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(54) STEEL

(57) This is an invention in metallurgy, referring specifically to steel with high ductility in subzero temperatures, good weldability, resistance to brittle behavior and corrosion, heat-resistance in high temperatures. Such steel can be used for the production of oil pipelines, natural gas pipelines, product pipelines, offshore platforms, welded structures and containers which can operate under pressure, different equipment and its component parts operating in temperatures from - 100˚C to +450˚C.

The steel containing carbon, manganese, silicium, chrome, nickel, vanadium, niobium, titanium, aluminium, calcium, sulphur, phosphorus, nitrogen, copper, stibium, stannum, arsenic and iron additionally includes molybdenum, with the following component ratio (weight, %):

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Carbon	0.02 – 0.11
Manganese	0.10 – 1.8
Silicium	0.06 – 0.6
Chrome	0.005 – 0.30
Nickel	0.005 – 1.0
Vanadium	0.01-0.12
Niobium	0.02-0.1
Titanium	0.01-0.04
Aluminium	0.01-0.05
Calcium	0.0005-0.008
Sulphur	0.0005-0.008
Phosphorus	0.001-0.012
Nitrogen	0.001-0.012
Copper	0.005-0.25
Stibium	0.0001-0.005
Stannum	0.0001-0.007
Arsenic	0.0001-0.008
Molybdenum	0.0001-0.5
Iron	remaining share

This being the case, total content of nickel and manganese is related to molybdenum and phosphorus content (weight. %) according to the following equation:

$$\frac{Ni + Mn}{1 + Mo} \cdot P \langle 0.03$$

Description

TECHNICAL FIELD

[0001] This is an invention in metallurgy, referring specifically to steel with high ductility in subzero temperatures, good weldability, resistance to brittle behavior and corrosion, heat-resistance in high temperatures. Such steel can be used for the production of oil pipelines, natural gas pipelines, product pipelines, offshore platforms, welded structures and containers which can operate under pressure, different equipment and its component parts operating in temperatures from - 100˚C to +450˚C.

BACKGROUND ART

[0002] There is steel having the following component ratio (weight, %):

Carbon	0.03 - 0.11
Manganese	0.9 - 1.8
Silicium	0.06 - 0.6
Chrome	0.005 - 0.30
Nickel	0.005 - 0.3
Vanadium	0.02-0.12
Niobium	0.03-0.1
Titanium	0.01-0.04
Aluminium	0.01-0.055
Calcium	0.001-0.005
Sulphur	0.0005-0.008
Phosphorus	0.0005-0.010
Nitrogen	0.001-0.012
Copper	0.005-0.25
Stibium	0.001-0.005
Stannum	0.001-0.007
Arsenic	0.001-0.008
Iron	remaining share

(Patent of the Russian Federation No. 2141002, publication date 10.11.1999).

[0003] This steel has all properties required for the production of oil pipelines, natural gas pipelines, product pipelines and other welded structures which can operate in temperatures from -100˚C to +450˚C. However, such steel has strength properties which are insufficient for the manufacture of the above and other products made of steel sheets above 20 mm thick. This drawback can be eliminated by way of increasing hardening characteristics through higher content of alloying agents; nevertheless such steel may demonstrate brittle behavior.

DISCLOSURE OF THE INVENTION

[0004] This invention is aimed at improvement of steel strength properties. The result of this invention is as follows: sheets and billets up to 50 mm thick with the following properties: yield stress above 550 N/mm^2, breaking strength above 620 N/mm^2; preserving high ductility in temperatures down to -100˚C, resistance to brittle behavior during manufacture and operation, good weldability in factory and field environment.

[0005] Technically, the required result is obtained due to the fact that the steel containing carbon, manganese, silicium, chrome, nickel, vanadium, niobium, titanium, aluminium, calcium, sulphur, phosphorus, nitrogen, copper, stibium, stannum, arsenic and iron additionally includes molybdenum, with the following component ratio (weight, %):

Carbon	0.02 - 0.11
Manganese	0.10 - 1.8
Silicium	0.06 - 0.6
Chrome	0.005 - 0.30
Nickel	0.005 - 1.0

(continued)

Vanadium	0.01-0.12
Niobium	0.02-0.1
Titanium	0.01-0.04
Aluminium	0.01-0.05
Calcium	0.0005-0.008
Sulphur	0.0005-0.008
Phosphorus	0.001-0.012
Nitrogen	0.001-0.012
Copper	0.005-0.25
Stibium	0.0001-0.005
Stannum	0.0001-0.007
Arsenic	0.0001-0.008
Molybdenum	0.0001- 0.5
Iron	remaining share

This being the case, total content of nickel and manganese is related to molybdenum and phosphorus content (weight. %) according to the following equation:

$$\frac{Ni+Mn}{1+Mo}\cdot P\langle 0.03$$

[0006] The above mentioned nickel, manganese, molybdenum and phosphorus limits in steel supported by the enumerated ration of components provide both improved hardening characteristics for steel sheets up to 50 mm thick, high values of strength and ductility in low temperatures (down to -100˚C) and elimination of embrittlement in the process of manufacture and use of products made from these sheets.

THE BEST MODE FOR CARRYING OUT THE INVENTION

[0007] Table 1 shows the chemical composition of three heats of this steel in comparison with a known composition of steel. Compositions have been selected in such a way so as to estimate molybdenum and nickel contribution to steel sheet strength.

