 % Ni, 0,1 - 0,5 % Mo, 0,06 - 0,10 % N, den Rest von Fe und unvermeidliche Verunreinigungselemente und die Verunreinigungselemente $\text{Al} \leq 0,02\%$, $\text{P} \leq 0,025\%$, $\text{S} \leq 0,005\%$, $\text{O} \leq 0,003\%$ und $\text{H} \leq 0,0002\%$ umfassen.

2. Verfahren zum Schmelzen des Kunststoffformstahls mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 1, **dadurch gekennzeichnet, dass** Schritt D ferner das Schmieden oder Walzen zu 180 - 250 mm dickem Flachstahl nach dem Gießen zu Blöcken umfasst.

3. Verfahren zum Schmelzen des Kunststoffformstahls mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Schmelztemperatur in Schritt A 1630 - 1650°C beträgt.

4. Verfahren zum Schmelzen von Kunststoffformstahl mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Stickstoffeinblaszeit in Schritt C 10 - 20 min beträgt.

5. Wärmebehandlungsverfahren für Kunststoffformstahl mit hohem Stickstoff- und hohem Chromgehalt, **dadurch gekennzeichnet, dass** es die folgenden Schritte umfasst:

A. Kugelglühen: Erhitzen des Flachstahls unter 500°C, der durch das Schmelzverfahren des Kunststoffformstahls mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 2 erhalten wurde, auf 940 - 960°C, und Halten für 8 - 12 h, dann Abkühlen auf 760 - 780°C und Halten für 7 - 10 h, Abkühlen unter 500°C, Entladen und Luftabkühlung auf Raumtemperatur;

B. isothermes Abschrecken-Tempnen: Erhitzen des in Schritt A erhaltenen Flachstahls unter 450°C auf 810 - 830°C und Halten für 5 - 8 h, und dann Erhitzen auf 1030 - 1060°C und Halten für 1 - 1,5 h; dann Einbringen des erhitzten Flachstahls in ein Salzbad zur Salzbadbehandlung, Herausnehmen des behandelten Flachstahls zum Tempnen bei 550 - 650°C, Entladen und Luftabkühlung auf Raumtemperatur, wobei

in Schritt B das Salzbad aus NH_4NO_2 und KNO_2 besteht, die in einem Massenverhältnis von 1: 1,5 - 2,0 gemischt werden und die Temperatur des Salzbad 210 - 230°C beträgt.

6. Wärmebehandlungsverfahren des Kunststoffformstahls mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 5, **dadurch gekennzeichnet, dass** in Schritt A mindestens eines von Folgendem erfüllt ist:

die Aufheizgeschwindigkeit zum Erhitzen auf 940 - 960°C 90 - 100°C/h beträgt;

die Temperatur 8-12 Stunden lang auf 940 - 960 °C gehalten wird;

die Abkühlungsgeschwindigkeit zum Kühlen auf 760 - 780°C 40 - 50°C/h beträgt;

die Abkühlungsgeschwindigkeit zum Kühlen auf unter 500°C 40-50°C/h beträgt; und

die Temperatur 7-10 Stunden lang auf 760 - 780 °C gehalten wird.

7. Wärmebehandlungsverfahren für Kunststoffformstahl mit hohem Stickstoff- und hohem Chromgehalt nach Anspruch 5, **dadurch gekennzeichnet, dass** in Schritt B mindestens eines von Folgendem erfüllt ist:

die Aufheizgeschwindigkeit zum Erhitzen auf 810 - 830°C 90 - 100°C/h beträgt;

die Temperatur 5 - 8h Stunden lang auf 810 - 830°C gehalten wird;

die Aufheizgeschwindigkeit zum Erhitzen auf 1030 - 1060°C 90 - 100°C/h beträgt;

die Temperatur 1 - 1,5 Stunden lang auf 1030 - 1060 °C gehalten wird;

das Salzbad aus NH_4NO_2 und KNO_2 besteht, die in einem Massenverhältnis von 1: 1,5 - 2,0, vorzugsweise in einem Massenverhältnis von 1: 1,5, gemischt werden;

die Temperatur des Salzbad 210 - 230°C beträgt;

die Salzbadbehandlung 15 - 20 Minuten dauert; und

das Tempnen bei 550 - 650°C 5 - 8h dauert.

