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(54) Title: HOT ROLLED AND HEAT-TREATED STEEL SHEET AND METHOD OF MANUFACTURING THE SAME

(57) Abstract: The invention deals with a hot rolled and heat-treated steel sheet, made of a steel having a composition comprising, by weight percent: C: 0.03 - 0.18 % Mn: 6.0 – 11.0 % Mo: 0.05 - 0.5 % B: 0.0005 – 0.005% S ≤ 0.010 % P ≤ 0.020 % N ≤ 0.008 % and comprising optionally one or more of the following elements, in weight percentage: Al < 3% Si ≤ 1.20 % Ti ≤ 0.050 % Nb ≤ 0.050 % Cr ≤ 0.5% V ≤ 0.2% the remainder of the composition being iron and unavoidable impurities resulting from the smelting, said steel sheet having a microstructure comprising, in surface fraction, - from 10% to 60% of retained austenite, - from 40% to 90% of ferrite, - less than 5% of martensite, - carbides below 0.8%, - and an inhomogeneous repartition of manganese, characterized by a manganese distribution with a slope above or equal to -40.

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Hot rolled and heat-treated steel sheet and method of manufacturing the same

The present invention relates to a high strength steel sheet having good weldability properties and to a method to obtain such steel sheet.

To manufacture various items such as parts of body structural members and body panels for automotive vehicles, it is known to use sheets made of DP (Dual Phase) steels or TRIP (Transformation Induced Plasticity) steels.

One of the major challenges in the automotive industry is to decrease the weight of vehicles in order to improve their fuel efficiency in view of the global environmental conservation, without neglecting the safety requirements. To meet these requirements, new high strength steels are continuously developed by the steelmaking industry, to have sheets with improved yield and tensile strengths, and good ductility and formability.

One of the developments made to improve mechanical properties is to increase content of manganese in steels. The presence of manganese helps to increase ductility of steels thanks to the stabilization of austenite. But these steels present weaknesses of brittleness. To overcome this problem, elements as boron are added. These boron-added chemistries are very tough at the hot-rolled stage but the hot band is too hard to be further processed. The most efficient way to soften the hot band is batch annealing, but it leads to a loss of toughness.

In addition to these mechanical requirements, such steel sheets have to show a good resistance to liquid metal embrittlement (LME). Zinc or Zinc-alloy coated steel sheets are very effective for corrosion resistance and are thus widely used in the automotive industry. However, it has been experienced that arc or resistance welding of certain steels can cause the apparition of particular cracks due to a phenomenon called Liquid Metal Embrittlement (“LME”) or Liquid Metal Assisted Cracking (“LMAC”). This phenomenon is characterized by the penetration of liquid Zn along the grain boundaries of underlying steel substrate, under applied stresses or internal stresses resulting from restraint, thermal dilatation or phases

transformations. It is known that adding elements like carbon or silicon is detrimental for LME resistance.

The automotive industry usually assesses such resistance by limiting the upper value of a so-called LME index calculated according to the following equation:

LME index = C% + Si%/4,

wherein C% and Si% stands respectively for the weight percentages of carbon and silicon in the steel.

The purpose of the invention is to provide a hot rolled and annealed steel sheet having high toughness with Charpy impact energy at 20°C higher than 0.4J/mm² together with good weldability properties.

Preferably, the hot rolled and annealed steel sheet according to the invention has a LME index of 0.36 or less.

Preferably, the hot rolled and annealed steel according to the invention has a carbon equivalent Ceq lower than 0.4, the carbon equivalent being defined as

Ceq = C%+Si%/55+Cr%/20+Mn%/19-Al%/18+2.2P%-3.24B%-0.133*Mn%*Mo%

with elements being expressed by weight percent.

The object of the present invention is achieved by providing a steel sheet according to claim 1. The steel sheet can also comprise characteristics of anyone of claims 2 to 9.

Another object of the invention is a resistance spot weld of two steel parts according to claim 10.

The invention will now be described in detail and illustrated by examples without introducing limitations.

