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

(11) **EP 4 035 787 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
22.01.2025 Bulletin 2025/04

(21) Application number: **20866991.1**

(22) Date of filing: **19.06.2020**

(51) International Patent Classification (IPC):
B21B 3/02 *(2006.01)* ***C22C 38/40*** *(2006.01)*
C21D 8/02 *(2006.01)* ***C21D 9/46*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C21D 8/0205; C21D 8/021; C21D 8/0226; C21D 8/0242; C21D 9/46; C22C 38/40;
B21B 2201/02; B21B 2261/20; B21B 2265/22; C21D 2211/001

(86) International application number:
PCT/CN2020/096958

(87) International publication number:
WO 2021/057117 (01.04.2021 Gazette 2021/13)

(54) METHOD FOR ROLLING SUPER AUSTENITIC STAINLESS STEEL

VERFAHREN ZUM WALZEN VON SUPERAUSTENITISCHEM ROSTFREIEM STAHL

PROCÉDÉ DE LAMINAGE D'ACIER INOXYDABLE SUPER-AUSTÉNITIQUE

(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: **23.09.2019 CN 201910902611**

(43) Date of publication of application:
03.08.2022 Bulletin 2022/31

(73) Proprietor: **Nanjing Iron & Steel Co., Ltd.**
Nanjing, Jiangsu 210035 (CN)

(72) Inventors:
- **ZHANG, Miao**
  Nanjing, Jiangsu 210035 (CN)
- **ZHENG, Mingzhe**
  Nanjing, Jiangsu 210035 (CN)
- **SUN, Xudong**
  Nanjing, Jiangsu 210035 (CN)
- **CHE, Chao**
  Nanjing, Jiangsu 210035 (CN)
- **HUANG, Long**
  Nanjing, Jiangsu 210035 (CN)
- **FAN, Wei**
  Nanjing, Jiangsu 210035 (CN)
- **DENG, Feixiang**
  Nanjing, Jiangsu 210035 (CN)

(74) Representative: **Murgitroyd & Company**
Murgitroyd House
165-169 Scotland Street
Glasgow G5 8PL (GB)

(56) References cited:
CN-A- 104 275 350
CN-A- 107 419 194
CN-A- 107 419 194
CN-A- 107 641 698
CN-A- 107 716 584
CN-A- 108 787 751
CN-A- 108 838 216
CN-A- 110 066 957
CN-A- 110 773 565
JP-A- 2003 041 352

EP 4 035 787 B1

Description

TECHNICAL FIELD

[0001] The present invention belongs to the technical field of steel rolling, and in particular, relates to a method for rolling super austenitic stainless steel.

BACKGROUND

[0002] NAS 254NM (equivalent to UNS N08367) is high corrosion resistant stainless steel containing high chromium and high molybdenum. The specifications of this grade of steel still maintain good corrosion resistance even in the harsh environments of high temperature, seawater or flue gas and desulfurization equipment. It can be on a par with Hastelloy alloys and titanium plates under some environments, and it is highly economical stainless steel with high corrosion resistance.

[0003] N08367 contains 21% of Cr and 6% of Mo, so the deformation resistance thereof in a high temperature range is 2.5 to 3 times larger than that of ordinary grades of steel. When thin specification rolling is conducted to a low temperature section, a rolling pressure is too large, and as the width increases, the load is further increased. According to the existing rolling processes, extremely thin specification rolling cannot be conducted, rolling interrupting or a poor plate shape occurs, and quality goods cannot be obtained. CN 107 419 194 A discloses a rolling of a superaustenitic stainless steel.

SUMMARY

[0004] Purpose of the invention: in order to overcome the problems of failing to roll due to too large load, extremely poor plate shape and failing to obtain quality goods when thin specification super austenitic stainless steel is rolled in the art, the present invention provides a method for rolling super austenitic stainless steel. This method rolls super austenitic stainless steel with the specifications of a thickness of below 10 mm and a width of above 2500 mm.

[0005] The technical solution is defined in the independent claim.

