

[54] **FERRITIC, AUSTENITIC,
MARTENSITIC STAINLESS STEEL**

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[22] Filed: **Oct. 13, 1969**
[21] Appl. No.: **871,396**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 856,872, July 3,
1969, which is a continuation of Ser. No. 558,998,
June 20, 1966, abandoned.
[52] U.S. Cl.**29/196.1, 75/128 R**
[51] Int. Cl.**B32b 15/00, C22c 39/20**
[58] Field of Search**29/196.1; 75/128 N, 128 R**

[56]

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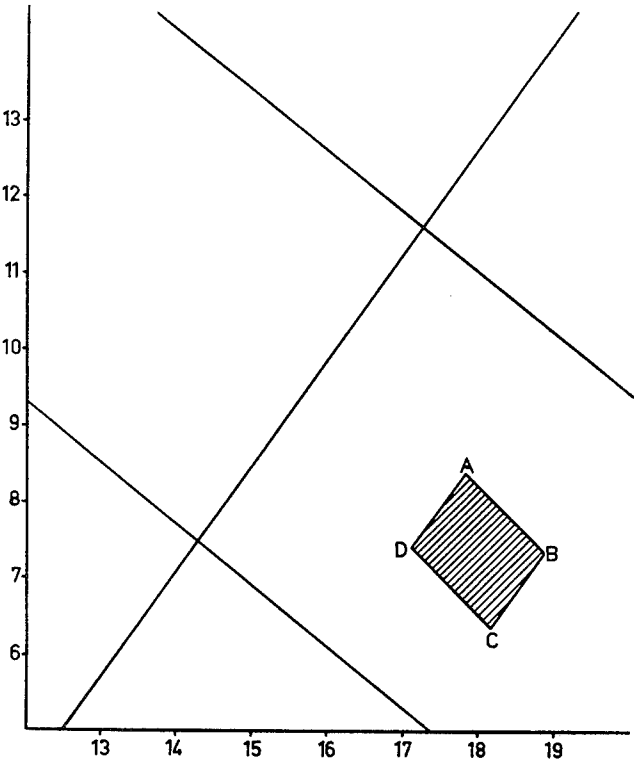
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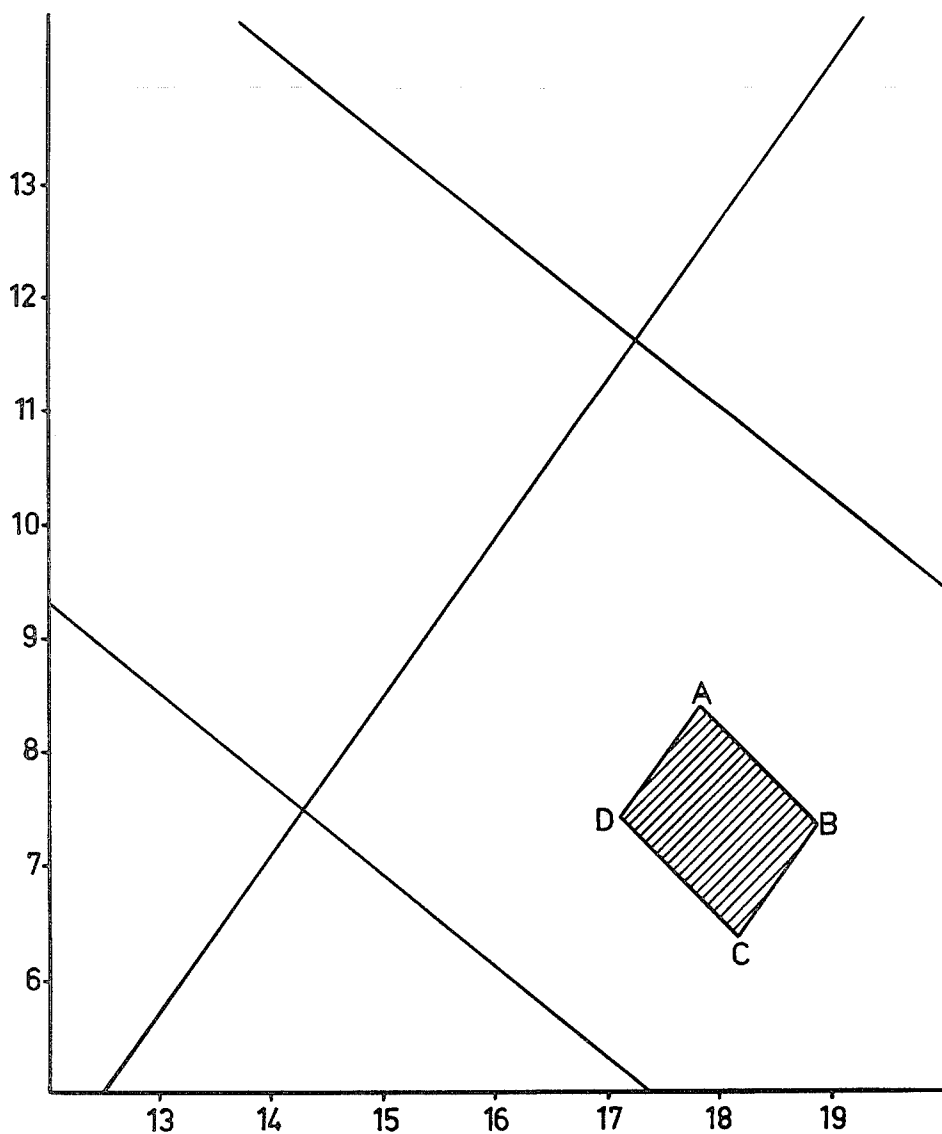
[57]