The composition of the steel according to the invention will now be described, the content being expressed in weight percent.

According to the invention the carbon content is from 0.03% to 0.18 % to ensure a satisfactory strength and good weldability properties. Above 0.18% of carbon, weldability of the steel sheet and the resistance to LME may be reduced. The temperature of the soaking depends in particular on carbon content: the higher the carbon content, the lower the soaking temperature to stabilize austenite. If the carbon content is lower than 0.03%, the austenite fraction is not stabilized enough to obtain, after soaking, the desired tensile strength and elongation. In a preferred

embodiment of the invention, the carbon content is from 0.05% to 0.15%. In another preferred embodiment of the invention, the carbon content is from 0.07% to 0.12%.

The manganese content is from 6.0% to 11.0%. Above 11.0% of addition, weldability of the steel sheet may be reduced, and the productivity of parts assembly can be reduced. Moreover, the risk of central segregation increases to the detriment of the mechanical properties. As the temperature of soaking depends on manganese content too, the minimum of manganese is defined to stabilize austenite, to obtain, after soaking, the targeted microstructure and properties. Preferably, the manganese content is from 6% to 9.0%.

According to the invention, aluminium content is below 3% to decrease the manganese segregation during casting. Aluminium is a very effective element for deoxidizing the steel in the liquid phase during elaboration. Above 3% of addition, the weldability of the steel sheet may be reduced, so as castability. Moreover, the higher the aluminium content, the higher the soaking temperature to stabilize austenite. Aluminium is preferably added at least up to 0.2% to improve product robustness by enlarging the intercritical range, and to improve weldability. Moreover, aluminium can be added to avoid the occurrence of inclusions and oxidation problems. In a preferred embodiment of the invention, the aluminium content is from 0.2% to 2.5 % and more preferably from 0.5 and 2.2%.

Molybdenum content is from 0.05% to 0.5% in order to decrease the manganese segregation during casting. Moreover, an addition of at least 0.05% of molybdenum provides resistance to brittleness. Above 0.5%, the addition of molybdenum is costly and ineffective in view of the properties which are required. In a preferred embodiment of the invention, the molybdenum content is from 0.1% to 0.3%.

According to the invention, the boron content is from 0.0005% to 0.005% in order to improve the toughness and the spot weldability of the hot rolled steel sheet. Above 0.005%, the formation of borocarbides at the prior austenite grain boundaries is promoted, making the steel more brittle. In a preferred embodiment of the invention, the boron content is from 0.001% to 0.003%.

Optionally some elements can be added to the composition of the steel according to the invention.

The maximum addition of silicon content is limited to 1.20% in order to improve the resistance to LME. In addition, this low silicon content makes it possible to simplify the process by eliminating the step of pickling the hot rolled steel sheet before the hot band annealing. Preferably the maximum silicon content added is 1.0%.

Titanium can be added up to 0.050 % to provide precipitation strengthening.

Preferably, a minimum of 0.010% of titanium is added in addition of boron to protect boron against the formation of BN.

Niobium can optionally be added up to 0.050 % to refine the austenite grains during hot-rolling and to provide precipitation strengthening. Preferably, the minimum amount of niobium added is 0.010%.

Chromium and vanadium can optionally be respectively added up to 0.5% and 0.2% to provide improved strength.

The remainder of the composition of the steel is iron and impurities resulting from the smelting. In this respect, P, S and N at least are considered as residual elements which are unavoidable impurities. Their content is less than 0.010 % for S, less than 0.020 % for P and less than 0.008 % for N.

The microstructure of the hot rolled and heat-treated steel sheet according to the invention will now be described.

A hot rolled steel sheet with a composition according to the invention undergoes an intercritical annealing, during which a microstructure comprising 10 to 60% of austenite, 40 to 90% of ferrite, a fraction of carbides below 0.8% and less than 5% of martensite is formed.