[0006] Beneficial effects: through technical optimization of the billet selection, the steel burning process, the descaling process, the steel rolling process and the straightening process in the method, rolling of super austenitic stainless steel with the specifications of a thickness of below 10 mm and a width of above 2500 mm may be achieved, and a steel plate with an N08367 grade of steel with the specifications of a thickness of 8.5 mm and widths of 2510 mm and 2610 mm is rolled successfully. This specification is the widest specification in the world under this thickness, filling a gap in a width range of 2510 to 2610 mm for the N08367 grade of steel at the thickness of 8.5 mm, moreover, a rolled plate shape is stable, and a rolling success rate reaches 95.4%. In addition, N08904 stainless steel with a thickness of 10.0 mm and a width range of 2620 to 2980 mm is further rolled successfully.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0007] A method for rolling super austenitic stainless steel, including the following steps.

(1) Billet selection:

[0008] Deformation resistance of the super austenitic stainless steel at a high temperature is 2.5 to 3 times that of ordinary products. Ultra-wide and thin specifications are developed in selection of billet types. In order to ensure a rolling success rate, the minimum number of passes is adopted. It is necessary to ensure that in a case of meeting rolling thickness requirements, a minimum billet design principle is adopted, namely a minimum thickness billet loadable into a heating furnace.

[0009] Specifically, the minimum thickness billet loadable into the heating furnace is determined according to a minimum billet thickness that can be measured by a laser detector in the heating furnace. A minimum thickness is 115 mm. When a steel plate with the specifications of a thickness of 8.5 mm and a width of 2610 mm is rolled, a billet with a thickness of 115 mm, a width of 1780 mm and a length of 2610 mm is adopted. For an original billet with a thickness of 142 mm, cogging treatment is first conducted to a thickness of 115 mm, so as to reduce a total number of rolling passes in subsequent processes.

(2) A steel burning process:

[0010] By utilizing the characteristic of easy oxidization at a high temperature of the super austenitic stainless steel, steel burning is conducted on the billet at 1250°C to 1270°C. Meanwhile, a temperature difference between upper and lower

surfaces of the billet is strictly controlled to be 25°C to 35°C, ensuring that head warping will not happen to the steel plate in a rolling process. Moreover, positions of upper and lower beams are adjusted to ensure a middle position in the steel burning process, improving a temperature uniformity of the steel plate.

(3) A descaling process:

[0011] By utilizing the characteristic of non-easy oxidization at the high temperature of the super austenitic stainless steel, a process mode that descaling must be conducted in a normal production process of a steel billet is broken, descaling operation is not conducted on the billet during rough descaling and rolling mill fine descaling, and the temperature difference between the upper and lower surfaces is maintained, preventing head warping of the steel plate caused by descaling.

(4) A steel rolling process:

[0012] A final rolling temperature is required to be above 850°C, avoiding a sharp increase in deformation resistance below 850°C.

[0013] According to the maximum distribution of rolling torque and rolling force, 12 passes of rolling are adopted, breaking the limitation that 9 passes of rolling must be adopted for the thin specification in traditional processes.

[0014] Moreover, a reduction in the last two passes of rolling is less than 0.8 mm, avoiding that due to too large reduction, a roll gap for a rolling mill exceeds an equipment limit during actual rolling, resulting in difficult rolling. Meanwhile, it is ensured that a roll gap parameter for the rolling mill is set to be not less than 3.5 mm, avoiding that when the roll gap parameter for the rolling mill is set to be too small, a CVC rolling mill cannot move due to rolling force, resulting in that it cannot move in place.

[0015] A second-level model system optimizes a coefficient under different thicknesses according to the deformation resistance at different temperatures, and meanwhile, adjusts a certain specific pass separately. That is, in order to ensure the measurement accuracy of a thickness gauge, the thermal expansion coefficient of this stainless steel under different passes is adjusted separately according to the deformation resistance at different temperatures. Specifically, the coefficient is adjusted from 1.0132×10^{-2} to 1.0133×10^{-2} at 873°C, and the coefficient is adjusted from $1.02\,84 \times 10^{-2}$ to 1.0285×10^{-2}at 880°C, ensuring the accuracy of thickness self-learning correction by a second-level model.

