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(54) A steel

(57) A chain type steel, suitable for the production of bars with a diameter of up to about 160 mm, e.g. to be used for the manufacture of heavy anchor chains, comprising, in weight-%:

C 0.15 - 0.23
Si 0.10 - 0.40
Mn 1.00 - 1.50
P max. 0.025
S max. 0.025
Cr 1.50 - 2.20
Ni 0.80 - 1.50
Mo 0.30 - 0.60
Cu max. 0.30
Al < 0.2
V < 0.2
Nb < 0.2
Ti < 0.2

the balance being Fe.

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Description

BACKGROUND OF THE INVENTION

Technical field

[0001] The present invention relates to a steel, and more specifically a chain type steel, suitable for the production of bars with a diameter of up to about 160 mm, e.g. to be used for the manufacture of heavy anchor chains.

Prior art

[0002] For many years the applicant has delivered bars for the manufacture of heavy anchor chains primarily used for anchoring of oil riggs. Bar dimensions up to 155 mm diameter have been delivered. For the coarse dimensions a very low carbon steel type have been used which causes a number of difficulties in the steel plant, being very aggressive towards the melting equipment. The steel types used for smaller diameter anchor chains being low alloyd steels give unsatisfactory mechanical properties for bigger diameter anchor chains, that is for bar diameters above about 130 mm.
[0003] Thus, there is a need for an improved steel for making heavy anchor chains, which behaves better in the steel plant.
[0004] In e.g. GB 2 110 239 A, a steel for producing anchor chains is disclosed having the following composition, in wt.%: C 0.03 - 0.07; Si 0.10 - 1; Mn 1.2 - 2.5; Cr 1.8 - 3; Ni 1.5- 3; Mo $\leq$ 0.5; Nb,V,Ti total 0 - 0.10. This steel is claimed to have a yield point of at least 600 Mpa, a rupture limit of at least 900 Mpa at room temperature and an impact toughness of at least 40 Joule at -20°C. The restrictions of anchor steels for oil riggs in the ocean are becoming even stricter, and there is a demand for a steel with improved characteristics.
[0005] Through JP-61276956 is previously known a low alloy chain link steel including chromium and nickel being processed to obtain a tempered martensitic structure. This steel comprises, in wt.%: C 0.20 - 0.30; Si 0.10 - 0.30; Mn 0.70 - 1.70; Cr 0.40 - 0.70; Ni 0.75 - 2.00; Al 0.01 - 0.05; P $\leq$ 0.03; S $\leq$ 0.030. This steel is tempered after being quenched or case-hardened by means of carburising so that the microstructure is tempered martensite. At the upper region of the carbon content range, the weldability will deteriorate as well as the toughness, and there is a risk for hardening cracks. The absence of Mo means there is a risk for temper embrittlement. Ni is obviously used to compensate for a low Cr content, which will render this steel quite expensive.
[0006] Through JP-52006847B is previously known a high stregnth low alloy steel chain manufactured from steel bars containing, in wt.% C 0.1 - 0.2; Si 0.1 - 0.5; Mn 1.0 - 1.6; Cu 0.1 - 0.5; Ni 0.5 - 1.5; Cr 0.3 - 1.0; Mo 0.2 - 0.8, P < 0.02; S > 0.015, and acid.sol Al 0.02 - 0.1. The starting steel bars have a high tensile strength, improved weldability and good workability, and the steel chain produced is tempered at 550 - 680°C. The low Cr, and the low C content both affect the hardenability, which is deleterious for large diameter anchor chains.

THE INVENTION

Summary of the invention

[0007] The object of the invention is to provide a steel with improved mechanical properties and an improved behaviour in the steel plant.
[0008] This is obtained with a steel according to the invention, comprising in wieght-%:

C 0.15 - 0.23
Si 0.10 - 0.40
Mn 1.00 - 1.50
P max. 0.025
S max. 0.025
Cr 1.50 - 2.20
Ni 0.80 - 1.50
Mo 0.30 - 0.60
Cu max. 0.30
Al < 0.2
V < 0.2
Nb < 0.2
Ti < 0.2
the balance being Fe.