The austenite that is formed during such intercritical annealing is enriched in carbon and manganese. More precisely, areas with manganese content higher than nominal value and areas with manganese content lower than nominal value are formed, creating a heterogeneous distribution of manganese. Carbon co-segregate with manganese accordingly. This manganese heterogeneity is measured thanks to the slope of manganese distribution which has to be above or equal to -40, as shown on figure 2 and explained later.

Ferrite is present in an amount of 40 to 90% and is formed during the intercritical annealing.

Fresh martensite can be formed during the cooling following the intercritical annealing, from the destabilization of a part of austenite, less rich in carbon and manganese. This constituent of the microstructure is however not desired and its fraction has to remain below 5%.

Finally, the hot rolled steel and heat treated steel sheet contains less than 0.8% of carbides, which allows obtaining a good toughness, i.e. a Charpy impact energy at 20°C higher than 0.4J/mm² measured according to Standard ISO 148-1:2006 (F) and ISO 148-1:2017(F). In a preferred embodiment, the amount of carbides is 0.6% or less or even preferred 0.5% or less.

According to the invention, the hot rolled and annealed steels sheet has a carbon equivalent Ceq lower than 0.4 to improve weldability. The carbon equivalent is defined as Ceq = C%+Si%/55+Cr%/20+Mn%/19-Al%/18+2.2P%-3.24B%-0.133*Mn%*Mo% with elements being expressed by weight percent.

The hot rolled steel sheets according to the invention can be produced by any appropriate manufacturing method and the man skilled in the art can define one. It is however preferred to use the method according to the invention comprising the following steps:

A semi-product able to be further hot-rolled, is provided with the steel composition described above. The semi-product is heated to a temperature from 1150°C to 1300°C, to ease hot rolling, with a final hot rolling temperature FRT from 800°C to 1000°C. Preferably, the FRT is from 850°C to 950°C.

The hot-rolled steel is then cooled and coiled at a temperature T_{coil} from 20°C to 600°C. The hot rolled steel sheet is then cooled to room temperature and can be pickled.

The hot rolled steel sheet is then heated up to an annealing temperature T_{HBA} between Tc and 680°C. Tc is calculated through the below formula, which is valid for manganese contents above 4wt%:

$$Tc = Tec - (Mn\% - 4)/C\%$$

Tec being the carbides dissolution temperature at equilibrium condition that can be determined through thermodynamic calculations done with the use of a software like Thermo-Calc® and Mn% and C% being the weight nominal composition in manganese and carbon of the steel.

Preferably the temperature T_{HBA} is from 580°C to 680°C. The steel sheet is maintained at said temperature T_{HBA} for a holding time t_{HBA} from 0.1 to 120h to promote manganese diffusion and formation of inhomogeneous manganese distribution.

T_{HBA} is chosen to obtain after cooling, 10 to 60% of austenite, 40 to 90% of ferrite and less than 5% martensite, the fraction of carbides being maintained below 0.8%. In particular, the selection of the appropriate time and temperature of such intercritical annealing must consider the maximum carbide fractions that can be tolerated according to the invention, keeping in mind that increasing T_{HBA} limits carbide precipitation.

Regarding chemical composition, the higher the amount of carbon and aluminium in the steel, the greater the concentration of carbides for a given temperature. This means that for carbon and aluminium contents in the upper part of the claimed ranges, T_{HBA} must be increased to limit carbides precipitation accordingly.

Moreover, the lower the amount of manganese in the steel, the higher the carbide concentration for a given temperature. This means that for manganese content in the lower part of the claimed range, T_{HBA} must be increased to limit carbides precipitation accordingly.

The hot rolled and heat-treated steel sheet is then cooled to room temperature and can be pickled to remove oxidation.

The invention will be now illustrated by the following examples, which are by no way limitative.

Examples

Eleven grades, whose compositions are gathered in table 1, were cast in semi-products and processed into steel sheets

Table 1 - Compositions

The tested compositions are gathered in the following table wherein the element contents are expressed in weight percent.