[0016] (5) A straightening process: in a multi-pass straightening mode by a pre-straightening machine, a straightening pressure is increased by 1000 to 1500 tons according to plate shape conditions. If straightening force is too small, it will have no effect. If the straightening force is too large, it will exceed the equipment limit. During operation, pressing down 0.1 mm will increase about 100 tons of pressure, which corresponds to manually pressing down a roll gap by 1 to 1.5 mm.

[0017] By adopting the above method, the rolling of an N08367 grade of steel successfully break the width to 2610 mm. Specific implementation of a rolling schedule is shown in Table 1:

Table 1 Rolling schedule table of N08367 with a thickness of 8.5 mm

Rotating steel	Outlet thickness mm	Width mm	Length mm	Roll gap mm	Reduction mm	Reduction rate %	Rolling force kN	Torque Kn/m	Biting speed m/s	Rolling speed m/s
Y	97.73	2656.39	1.91	91.29	17.87	15.46	76277	8691	1.50	1.50
N	80.70	2659.42	2.31	74.26	17.03	17.43	76263	8472	1.75	1.75
N	64.66	2662.27	2.88	58.17	16.04	19.88	76599	8253	1.75	1.75
N	49.82	2664.87	3.73	43.23	14.84	22.95	77495	8032	2.00	2.53
N	36.03	2667.19	5.16	28.35	13.79	27.68	86646	8680	2.25	2.80
N	26.81	2668.06	6.93	19.94	9.22	25.59	79879	6599	2.00	3.03
N	20.03	2667.59	9.27	13.53	6.78	25.28	76749	5488	2.00	3.48
N	15.17	2665.64	12.23	9.15	4.86	24.25	72741	4459	1.50	3.73
N	12.13	2662.62	15.30	6.72	3.44	20.03	67609	3362	2.50	4.33
N	10.27	2659.63	18.08	5.37	1.87	15.40	63273	2562	2.50	4.63
N	9.09	2657.77	20.42	4.86	0.78	11.47	57656	1939	2.25	4.82
N	8.64	2656.78	21.48	7.50	0.45	4.95	32571	722	2.25	4.98

(continued)

Rotating steel	Outlet thickness mm	Width mm	Length mm	Roll gap mm	Reduction mm	Reduction rate %	Rolling force kN	Torque Kn/m	Biting speed m/s	Rolling speed m/s
N	8.64	2655.80	21.48	33.64	0.00	0.00	0	0	5.2	5.20

[0018] Rolling specifications and success rates are shown in Table 2:

Table 2 Rolling pass rates of N08367 with a thickness of 8.5 mm

Rolling specifications (thickness*width) mm*mm	Total number of rolled blocks	Number of successfully rolled blocks	Pass rate
8.5*2510	17	17	100%
8.5*2610	70	66	94.3%
Sum	87	83	95.4%

[0019] Performance index requirements of the grade of steel and specifications are shown in Table 3:

Table 3 Performance index requirements of N08367 with a thickness of 8.5 mm

0.2% yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Hardness (HRB)
≥310	≥690	≥30	≤241

[0020] Actual performance indexes of the grade of steel and specifications are shown in Table 4:

Table 4 Actual performance indexes of N08367 with a thickness of 8.5 mm

Performance index	0.2% yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Hardness (HRB)
Hot rolled plate 8.5 mm	439	762	45	211

[0021] It can be seen that by adopting the rolling method of the present invention, the steel that meets the performance index requirements of the N08367 with the thickness of 8.5 mm can be rolled, and a higher success rate is achieved.