Revendications

1. Procédé de fusion d'acier pour moule plastique à haute teneur en azote et en chrome 1, **caractérisé en ce qu'il** comprend les étapes suivantes :

A. fusion : fusion d'un acier FI dans un four électrique jusqu'à ce que l'acier FI soit complètement fondu ;

B. Affinage : déversement de l'acier en fusion complètement fondu dans un four LF pour la scorification et l'alliage ;

C. nitruration : soufflage d'azote pour l'alliage à l'azote ; et

D. taraudage : taraudage et coulée en lingots après soufflage à l'azote, dans lequel

la température de commande d'acier en fusion est de 1540 - 1560°C à l'étape D,

l'acier pour moule plastique à haute teneur en azote et en chrome comprend les composants chimiques suivants en masse : 0,25 - 0,35 % de C, 0,45 - 0,8 % de Si, 0,4 - 0,7 % de Mn, 16,5 - 17,5 % de Cr, 0,1 - 0,3 % de Ni, 0,1 - 0,5 % de Mo, 0,06 - 0,10 % de N, et le reste de Fe et d'éléments d'impureté inévitables, et les éléments d'impureté comprennent $\text{Al} \leq 0,02\%$, $\text{P} \leq 0,025\%$, $\text{S} \leq 0,005\%$, $\text{O} \leq 0,003\%$ et $\text{H} \leq 0,0002\%$.

2. Procédé de fusion de l'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 1, **caractérisé en ce que** l'étape D comprend en outre le forgeage ou le laminage en acier plat d'une épaisseur de 180 à 250 mm après la coulée en lingots.

3. Procédé de fusion de l'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 1 ou 2, **caractérisé en ce que** la température de fusion est de 1630 - 1650°C à l'étape A.

EP 3 889 285 B1

4. Procédé de fusion de l'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 1 ou 2, **caractérisé en ce que** le temps de soufflage de l'azote est de 10 à 20 min à l'étape C.

5. Procédé de traitement thermique de l'acier pour moule plastique à haute teneur en azote et en chrome, **caractérisé en ce qu'il** comprend les étapes suivantes :

A. recuit de sphéroïdisation : chauffage de l'acier plat à moins de 500°C obtenu par le procédé de fusion d'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 2 à 940 - 960°C et maintien 8 - 12 h, puis refroidissement à 760 - 780°C et maintien 7 - 10 h, refroidissement à moins de 500°C, déchargement et refroidissement à l'air jusqu'à température ambiante ;

B. trempe-trempe isotherme : chauffage de l'acier plat à moins de 450°C obtenu à l'étape A à 810 - 830°C et maintien à 5 - 8 h, puis chauffage à 1030 - 1060°C et maintien à 1 - 1,5 h ; mise en bain de sel de l'acier plat chauffé pour un traitement par bain de sel, extraction de l'acier plat traité pour trempe à 550 - 650°C, déchargement et refroidissement à l'air jusqu'à la température ambiante, dans lequel

à l'étape B, le bain de sel est constitué de NH_4NO_2 et de KNO_2 qui sont mélangés dans un rapport de masse de 1: 1,5 - 2,0 et la température du bain de sel est de 210 - 230°C.

6. Procédé de traitement thermique de l'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 5, **caractérisé en ce qu'à** l'étape A, au moins l'une des conditions suivantes est satisfaite :

la vitesse de chauffage pour le chauffage à 940 - 960°C est de 90 - 100°C/h ;

la température est maintenue entre 940 et 960°C pendant 8 à 12 heures ;

la vitesse de refroidissement pour le refroidissement à 760 - 780°C est de 40 - 50°C/h ;

la vitesse de refroidissement pour refroidissement à moins de 500°C est de 40-50°C/h ; et

la température est maintenue entre 760 et 780°C pendant 7 à 10 heures.

7. Procédé de traitement thermique de l'acier pour moule plastique à haute teneur en azote et en chrome selon la revendication 5, **caractérisé en ce qu'à** l'étape B, au moins l'une des conditions suivantes est satisfaite :

la vitesse de chauffage pour le chauffage à 810 - 830°C est de 90 - 100°C/h ;

la température est maintenue entre 810 et 830°C pendant 5 à 8 heures ;

la vitesse de chauffage pour le chauffage à 1030 - 1060°C est de 90 - 100°C/h ;

la température est maintenue à 1030 - 1060°C pendant 1 - 1,5h ;

le bain de sel est constitué de NH_4NO_2 et de KNO_2 qui sont mélangés dans un rapport de masse de 1: 1,5 - 2,0, de préférence dans un rapport de masse de 1: 1,5 ;

la température du bain de sel est de 210 à 230°C ;

le traitement par bain de sel dure de 15 à 20 minutes ; et

la trempe à 550 - 650°C dure de 5 à 8 heures.