Steel	C	Mn	Al	Mo	B	S	P	N	Si	Nb	Ti	Tec (°C)	Ceq	Ae1 (°C)	Ae3 (°C)
A	0.07	7.9	0.90	0.32	0.002	0.002	0.011	0.003	0	0.032	0.015	605	0.15	510	725
B	0.09	9.5	1.69	0.33	0.002	0.002	0.010	0.003	0	0.031	0.015	605	0.16	530	705
C	0.15	7.7	0.96	0.22	0.003	0.002	0.012	0.003	0.02	0	0.018	625	0.33	540	715
D	0.16	7.7	0.96	0.22	0.003	0.002	0.012	0.003	0.81	0	0.018	635	0.35	550	735
E	0.19	7.6	0.97	0.22	0.003	0.002	0.013	0.003	0.98	0	0.018	650	0.39	540	730
F	0.12	9.0	0.94	0.21	0.003	0.004	0.013	0.002	0.02	0	0.021	595	0.34	520	695
G	0.13	9.0	0.95	0.21	0.003	0.004	0.013	0.002	0.52	0	0.021	600	0.35	520	695
H	0.21	4.0	0.03	0.001	0	0.001	0.011	0.003	1.50	0	0	675	0.47	610	765
I	0.21	4.9	0.02	0	0	0.001	0.020	0.002	0.01	0	0	645	0.51	550	720
J	0.20	5.0	1.03	0	0	0.002	0.022	0.002	0.01	0	0	650	0.49	540	780
K	0.20	4.8	0.02	0	0	0.001	0.020	0.004	1.51	0	0	665	0.52	580	750

Ae1, Ae3 and Tec temperatures have been determined through thermodynamic calculations done with the use of a software like Thermo-Calc® .

Table 2 – Process parameters of the hot rolled and heat-treated steel sheets

Steel semi-products, as cast, were reheated at 1200°C, hot rolled and then coiled. The hot rolled and coiled steel sheets are then heat treated at a temperature T_{HBA} and maintained at said temperature for a holding time t_{HBA}. The following specific conditions to obtain the hot rolled and heat-treated steel sheets were applied:

Trials	Steel	Hot rolling	Coiling (°C)	Hot band annealing (HBA)		Tc
		FRT (°C)		T_{HBA}(°C)	t_{HBA}(h)	(°C)
1	A	900	450	640	10	547
2	A	850	450	630	40	547
3	A	850	450	650	40	547
4	A	850	450	-	-	547
5	B	900	450	640	10	544
6	C	850	450	514	15	600
7	C	850	450	547	15	600
8	C	850	450	589	15	600
9	C	850	450	616	15	600
10	C	850	450	630	15	600
11	C	850	450	630	40	600
12	C	850	450	650	40	600
13	D	850	450	558	15	611
14	D	850	450	582	15	612
15	D	850	450	602	15	612
16	D	850	450	630	15	612
17	D	850	450	630	40	612
18	D	850	450	650	40	612
19	E	850	450	592	15	631
20	E	850	450	624	15	631
21	E	850	450	630	15	631
22	F	850	450	521	15	554
23	F	850	450	558	15	554
24	F	850	450	568	15	554
25	F	850	450	611	15	554
26	F	850	450	631	15	554
27	G	850	450	529	15	562
28	G	850	450	538	15	562
29	G	850	450	568	15	562
30	G	850	450	586	15	562
31	G	850	450	624	15	562
32	G	850	450	631	15	562

Trials	Steel	Hot rolling	Coiling (°C)	Hot band annealing (HBA)		Tc
33	H	900	30	600	5	675
34	I	930	580	600	5	641
35	J	930	580	600	5	645
36	K	930	450	600	5	661

Underlined values: parameters which do not allow to obtain the targeted properties

The hot rolled and heat-treated steel sheets were analyzed, and the corresponding properties are gathered in table 3.