[0022] Moreover, by adopting the above method, the limit specifications of 10*2620 mm, 10*2820 mm, 10*2980 mm, etc., of the same series of grade of steel N08904 are successfully developed. Rolling specifications and success rates thereof are shown in Table 5:

Table 5 Rolling pass rates of N08904 with a thickness of 10.0 mm

Rolling specifications (thickness*width) mm*mm	Total number of rolled blocks	Number of successfully rolled blocks	Pass rate
10.0*2620	8	8	100%
10.0*2820	10	10	100%
10.0*2980	2	2	100%
Sum	20	20	100%

[0023] Performance index requirements of the grade of steel and specifications are shown in Table 6:

Table 6 Performance index requirements of N08904 with a thickness of 10.0 mm

0.2% yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Hardness (HRB)
≥220	≥490	≥35	≤90

[0024] Actual performance indexes of the grade of steel and specifications are shown in Table 7:

Table 7 Actual performance indexes of N08904 with a thickness of 10.0 mm

Performance index	0.2% yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Hardness (HRB)
10.0 mm	245	598	48	80

[0025] It can be seen that by adopting the rolling method of the present invention, the steel that meets the performance index requirements of the N08904 with the thickness of 10.0 mm can be rolled, and a higher success rate is also achieved.

Claims

1. A method for rolling super austenitic stainless steel with the specifications of a thickness of below 10 mm and a width of above 2500 mm, comprising the following steps:

   (1) selecting a minimum thickness billet loadable into a heating furnace, wherein the minimum thickness is 115 mm;
   (2) conducting steel heating on the billet at 1250° C to 1270° C, and controlling a temperature difference between upper and lower surfaces to be 25° C to 35° C;
   (3) not conducting descaling operation on the billet, and maintaining the temperature difference between the upper and lower surfaces, so that a temperature of the upper surface is higher than that of the lower surface;
   (4) controlling a final rolling temperature to be above 850° C; adopting 12 passes of rolling, wherein a reduction in the last two passes of rolling is less than 0.8 mm; and ensuring that a roll gap parameter for a rolling mill is set to be not less than 3.5 mm; during rolling, according to deformation resistance at different temperatures, optimizing a thermal expansion coefficient under different thicknesses, and adjusting the thermal expansion coefficient of this stainless steel under different passes separately, wherein, when a temperature is below 873° C, the thermal expansion coefficient of the stainless steel is set to be 1.0133×10^{-2}, and when the temperature is higher than 873° C and below 880° C, the thermal expansion coefficient of the stainless steel is set to be 1.0285×10^{-2}; and
   (5) in a multi-pass straightening mode by a pre-straightening machine to ensure straightness of a final plate shape a roll gap is pressed down manually by 1 to 1.5 mm according to plate shape conditions.

2. The method for rolling the super austenitic stainless steel according to claim 1, wherein cogging treatment is adopted for an original billet greater than a design thickness of 115 mm to make the original billet reach the design thickness for billet selection.

Patentansprüche

1. Ein Verfahren zum Walzen von superaustenitischem rostfreiem Stahl mit den Spezifikationen einer Dicke von unter 10 mm und einer Breite von über 2 500 mm, das die folgenden Schritte beinhaltet:

   (1) Auswählen eines Rohlings mit einer minimalen Dicke, der in einen Heizofen geladen werden kann, wobei die minimale Dicke 115 mm beträgt;
   (2) Durchführen von Stahlerhitzen des Rohlings bei 1 250 °C bis 1 270 °C und Steuern eines Temperaturunterschieds zwischen einer oberen und einer unteren Oberfläche auf 25 °C bis 35 °C;
   (3) kein Durchführen eines Entzunderungsvorgangs auf dem Rohling und Aufrechterhalten des Temperaturunterschieds zwischen der oberen und der unteren Oberfläche, sodass eine Temperatur der oberen Oberfläche höher ist als die der unteren Oberfläche;
   (4) Steuern einer Walzendtemperatur auf über 850 °C; Annehmen von 12 Walzstichen, wobei eine Reduzierung in den letzten beiden Walzstichen weniger als 0,8 mm beträgt; und Sicherstellen, dass ein Walzspaltparameter für ein Walzwerk auf nicht weniger als 3,5 mm eingestellt wird; während des Walzens, je nach dem Verformungswiderstand bei unterschiedlichen Temperaturen, Optimieren eines Wärmeausdehnungskoeffizient unter unterschiedlichen Dicken und separates Einstellen des Wärmeausdehnungskoeffizienten dieses rostfreien Stahls unter unterschiedlichen Walzstichen, wobei, wenn eine Temperatur unter 873 °C liegt, der Wärmeausdehnungskoeffizient des rostfreien Stahls auf $1{,}0133 \times 10^{-2}$ eingestellt wird, und wenn die Temperatur höher als 873 °C ist und unter 880 °C liegt, der Wärmeausdehnungskoeffizient des rostfreien Stahls auf $1{,}0285 \times 10^{-2}$ eingestellt