ABSTRACT

Rollable and weldable stainless steel with a high degree of tension and toughness within a wide range of temperatures both in a hardened and a tough-hardened condition comprising 5–15 percent by weight of ferrite, 10–40 percent by weight of austenite and the remainder tempered martensite.

3 Claims, 1 Drawing Figure





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FERRITIC, AUSTENITIC, MARTENSITIC STAINLESS STEEL

This is a continuation-in-part of my copending application Ser. No. 856,872 filed July 3, 1969 which is in turn a continuation of my application Ser. No. 558,998 filed June 20, 1966, now abandoned. This invention relates to rollable and weldable stainless steel with a high tension and toughness within a wide range of temperature both in a hardened and a tough-hardened condition and to products produced from the steel. Among the products welded constructions can especially be mentioned, e.g., pressure vessels where it is desirable to reduce the thickness of the material by using a material with a high strength. The present invention relates further to a stainless sheet iron material with a high strength, good corrosion resistance and a low coefficient of thermal expansion for use as press platens in the process of pressing wallboards and laminates (formica). Finally, wire and strip products may also be mentioned, such, for example as are intended to be used as filler materials in the process of welding.

Austenitic stainless steels are mainly used for welded constructions of steel resistant to corrosion. These steels are normally known as 18-8 (18 percent Cr, 8 percent Ni), 18-10 (18 percent Cr, 10 percent Ni), 18-10-Mo (18 percent Cr, 10 percent Ni plus about 1-4 percent Mo), 25-12 (25 percent Cr, 12 percent Ni), 25-20 (25 percent Cr, 20 percent Ni) etc. They are characterized by a very good toughness, good ductility and very good weldability. In comparison to unalloyed and low-alloyed steel of a ferrite-carbide structure (such as ferrite plus perlite, bainite, tempered martensite) they have a low strength. The yield limit ("0.2-limit") is particularly low, in general below 25 kg/mm². Owing to this circumstance a construction exposed to mechanical stresses, e.g., a pressure vessel of austenitic stainless steel, often has an uneconomical thickness. In order to reduce the stainless steel portion it is therefore sometimes necessary to make use of a stainless lining combined with certain high-strength unalloyed or low-alloyed steels or to so-called compound steel, a method which in both cases leads to certain technical difficulties, e.g., welding problems. In spite of their low strength, however, the austenitic steels are very widely utilized owing to their great toughness, good ductility and particularly because they are easy to weld.

In cases when greater strength is required and the demands on corrosion resistance are moderate certain stainless steels have up to now been used, their high strength being obtained by means of a high carbon content. This refers to so-called martensite steels which reach their high strength in connection with hardening and tempering. In these steels chromium is the main alloying element. As an example some stainless steels standardized in Sweden having 13-17 percent of chromium may be mentioned.

SIS steel***	Condition**	Carbon (percent)	Chromium (percent)	Nickel (percent)	Yield limit kg/mm ²	Ultimate strength kg/mm ²	Hardness Brinell
2303.....	-4	0.18-0.25...	min 12.0.....		min 70.....	90-105.....	270-320
2304.....	-3	0.30-0.40...	min 13.0.....		min 110.....	min 150.....	*455-625
2321.....	-3	max 0.25....	min 16.....	2.5-3.0.....	min 65.....	85-100.....	250-300

*Vickers.