Table 3 – Microstructure and properties of the hot rolled and heat-treated steel sheet

The surface fractions of phases in the microstructure are determined through the following method: a specimen is cut from the hot rolled and annealed steel sheet, polished and etched with a reagent known per se, to reveal the microstructure. The section is afterwards examined through scanning electron microscope, for example with a Scanning Electron Microscope with a Field Emission Gun ("FEG-SEM") at a magnification greater than 5000x, in secondary electron mode.

The determination of the surface fraction of ferrite is performed thanks to SEM observations after Nital or Picral/Nital reagent etching.

The determination of the volume fraction of retained austenite is performed thanks to X-ray diffraction.

The fraction of carbides is determined thanks to a section of sheet examined through Scanning Electron Microscope with a Field Emission Gun ("FEG-SEM") and image analysis at a magnification greater than 15000x.

Trials	Ferrite (%)	Austenite (%)	Martensite (%)	Carbides (%)
1	66.0	34	0	0.0
2	65.0	35	0	0.0
3	57.0	43	0	0.0
4	0	0	100	0.0
5	54.0	46	0	0.0

Trials	Ferrite (%)	Austenite (%)	Martensite (%)	Carbides (%)
6	95.0	3	0	2.0
7	93.1	5	0	1.9
8	84.1	15	0	0.9
9	73.4	26	0	0.6
10	67.5	32	0	0.5
11	60.5	39	0	0.5
12	53.9	46	0	0.1
13	93.2	5	0	1.8
14	88.9	10	0	1.1
15	81.1	18	0	0.9
16	69.4	30	0	0.6
17	63.4	36	0	0.6
18	55.8	44	0	0.2
19	84.4	14	0	1.6
20	72.8	26	0	1.2
21	68.9	30	0	1.1
22	93.4	5	0	1.6
23	79.4	20	0	0.6
24	76.6	23	0	0.4
25	67.0	33	0	0
26	60.0	40	0	0
27	91.4	7	0	1.6
28	87.2	12	0	0.8
29	81.4	18	0	0.6
30	71.7	28	0	0.3
31	60.0	40	0	0
32	58.0	42	0	0
33	97.2	0	0	2.8
34	94.2	3	0	2.8
35	97.3	0	0	2.7
36	97.2	0	0	2.8

Underlined values: do not match the targeted values

The slope of the manganese distribution and the Charpy impact energy at 20°C were determined.

The Charpy impact energy is measured according to Standard ISO 148-1:2006 (F) and ISO 148-1:2017(F).

The heat treatment of the hot rolled steel sheet allows manganese to diffuse in austenite: the repartition of manganese is heterogeneous with areas with low manganese content and areas with high manganese content. This manganese heterogeneity helps to achieve mechanical properties and can be measured thanks to manganese distribution.

Figure 1 represents a section of the hot rolled and heat-treated steel sheet of trial 1 and trial 4. The black area corresponds to area with lower amount of manganese, the grey area corresponds to a higher amount of manganese.

This figure is obtained through the following method: a specimen is cut at ¼ thickness from the hot rolled and heat-treated steel sheet and polished.

The section is afterwards characterized through electron probe micro-analyzer, with a Field Emission Gun ("FEG") at a magnification greater than 10000x to determine the manganese amounts. Three maps of 10µm*10µm of different parts of the section were acquired. These maps are composed of pixels of 0.01µm². Manganese amount in weight percent is calculated in each pixel and is then plotted on a curve representing the accumulated area fraction of the three maps as a function of the manganese amount.

This curve is plotted in Figure 2 for trial 1 and trial 4: 100% of the sheet section contains more than 1% of manganese. For trial 1, 20% of the sheet section contains more than 10% of manganese.

The slope of the curve obtained is then calculated between the point representing 80% of accumulated area fraction and the point representing 20% of accumulated area fraction. For trial 1, this slope is higher than -40, showing that the repartition of manganese is heterogeneous, with areas with low manganese content and areas with high manganese content.

On the contrary, for trial 4, the absence of heat treatment after hot rolling implies that the repartition of manganese is not heterogeneous, which can be seen by the value of the slope of the manganese distribution lower than -40.