[0009] Embodiments of the steel according to the invention are claimed in the subclaims.

Brief description of the accompanying drawings

[0010] Fig. 1 is a graph showing the hardness as a function of the tempering temperature for laboratory melt sample materials.
[0011] Fig. 2 is a graph showing the hardness as a function of the depth underneath the surface, for hardened and not tempered samples of said laboratory melt sample materials.
[0012] Fig. 3 is a graph showing the hardness as a function of the depth underneath the surface, for hardened and tempered samples of said laboratory melt sample materials.
[0013] Fig. 4 is a graph showing the jominy hardenability for said laboratory melt sample materials.
[0014] Fig. 5 is a graph showing the jominy hardenability for a full scale melt material.

Description of preferred embodiments of the invention

[0015] The steel grade according to the invention is intended for manufacture of so called K4 chain with a diameter up to about 160 mm, and is not aggressive towards the melting equipment, and which steels result in very high qualities of the the finished chain.
[0016] For the investigation, sample material was manufactured as laboratory melts with ingot dimensions of 225x225 mms. The respective ingots were forged into bars with a diameter of 140 mms. This gives a reduction rate of about 3, which is insufficient in normal production. This means that the results from normal production will be significantly better than the test results discussed in the following description.
[0017] Test samples were produced having two different analyses, MnCrNiMo variant, and MnCrNiMoV, respectively
[0018] The steel according to the invention, after through hardening gives a very small difference between surface hardness and hardness at the center.
[0019] In table I, the analyses are given for two different steel samples.

Table I

Variant	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Al
MnCrNiMo No. 129	0.20	0.30	1.26	0.008	0.004	1.80	1.25	0.45	0.19		0.022
MnCrNiMoV No. 131	0.19	0.24	1.10	0.007	0.003	1.78	1.20	0.33	0.18	0.10	0.024

These two sample steels were analyzed according to the following.

1. **Tempering:**

[0020] Fig. 1 shows the hardness as a function of the tempering temperature, tempering time 1 hour. Hardening temperatures for the respective melts are 850°C for melt No. 129, and 890°C for melt No. 131. Sample size 25x25x25 mm.
[0021] As can be seen in Fig. 1 melt No. 129 exhibits a flat curve without breaking points, which makes it less sensitive to variations in tempering temperature fluctuations. For the melt 131 the vanadium gives a strong tempering resistance up to 630°C, but at higher temperatures a steep curve is obtained with an increased sensitivity for temperature variations.

2. **Through hardening:**

[0022] Fig. 2 shows the hardness as a function of the depth underneath the surface of a hardened not tempered sample with a diameter of 140 mm, and
[0023] Fig. 3 shows the hardness after tempering at 615°C for the melt No. 129 and at 645°C for melt No. 131.
[0024] The hardening temperature for the melt No. 129 was 850°C and for the melt No. 131, 890°C, all being quenched in water.
[0025] As is evident from the diagramms the melt No. 129 exhibits the best result of the through hardening both for the not tempered and the tempered sample. The difference in hardness between surface and center is very small.

3. **Jominy:**

[0026] Fig. 4 shows the result of the jominy test. The austenitization temperature has been the same as with the through hardening test according to item 2 above.

[0027] The jominy test result corresponds well with the through hardening result according to item 2. Melt No. 129 has the best hardenability.

4. **Mechanical properties**

[0028] Table II below shows the mechanical properties of hardened and tempered bar samples with a diameter of 140 mm. Heat treatment and taking of samples were made according to normal practice for testing of chain material. The melt No. 129 showing the best results in the hardenability testing and tempering tests has been examined at three different tempering temperatures.