wird; und
(5) in einem Modus zum Richten in mehreren Durchgängen mit einer Vorrichtmaschine, um die Geradheit der endgültigen Blechform zu gewährleisten, wird der Walzspalt je nach den Bedingungen der Blechform manuell um 1 bis 1,5 mm nach unten gedrückt.

2. Verfahren zum Walzen von superaustenitischem rostfreiem Stahl gemäß Anspruch 1, wobei für einen ursprünglichen Rohling, der eine Konstruktionsdicke von 115 mm übersteigt, eine Vorwalzbehandlung ("Cogging") durchgeführt wird, damit der ursprüngliche Rohling die Konstruktionsdicke für die Rohlingauswahl erreicht.

Revendications

1. Un procédé pour laminer de l'acier inoxydable super-austénitique conforme au cahier des charges d'une épaisseur d'en deçà de 10 mm et d'une largeur d'au-dessus de 2 500 mm, comprenant les étapes suivantes :

(1) le fait de sélectionner une billette d'épaisseur minimale pouvant être chargée dans un four de réchauffage, l'épaisseur minimale étant de 115 mm ;
(2) le fait de procéder à un chauffage de l'acier sur la billette à de 1 250 °C à 1 270 °C, et le fait de commander une différence de température entre des surfaces supérieure et inférieure afin qu'elle soit de 25 °C à 35 °C ;
(3) le fait de ne pas procéder à une opération de détartrage sur la billette, et le fait de maintenir la différence de température entre les surfaces supérieure et inférieure, de sorte qu'une température de la surface supérieure est plus élevée que celle de la surface inférieure ;
(4) le fait de commander une température de laminage finale afin qu'elle soit au-dessus de 850 °C ; le fait d'adopter 12 passes de laminage, une réduction dans les deux dernières passes de laminage étant inférieure à 0,8 mm ; et le fait de s'assurer qu'un paramètre d'écartement de rouleaux d'un laminoir est déterminé pour qu'il ne soit pas inférieur à 3,5 mm ; au cours du laminage, selon la résistance à la déformation à différentes températures, le fait d'optimiser un coefficient de dilatation thermique sous différentes épaisseurs, et le fait d'ajuster le coefficient de dilatation thermique de cet acier inoxydable sous différentes passes séparément, où, lorsqu'une température est en dessous de 873 °C, le coefficient de dilatation thermique de l'acier inoxydable est déterminé pour qu'il soit de $1{,}0133 \times 10^{-2}$, et lorsque la température est plus élevée que 873 °C et en dessous de 880 °C, le coefficient de dilatation thermique de l'acier inoxydable est déterminé pour qu'il soit de $1{,}0285 \times 10^{-2}$; et
(5) dans un mode de redressement multi-passes par une machine de pré-redressement afin d'assurer le redressement d'une forme de plaque finale, un écartement de rouleau est réduit de 1 à 1,5 mm par pression manuelle selon les conditions de la forme de plaque.

2. Le procédé pour laminer l'acier inoxydable super-austénitique selon la revendication 1, où un traitement de dégrossissement est adopté pour une billette d'origine supérieure à une épaisseur de conception de 115 mm afin que la billette d'origine atteigne l'épaisseur de conception pour la sélection de billette.

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 107419194 A **[0003]**