Trials	Slope of the Mn distribution	Charpy energy (J/mm²)
1	-13	1.22
2	-24.9	1.26
3	-27	1.30
4	-69	0.91
5	-12.4	1.20
6	-60	0.19
7	-55	0.25
8	-40	0.32
9	-25	0.47
10	-19.5	0.53
11	-26.6	0.68
12	-28	0.78
13	-55	0.19
14	-45	0.26
15	-35	0.32
16	-20.5	0.42
17	-22.4	0.51
18	-25	0.65
19	-40	0.19
20	-25	0.26
21	-22	0.32
22	-55	0.32
23	-30	0.46
24	-25	0.49
25	-19	0.58
26	-13.5	0.62
27	-50	0.32
28	-44	0.38
29	-35	0.44
30	-23	0.44
31	-15	0.53
32	-13.5	0.63
33	-60	0.21

Trials	Slope of the Mn distribution	Charpy energy (J/mm²)
34	-60	0.12
35	-60	0.13
36	-60	0.05

Underlined values: do not match the targeted values.

For trials 6 and 7, the T_{HBA} temperature is significantly lower than Tc, leading to the formation of too much carbides, which results in the increase in strength but decrease in ductility. Moreover, the small volume fraction of austenite (<10%) is not sufficient to cover all grain boundaries which are very rich in manganese, leading to the grain boundary embrittlement, and thus the degradation of toughness.

For trial 8, performed at relatively higher T_{HBA} temperature (but still lower than Tc), carbides tend to grow along prior austenite grain boundaries, which is harmful to toughness.

Trials 13, 14, 15, 19, 20, 21, 22, 27, 28, 33, 34, 35, 36 show similar trends and include too much carbides as well.

Table 4 – Weldability properties of the hot rolled and heat-treated steel sheet

Weldability properties of the obtained hot rolled and heat-treated steel sheet were determined and gathered in the following table.

Spot welding in standard ISO 18278-2 condition has been done on the hot rolled and annealed steel sheets, which were pickled before welding.

In the test used, the samples are composed of two sheets of steel in the form of cross welded equivalent. A force is applied so as to break the weld point. This force, known as cross tensile Strength (CTS), is expressed in daN. It depends on the diameter of the weld point and the thickness of the metal, that is to say the thickness of the steel and the metallic coating. It makes it possible to calculate the coefficient α which is the ratio of the value of CTS on the product of the diameter of the welded point multiplied by the thickness of the substrate. This coefficient is expressed in daN/mm².

The resistance spot welds joining the first sheet to the second sheet are characterized by a high resistance in cross-tensile test defined by an α value of at least 30 daN/mm2.

Trials	α (daN/mm²)	LME index
1	60	0.07
2	60	0.07
3	60	0.07
4	60	0.07
5	63	0.16
6	40	0.16
7	40	0.16
8	40	0.16
9	40	0.16
10	40	0.16
11	40	0.16
12	40	0.16
13	40	0.36
14	40	0.36
15	40	0.36
16	40	0.36
17	40	0.36
18	40	0.36
19	28	0.44
20	28	0.44
21	28	0.44
22	48	0.13
23	48	0.13
24	48	0.13
25	48	0.13
26	48	0.13
27	46	0.26
28	46	0.26
29	46	0.26
30	46	0.26

Trials	α (daN/mm²)	LME index
31	46	0.26
32	46	0.26
33	30	0.58
34	21	0.21
35	28	0.20
36	24	0.58

Underlined values: do not match the targeted values.

LME index = C% + Si%/4,

In trials 19, 20, 21, 33, 34, 35 and 36, the chemical composition does not allow to obtain the targeted weldability properties of the invention.