Table II

Mechanical properties									
Melt	Harden. temp °C	Tempering. temp°C	Rel Mpa	Rm Mpa	AS %	Z %	KV,J		
							- 40°C	- 20°C	±0°C
129	850	615	822	917	17	63	83	134	138
		590	857	937	16	72	89	101	142
		570	923	992	15	67	108	102	123
131	890	645	896	963	17	64	99	122	126
Demand acc. to DNV			580	860	12	50		50	70

[0029] The two melt samples show rather similar results. The lowest allowed tempering temperature for chain K4 is 570°C according to DNV (Det Norske Veritas). As is evident from Table II this demand would not cause any problems, but at the same time does not allow for any substantial reductions of alloy elements.

[0030] The impact toughness at -20°C is close to the demand according to DNV, but only an area reduction rate of 3 is made with the melt sample, while castings in the production will have an area reduction rate of about 12, so this feature will be substantially improved.

5. **Testing according to DNV approval rules of a full scale production melt.**

[0031] Charge analysis for the production of 160 mmØ bar:

C	Si	Mn	P	S	Cr	Ni	Mo	Cu
0.19	0.26	1.19	0.008	0.009	1.75	1.18	0.44	0.14

Al	Sn	Sb(ppm)	As	B (ppm)	O (ppm)	N (ppm)
0.015	0.007	2	0.008	≤1	9.8	72

Heat treatment sensitivity analysis

Varied austenitization temperature

[0032] Austenitisation 30 min, cooling in water at hardening Tempering 610°C, 60 min, cooling in water after tempering

Sample No.	Austenitisation temperature °C	Rel Mpa	Rm Mpa	A5 %	Z %	KV -20°C J
1	840	890	958	18	70	over 147*
2	870	879	957	17	71	over 147*
3	910	879	957	18	72	over 147*

*Max. force in testing equipment

Heat treatment sensitivity analysis

Varied tempering temperature

[0033] Austenitisation 870°C, 30 min, cooling in water at hardening Tempering 60 min, cooling in water after tempering

Sample No.	Tempering temperature °C	Rel Mpa	Rm Mpa	A5 %	Z %	KV -20°C J
6	570	991	1057	16	67	over 147*
7	590	925	999	17	69	over 147*
2	610	879	957	17	71	over 147*
8	630	838	914	20	72	over 147*
9	650	782	858	21	73	over 147*

*Max. force in testing equipment

Heat treatment sensitivity analysis

Varied tempering time

[0034] Austenitisation 870°C, 30 min, cooling in water at hardening Tempering 610°C, cooling in water after tempering

Sample No.	Tempering time, min	Rel Mpa	Rm Mpa	A5 %	Z %	KV -20°C J
4	30	890	958	18	70	over 147*
2	60	879	957	17	71	over 147*
5	90	869	941	18	74	over 147*

*Max. force in testing equipment

Testing for temper embrittelment

Varied cooling velocity after tempering

[0035] Austenitizing 870°C, 30 min, cooling in water at hardening Tempering 610°C, 60 min

Sample No.	Cooling after tempering	KV -0°C J	KV -20°C J	KV -40°C J
2	Water	147*	147*	147*
2L	>40 min to 300°C	147*	147*	147*

*Max. force in testing equipment

The degree of reduction is about 12 times, which fact explains the big differences in performance compared to the laboratory test materials, having a degree of reduction of only about 3 times, but still being improved compared to the prior art.

Claims

1. A chain type steel, suitable for the production of bars with a diameter of up to about 160 mm, e.g. to be used for the manufacture of heavy anchor chains, comprising, in weight-%:

C 0.15 - 0.23
Si 0.10 - 0.40
Mn 1.00 - 1.50
P max. 0.025
S max. 0.025
Cr 1.50 - 2.20
Ni 0.80 - 1.50
Mo 0.30 - 0.60
Cu max. 0.30
Al < 0.2
V < 0.2
Nb < 0.2
Ti < 0.2
the balance being Fe.

2. A chain type steel according to claim 1, comprising, in weight-%:

C 0.19 - 0.21
Si 0.20 - 0.30
Mn 1.15 - 1.25
P max. 0.015
S max. 0.020
Cr 1.65 - 1.75
Ni 1.15 - 1.25
Mo 0.42 - 0.48
Cu max. 0.25
Al < 0.2
V < 0.2
Nb < 0.2
Ti < 0.2
the balance being Fe.