**The figures refer to the condition according to the standards.

***The Swedish Standards Association.

The drawback regarding these steels is the high carbon content, which means that the steels grow sensitive to cracks in welding, since the martensite which is created in the heat-actuated zone is hard and brittle. In order to avoid the formation of cracks in these steels it is necessary to pre-heat them in the process of welding and to temper them after the welding.

There are also ferrite austenitic stainless steels having a comparatively high yield limit such as, for example, the following standardized steel:

SIS steel²⁷ - 2324

Carbon %	max 0.10
Chromium %	24-27
Nickel %	4.5-6.0
Molybdenum %	1.3-1.8
Yield limit kg./mm. ²	min 42

Ultimate strength kg./mm.²
Hardness Brinell

min 60
max 260

²⁷ The Swedish Standards Association

However, the weldability of steels of this type is not as good, since they are sensitive to grain growth. In welding, the heat-actuated zone becomes coarse-grained, a circumstance which renders the steels brittle.

The steel according to the present invention is characterized in that it comprises:

Percent	Percent	Percent
0.020 - 0.040, preferably	0.030 - 0.040	Carbon
0.2 - 1.0, preferably	0.3 - 0.5	Silicon
0.2 - 2.0, preferably	0.6 - 1.0	Manganese
15 - 18, preferably	16 - 17	Chromium
4 - 6, preferably	4.5 - 5.5	Nickel
0 - 2, preferably	0.8 - 1.3	Molybdenum
0.02 - 0.08, preferably	0.02 - 0.05	Nitrogen

the balance being iron and the contents of the alloying materials mutually adapted in such a way that the chromium equivalent plus the nickel equivalent are between 24.5 and 26.2 and 1.4 times the chromium equivalent minus the nickel equivalent is between 16.5 and 19.0, the chromium equivalent being percent Cr + percent Si + percent Mo, and the nickel equivalent percent Ni + 0.5 × percent Mn + 30 × (percent C + percent N); as a result after the hardening the structure contains martensite, ferrite and austenite. From the analytic and structural point of view the steel may be defined as a transformation form between an austenitic and a ferrite-martensitic steel.

The phase composition of the alloys according to the present invention is shown in graphical form in the accompanying drawing.

In the diagram the chromium equivalent is given as the abscissa and the nickel equivalent as the ordinate. The alloys according to the present invention lie within the dashed area ABCD, being within the three-phase area, austenite plus martensite plus ferrite. Owing to this condition the structure of the alloys will after rolling and hardening at above 900° C. and tempering at 500°-630° C., contain 5-15 percent ferrite, 10-40 percent austenite, and the remainder tempered martensite.

The steel is heat-treated by means of air hardening at more than 900° C. and subsequent tempering within a temperature range of 500°-630° C. At the hardening temperature the structure consists of austenite plus 5 to 15 percent ferrite. In the process of cooling to room temperature or below no transformation of the ferrite takes place, while the austenite is transformed into martensite. However, a few per cent of the austenite remain untransformed.

By heating the hardened steel up to 500°-630° C. a tempering of the martensite and an equalization of the hardening stresses is obtained, which is normal for toughened steel, and

the toughness of the steel increases. However, what distinguishes this type of steel is that in the process of tempering within this range of temperature austenite is also created, which is stable also at low temperatures. This creation of stable austenite increases with an increased tempering temperature up to about 630° C. If heated up to higher temperatures the austenite created is no longer stable; it is transformed into martensite when cooled down to room temperature. By varying the temperature and the length of time of the tempering different levels of strength having yield limits varying between 50 and 80 kg./mm.² are obtained. A longer tempering time reacts in the same direction as an increase in the tempering temperature.

In spite of the low carbon content the steel has a high strength. It differs from the martensite steels having a high carbon content by being easy to weld. The martensite which is created in the heat-actuated zone is tough owing to the low carbon content of the steel. Consequently, this zone is not embrittled which it is as regards the chromium steels with a high carbon content. The austenite which is contained in the steel also contributes to the toughness of the heat-actuated zone. Consequently, the steel is not sensitive to cracks in the process of welding and can be welded without pre-heating. In order to obtain maximum toughness characteristics it is suitable to anneal after the welding within a temperature range of 500°–630° C. This produces an equalization of the welding stresses and a tempering of the martensite in the hardening zone. The annealing temperature that should be chosen depends on the temperature used in the tempering in connection with the tough hardening of the steel.