CLAIMS

1. Hot rolled and heat-treated steel sheet, made of a steel having a composition comprising, by weight percent:

C: 0.03 - 0.18 %
Mn: 6.0 – 11.0 %
Mo: 0.05 - 0.5 %
B: 0.0005 – 0.005%
S ≤ 0.010 %
P ≤ 0.020 %
N ≤ 0.008 %

and comprising optionally one or more of the following elements, in weight percentage:

Al < 3%
Si ≤ 1.20 %
Ti ≤ 0.050 %
Nb ≤ 0.050 %
Cr ≤ 0.5%

the remainder of the composition being iron and unavoidable impurities resulting from the smelting,

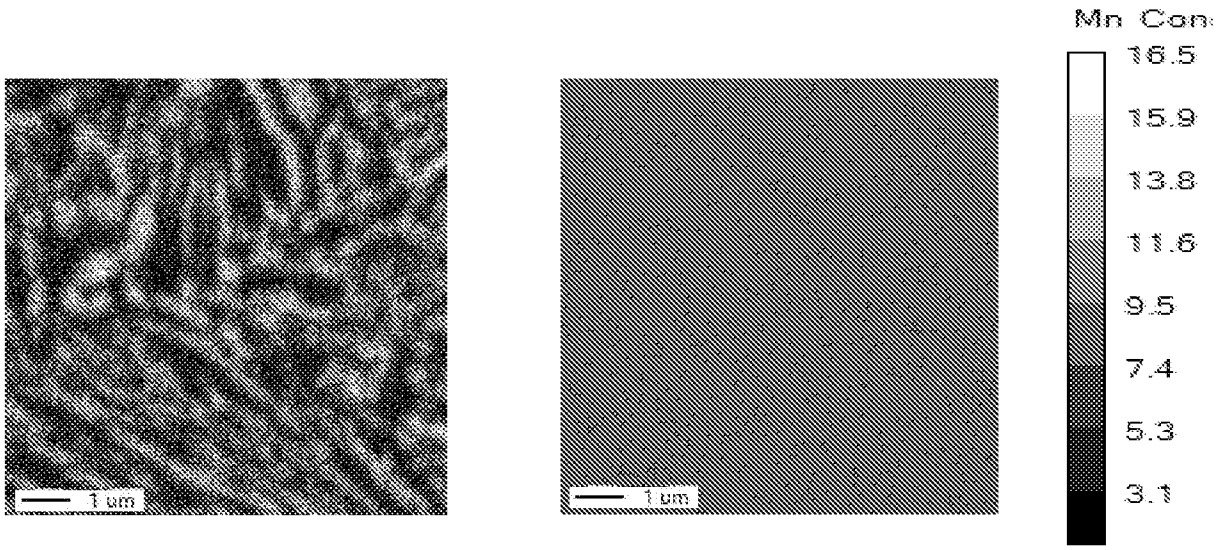
said steel sheet having a microstructure comprising, in surface fraction,

- from 10% to 60% of retained austenite,
- from 40% to 90% of ferrite,
- less than 5% of martensite,
- carbides below 0.8%, and
- an inhomogeneous repartition of manganese, characterized by a manganese distribution with a slope above or equal to -40.

2. A hot rolled and heat-treated steel sheet according to claim 1 wherein the steel sheet includes 0.6% or less of carbides.
3. A hot rolled and heat-treated steel sheet according to claim 2 wherein the steel sheet includes 0.5% or less of carbides.
4. A hot rolled and heat-treated steel sheet according to any one of claims 1 or 3 wherein the carbon content is from 0.05% to 0.15%.