3. A chain type steel according to claim 2, comprising, in weight-%:

C 0.18 - 0.20
Si 0.20 - 0.30
Mn 1.15 - 1.25
P max. 0.015
S max. 0.020
Cr 1.65 - 1.75
Ni 1.15 - 1.25
Mo 0.30 - 0.36
Cu max. 0.25
V 0.10 - 0.14
Al < 0.2
Nb < 0.2
Ti < 0.2
the balance being Fe.

4. A chain type steel according to claim 2, being hardened at 850°C, and tempered at 615°C.

5. A chain type steel according to claim 3, being hardened at 890°C, and tempered at above 630°C, preferably at 645°C.

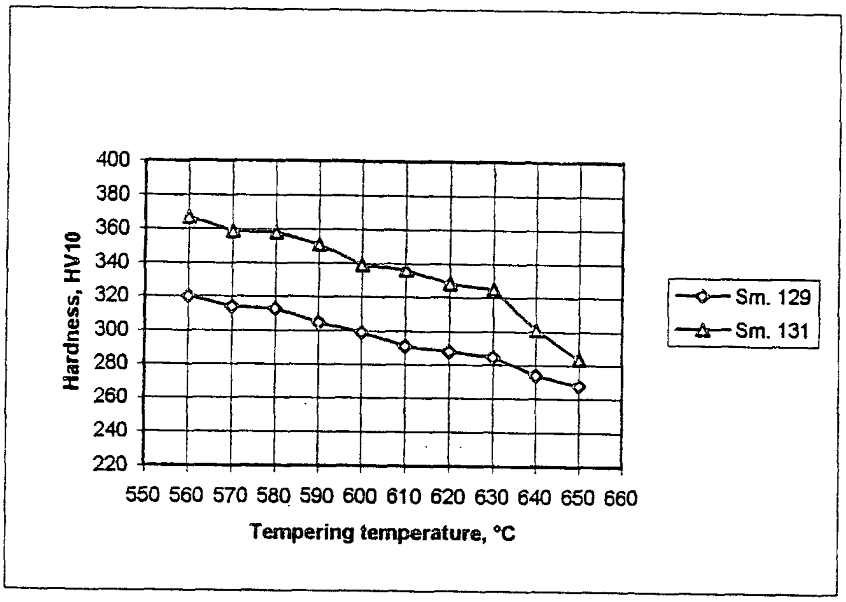
400
380
360
340
320
300
280
260
240
220
Hardness, HV10
550 560 570 580 590 600 610 620 630 640 650 660
Tempering temperature, °C
Sm. 129
Sm. 131

FIG. 1

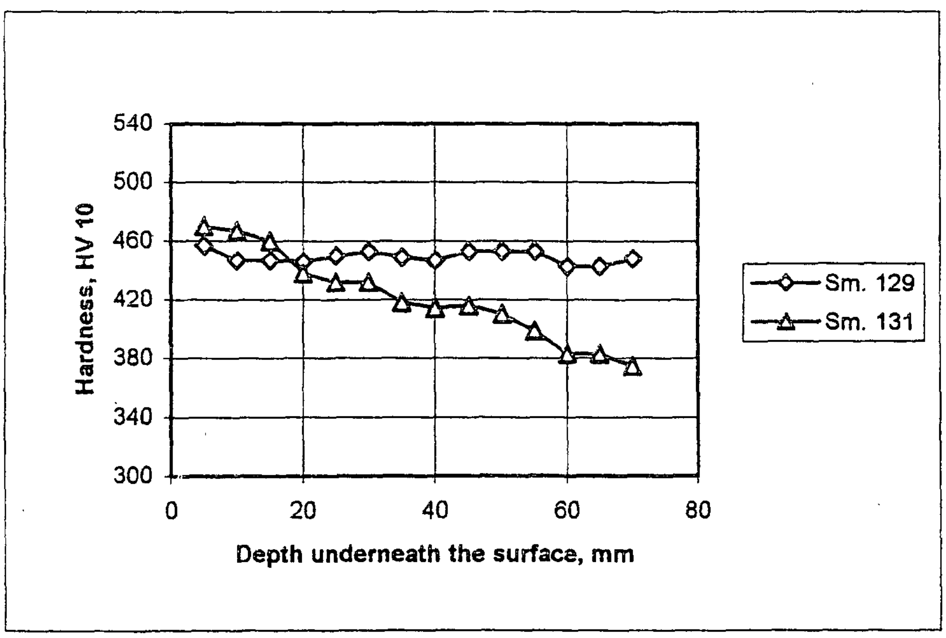
540
500
460
420
380
340
300
Hardness, HV 10
0
20
40
60
80
Depth underneath the surface, mm
Sm. 129
Sm. 131