[0008] All heats have been performed in a vacuum induction furnace. Furnace charge consisted of armco iron and, depending on variant of composition, of nickel, ferromolybdenum, copper and other charge materials. When the required underpressure in the furnace was achieved charge meltdown was started. After complete meltdown and metal heating up to 1630-1650˚C the charge was degasified and the required predetermined amounts of manganese, ferrovanadium and ferroniobium were added to the molten pool; then deoxidizing agents (ferrosilicium, aluminium and ferrotitanium) were added.

[0009] As the temperature of liquid steel reached the required level (1560-1580˚C) the airfree metal was run off directly from the smelting crucible to the casting mold. Molded ingots were then cooled in casting molds under normal pressure, not in vacuum.

[0010] On the whole, 12 trial heats have been performed in the vacuum induction furnace. Analysis of metal chemical composition has been performed for all heats and, on the basis of its results, three heats were selected with equivalent carbon content equal to 0.37.

[0011] The equivalent carbon content was determined by the following formula:

$$C_{eq}=C+\frac{Mn}{6}+\frac{Cr+Mo+Nb+V+Ti}{5}+\frac{Ni+Cu}{15}$$

Table 2 shows the properties of these heats in comparison with heats of a known composition whose C_{eq} is equal to 0.37. The obtained results demonstrate that the new steel of the above composition possesses the required strength

properties in 50-mm cross-sections and high ductility in low temperatures. The ratio between the total content of nickel and manganese and the concentration of molybdenum and phosphorus for heats 1, 2 and 3 is 0.01, 0.0057 and 0.0064, respectively, i.e. less than 0.03.

Table 1. Chemical composition of three heats of the proposed steel in comparison with a known composition of steel.

Component	Content (weight,%)			
	Heat 1	Heat 2	Heat 3	Heat of known steel
carbon	0.02	0.04	0.09	0.06
manganese	1.5	1.0	0.3	1.4
silicium	0.1	0.18	0.25	0.25
chrome	0.05	0.28	0.2	0.15
nickel	0.5	0.1	0.9	0.1
vanadium	0.1	0.05	0.01	0.07
niobium	0.032	0.06	0.087	0.06
titanium	0.01	0.015	0.035	0.015
aluminium	0.012	0.021	0.028	0.024
calcium	0.0005	0.003	0.006	0.005
sulphur	0.0035	0.004	0.008	0.003
phosphorus	0.005	0.007	0.008	0.005
nitrogen	0.005	0.006	0.007	0.007
copper	0.23	0.1	0.01	0.15
stibium	0.0003	0.0009	0.004	0.005
stannum	0.0005	0.005	0.007	0.005
arsenic	0.0002	0.004	0.008	0.006
molybdenum	0.0001	0.35	0.5	-
equivalent carbon content	0.37	0.37	0.37	0.37
$\frac{Ni + Mn}{1 + Mo} \cdot P$	0.01	0.0057	0.0064	-

Table 2. Properties of the heats of Table 1.

Heat	Cross section, mm	Breaking strength, N/mm^2	Yield stress, N/mm^2	Ductile-brittle transition point, ˚C
1	20/50	836/687	706/583	-90/-100
2	20/50	807/712	683/600	-90/-100
3	20/50	767/675	650/566	-90/-100
Heat of known steel	20/50	621/528	528/449	-80/-30

Claims

1. Steel, containing carbon, manganese, silicium, chrome, nickel, vanadium, niobium, titanium, aluminium, calcium, sulphur, phosphorus, nitrogen, copper, stibium, stannum, arsenic and iron. Its distinctive feature is additional content of molybdenum, with the following component ratio (weight, %):

Carbon	0.02-0.11
Manganese	0.10-1.8
Silicium	0.06-0.6
Chrome	0.005-0.30
Nickel	0.005-1.0
Vanadium	0.01-0.12
Niobium	0.02-0.1
Titanium	0.01-0.04
Aluminium	0.01-0.05
Calcium	0.0005-0.008
Sulphur	0.0005-0.008
Phosphorus	0.001-0.012
Nitrogen	0.001-0.012
Copper	0.005-0.25
Stibium	0.0001-0.005
Stannum	0.0001-0.007
Arsenic	0.0001-0.008
Molybdenum	0.0001-0.5
Iron	remaining share,

this being the case, total content of nickel and manganese is related to molybdenum and phosphorus content (weight. %) according to the following equation:

$$\frac{Ni + Mn}{1 + Mo} \cdot P \langle 0.03$$

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2004/000307

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/00, 38/18, 38/40, 38/58, 38/60, C21D 8/00-9/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	RU 2141002 C1 (AKTSIONERNOE OBSCHESTVO ZAKRYTOGO TIPA NAUCHNO-PROIZVODSTVENNOE OBIEDINENIE "POLIMETALL") 10.11.1999, the claims (cited in the description).	1
Y	RU 21376776 C1 (NIPPON STEEL CORPORATION) 10.09.1999, the abstract, claim 1, page 6 of the description, the penultimate paragraph	1
Y	I. I. Novikov. Teoriya termicheskogo obrabotki metallov, Moscow, Metallurgiya, 1974, pages 260-263	1
Y	RU 2180691 C1 (AKTSIONERNOE OPBSCHESTVO ZAKRYTOGO TIPA NAUCHNO-PROIZVODSTVENNOE OBIEDINENIE "POLIMETALL") 20.03.2002, the claim, table 4	1
A	FR 2400067 A1 (KAWASAKI STEEL CORPORATION) 09.03.1979, the abstract	1

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
(29.11.2004)	(02.12.2004)
Name and mailing address of the ISA/ RU Facsimile No.	Authorized officer Telephone No.

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