A characteristic feature of this steel is also that it has a certain content of ferrite. As regards hardable steels having a high content of carbon the problem has been how to adapt the analysis in such a way that ferrite is avoided. It is a well-known fact that ferrite in the martensitic steels with a high content of carbon lowers the toughness, which is the reason why the content of ferrite-forming substances must be maintained at a low rate when high toughness is required. If, on the other hand, the content of carbon is low, it has been proved that a good toughness of martensitic steels is obtained in spite of the existence of ferrite in the structure.

Thanks to this it has been possible to keep the content of chromium high at about 16 percent, and it has also been possible to add about 1 percent molybdenum. This means a considerably higher resistance to corrosion as compared with the results obtained with the previously known ferrite-free steels, whose content of chromium must be limited to about 14 percent if there is no molybdenum, and to about 13 percent if about 1 percent molybdenum is desired. Since the steel according to the present invention is hardenable it differs from the ferrite containing steels according to the French Patent specification No. 803.361 having 0.020–about 0.300 percent C, 1.3–3.0 percent Mn, 1.5–6.5 percent Ni, 16.0–23.0 percent Cr and possibly up to about 2.5 percent Cu or 3 percent Mo or 3 percent W. In these steels with their composition so adapted that two phases, ferrite plus austenite are obtained, the object of using ferrite is to reduce the sensitivity to inter-granular corrosion characteristic for austenitic steels having a high content of carbon.

The high toughness of the steel is also made obvious by the circumstance that the curve for impact work at various temperatures is rectilinear without any marked transition from a high to a low value and with a transition temperature below –196° C. As the transition temperature at impact tests it is usual to indicate the temperature at which the curve for impact work versus the temperature for an impact test specimen with an area of 10 × 10 mm.², a V-indication 2 mm. deep and a support distance of 45 mm. passes the value 2.8 kg. For welded constructions, especially for pressure vessels, it is desirable to use material with a low transition temperature; it is often prescribed that the transition temperature shall lie below 0° C. or –20° C. At –196° C. the present steel shows an impact work of about 5 kg., which is considerably above 2.8 kg., a value which is regarded as a criterion of the transition temperature.

The steel is also characterized in that the high temperature yield limit up to 300°–400° C. is only slightly less than the yield limit at room temperature.

The steel has a good resistance to irradiation with neutrons in a nuclear reactor, and it has even after being irradiated to neutron doses of 3 × 10¹⁹ neutrons/cm.² (>1 mev.) a transition temperature for impact tests below 80° C.

The steel has a low coefficient of expansion. At 20°–100° C. it is 12 × 10^{–6}; it is thus of the same magnitude as unalloyed steel and considerably lower than the figures for austenitic steel.

A few examples of steels according to the present invention and their properties are given below.

EXAMPLE 1

Sheet iron having a thickness of 14 mm. was produced from a steel having the following composition:

	Percent
C	0.038
Si	0.53
Mn	0.76
P	0.017
S	0.005
Cr	16.0
Ni	4.7
Mo	1.02
N	0.038

the remainder consisted of iron and unintentional impurities.

The sheet iron was heated up to 900° C., which temperature was maintained for 1 hour; it was then hardened in air and tempered at 600° C., the latter temperature being maintained for 6 hours. After testing the sheet iron heat-treated in this manner the following strength values were obtained:

Yield limit, "0.2-point"	60 kg./mm. ²
Ultimate Strength	91 kg./mm. ²
Elongation, 5 × d	20%
Impact work, 20° kv.	7.2 kg.
Hardness, Brinell	278

At a higher temperature the following strength values were obtained:

	100° C.	200° C.	300° C.	400° C.	500° C.
Yield limit, kg./mm. ²	60	60	60	59	51
Ultimate strength, kg./mm. ²	84	80	79	73	63
Elongation, 5 × d %	20	18	16	14	14

Impact work at different temperatures:

Testing temperatures	–196° C.	–74° C.	–20° C.	0° C.	+20° C.
Impact work, kv., kg.	5.3	6.3	6.7	7.1	7.2

The sheet iron was welded by means of coated electrodes having a similar composition. No cracks were noticed either in the weldings or in the zone actuated by the welding heat.