FIG. 2

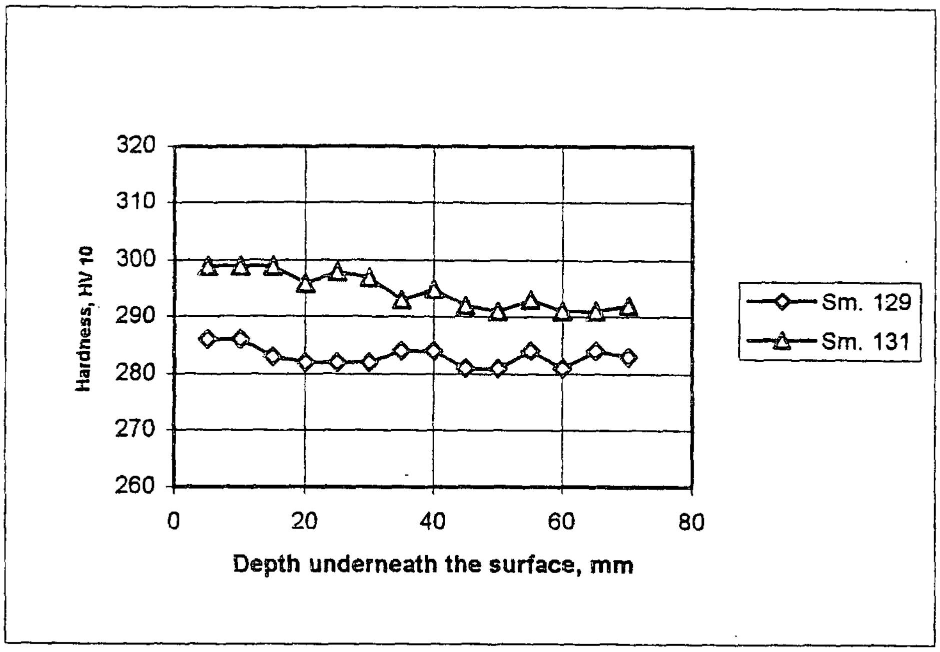
320
310
300
290
280
270
260
Hardness, HV 10
0
20
40
60
80
Depth underneath the surface, mm
Sm. 129
Sm. 131