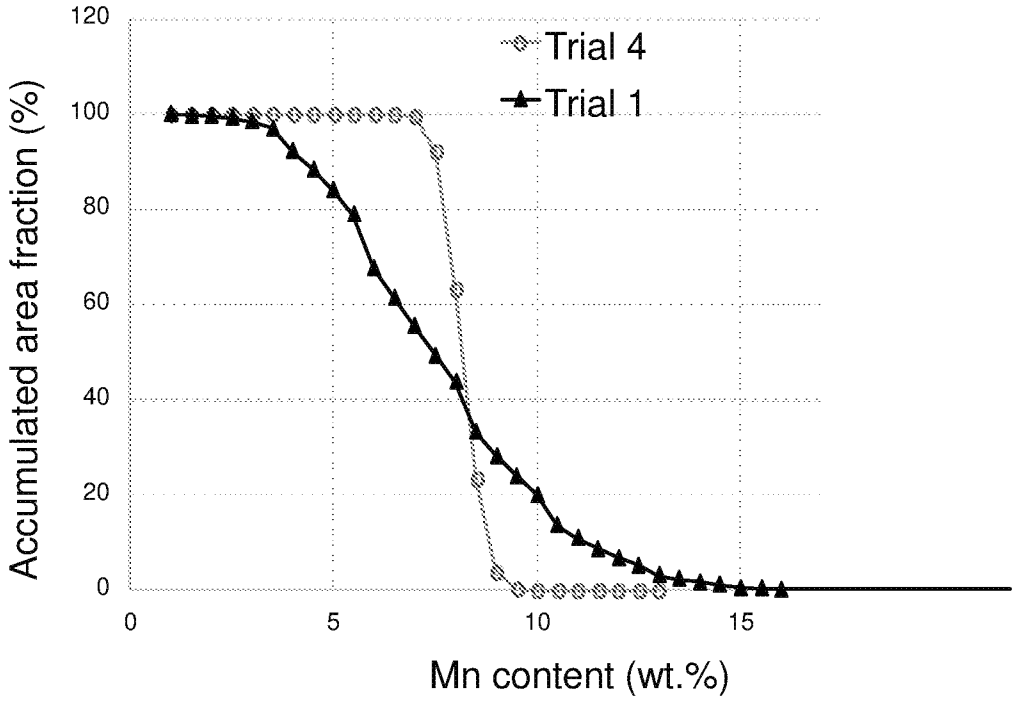
5. A hot rolled and heat-treated steel sheet according to any one of claims 1 to 4 wherein the manganese content is from 6.0% to 9.0%.
6. A hot rolled and heat-treated steel sheet according to any one of claims 1 to 5 wherein the aluminium content is from 0.2% to 2.5%.
7. A hot rolled and heat-treated steel sheet according to any one of claims 1 to 6 wherein the Charpy impact energy at 20°C is higher than 0.4J/mm^2.
8. A hot rolled and heat-treated steel sheet according to any one of claims 1 to 7 wherein the LME index is 0.36 or less.
9. A hot rolled and heat-treated steel sheet according to any one of claims 1 to 8 wherein the steel has a carbon equivalent Ceq lower than 0.4, the carbon equivalent being defined as
   Ceq = C% + Si%/55 + Cr%/20 + Mn%/19 -Al%/18 + 2.2P% - 3.24B% - 0.133xMn%xMo% with elements being expressed by weight percent.
10. A resistance spot weld of two steel parts made of the hot rolled and heat-treated steel sheet according to any one of claims 1 to 9, said resistance spot weld having an α value of at least 30 daN/mm^2.

FIGURE 1



Trial 1 **Trial 4**

FIGURE 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/057009

A. CLASSIFICATION OF SUBJECT MATTER
INV. C21D6/00 C21D9/46 C21D1/26 C21D8/02 C22C38/02
C22C38/04 C22C38/06 C22C38/12 C22C38/14
ADD. C22C38/32 C22C38/38
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)
C21D C22C

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	CN 111 218 621 A (UNIV HUNAN SCIENCE & TECHNOLOGY) 2 June 2020 (2020-06-02) paragraphs [0038], [0048], [0058], [0068], [0078]; claims 1-8	1-10
A	EP 3 336 212 A1 (JFE STEEL CORP [JP]) 20 June 2018 (2018-06-20) claims 1-11; tables 1, 4	1-10
A	US 10 633 727 B2 (AK STEEL PROPERTIES INC [US]) 28 April 2020 (2020-04-28) claims 1-9	1-10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"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
12 April 2021	18/05/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Pircher, Ernst

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/057009

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2019 014933 A (KOBE STEEL LTD) 31 January 2019 (2019-01-31) table 1 -----	1-10

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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