Example 2

70 mm sheet iron of the same charge as that used in Example 1 was hardened in air after being heated up to 900° C. for 2 hours and tempered at 600° C. for 6 hours. The following strength values were obtained:

Yield limit	64 kg./mm. ²
Ultimate strength	92 kg./mm. ²
Elongation, 5 × d	18%
Impact work, kv.	7.3 kg.

EXAMPLE 3

A forging round with a diameter of 170 mm. and 250 mm. in length was heat-treated by heating up to 900° C. for 4 hours subsequent cooling in air and tempering at 575° C. for 6 hours. The composition of the steel in percent by weight was:

C	Si	Mn	P	S	Cr	Ni	Mo	N
0.035	0.30	1.00	0.035	0.025	16.5	4.7	1.08	0.030

The following strength values were obtained:

Yield limit	76 kg./mm. ²
Ultimate strength	92 kg./mm. ²
Elongation, 5 × d	20%
Contraction	57%
Impact work, kv., 20° C.	14 kg.

At higher temperature the following strength values were obtained:

	200° C.	300° C.	400° C.
Yield limit, kg./mm. ²	70	68	62
Ultimate strength, kg./mm. ²	80	73	72
Elongation, 5 × d, %	18	17	16
Contraction, %	70	70	69

Impact work at different temperatures:

a tough hardened type, containing:

Testing temperature	-196° C.	-74° C.	-20° C.	0° C.	+20° C.
Impact work, kv., kg.	6.2	11	12	13	14

Percent	Carbon
0.020-0.040	Silicon
0.2-1.0	Manganese
0.2-2.0	Chromium
15-18	Nickel
4-6	Molybdenum
0-2	Nitrogen
0.020-0.080	

EXAMPLE 4

From 70-mm. sheet iron of the same charge as that in Example 1 tensile and impact test specimen were taken which were emitted in a nuclear reactor at 240°-260° C. Strength tests prior to and after the irradiation resulted in the following values:

Quantity of neutrons/cm. ² (>1 mev.)	Irradiation Temperature	Yield limit kg./mm. ²	Ultimate strength kg./mm. ²	Elongation %
Unirradiated		66	88	18
5·10 ¹⁸	265° C.	90	102	17

Transition Temperature for Impact Tests

Impact test specimen 3 × 3 mm. T 0.17 is the temperature at which impact work 0.17 kg. is obtained and corresponds approximately to the temperature T 2.8, at which impact work 2.8 kg. is obtained for a normal test specimen.

Quantity of neutrons/cm. ² (>1 mev.)	Irradiation Temperature	T0,17	HV
Unirradiated	—	-192°	293
5,000 × 10 ¹⁸	265° C.	-137°	332
1.1 × 10 ¹⁹	265° C.	-122°	344
3 × 10 ¹⁹	265° C.	-80°	369

I claim:

1. Welded constructions of stainless steel characterized in that both the basic metal and the weld metal comprise steel of

and the balance iron with the usual impurities, the contents of the alloying materials being mutually adapted such that the chromium equivalent plus the nickel equivalent are between 24.5 and 26.2 and 1.4 times the chromium equivalent and the nickel equivalent are between 16.5 and 19.0, where the chromium equivalent is percent Cr + percent Si + percent Mo and the nickel equivalent percent Ni + 0.5 percent Mn + 30 (percent C + percent N), said stainless steel having been hardened by heating up to at least 900° C. to obtain a structure of austenite and ferrite only and then rapidly cooled to a low temperature so that most of the austenite was transformed into martensite, and thereafter tempered by heating up to 500°-630° C. to obtain a structure comprising 5-15 percent by weight of ferrite, 10-40 percent by weight of austenite and the remainder tempered martensite.

2. Steel according to claim 1 wherein the steel contains:

Percent	Carbon
0.030-0.040	Silicon
0.3-0.5	Manganese
0.6-1.0	Chromium
16-17	Nickel
4.5-5.5	Molybdenum
0.8-1.3	Nitrogen
0.020-0.050	

3. Welded constructions produced from the steel according to claim 1, intended to be exposed to neutron irradiation.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,650,709 Dated March 21, 1972

Inventor(s) Lars Johan Gustaf Morsing

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 32, "5,000" should be --5,00--;
Column 6, line 13, "equivalent and the" should
be --equivalent minus the--.

Signed and sealed this 25th day of July 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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