FIG. 3

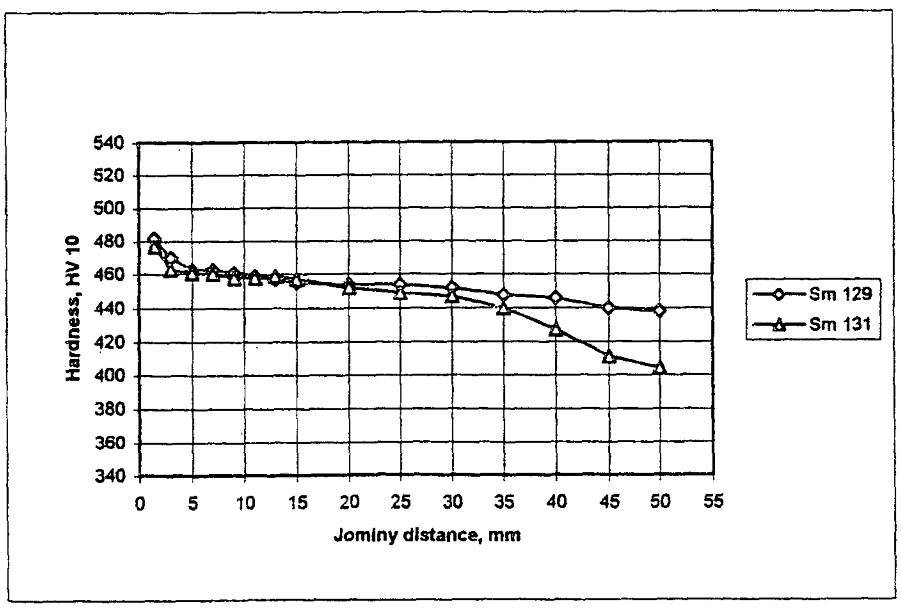
540
520
500
480
460
440
420
400
380
360
340
Hardness, HV 10
0
5
10
15
20
25
30
35
40
45
50
55
Jominy distance, mm
Sm 129
Sm 131

FIG. 4

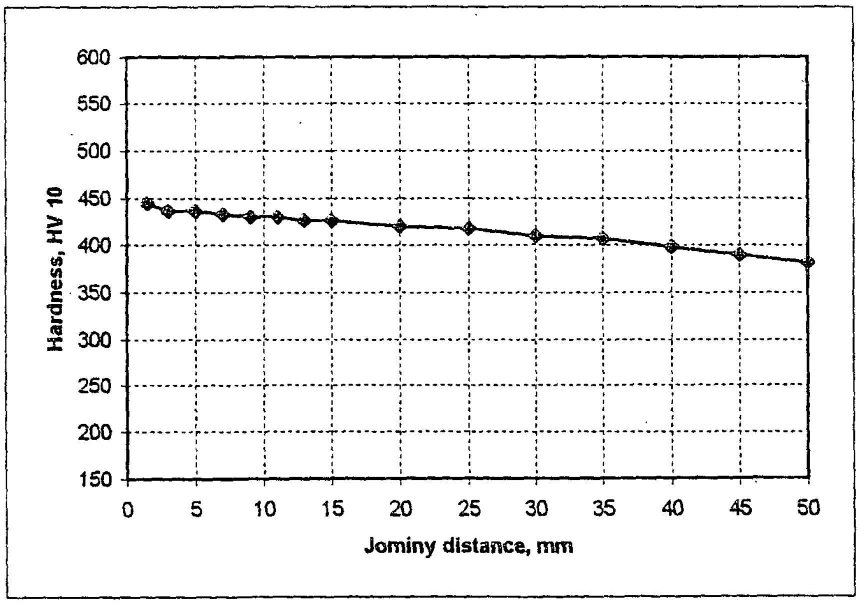
600
550
500
450
400
350
300
250
200
150
Hardness, HV 10
0
5
10
15
20
25
30
35
40
45
50
Jominy distance, mm

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 85 0029

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y,D	GB 2 110 239 A (UDDEHOLMS AB) 15 June 1983 (1983-06-15) * claims; tables *	1	C22C38/44
X	PATENT ABSTRACTS OF JAPAN vol. 015, no. 313 (C-0857), 9 August 1991 (1991-08-09) -& JP 03 115523 A (KOBE STEEL LTD), 16 May 1991 (1991-05-16) * tables 1 and 2, sample 5 * * abstract *	1	
Y	LLANOS J M: "NEW STEEL GRADE WITH AN OPTIMUM COMPROMISE BETWEEN HARDENABILITY AND TOUGHNESS" INTERNATIONAL CONGRESS ON HEAT TREATMENT AND SURFACE ENGINEERING,XX,XX, 26 September 1994 (1994-09-26), pages 111-119, XP000653532 * table 2; page 113 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

C22C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	18 June 2001	Bjoerk, P

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

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18-06-2001

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82