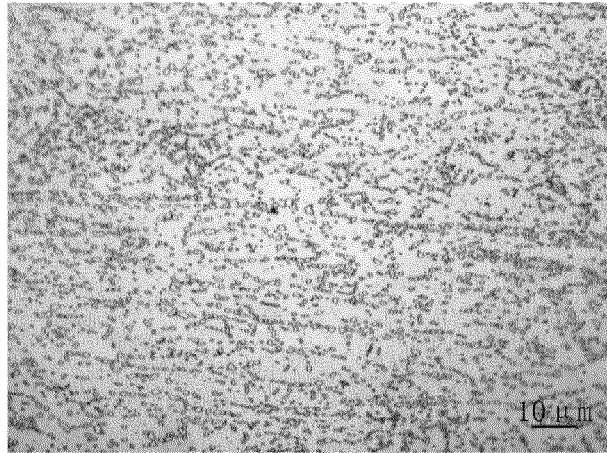


Fig. 1

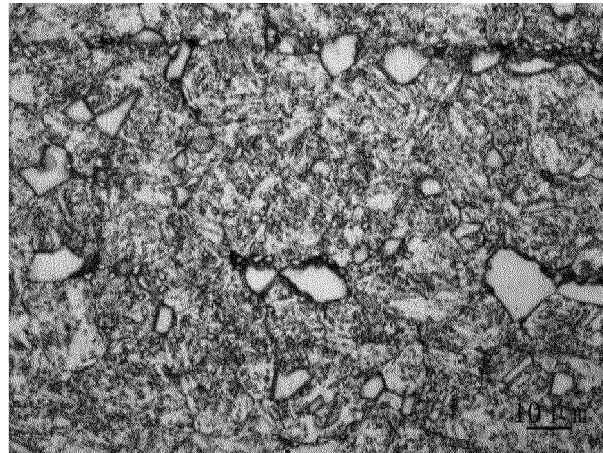


Fig. 2

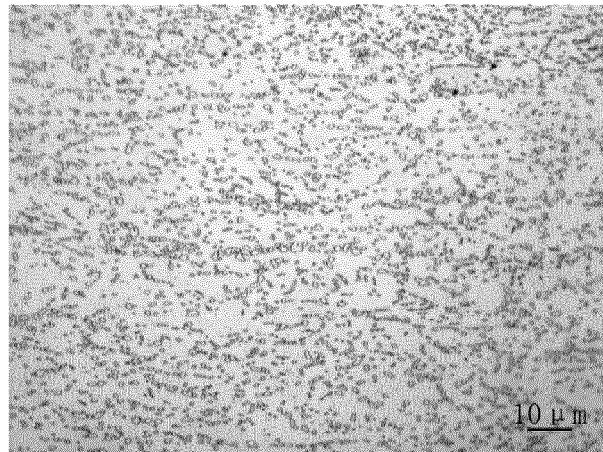


Fig. 3

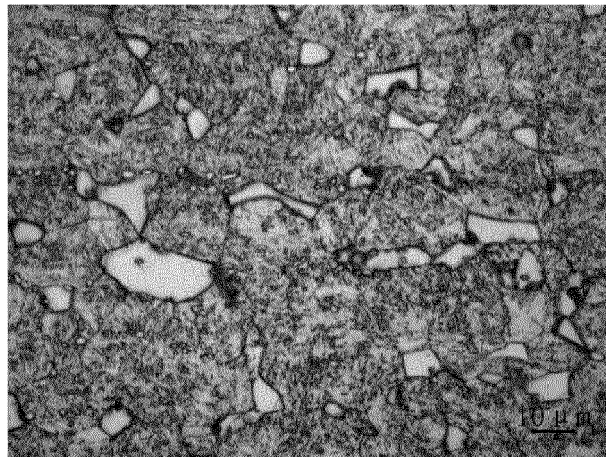


Fig. 4

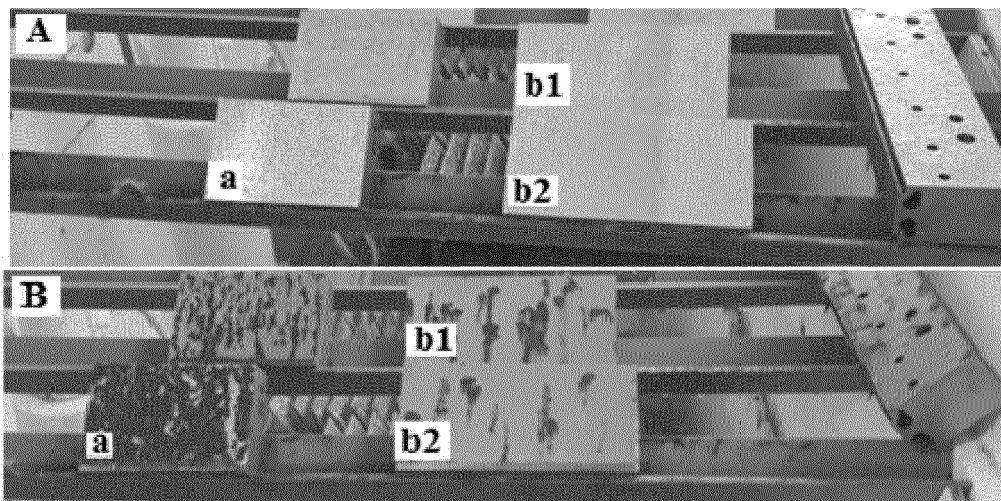


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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