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

(11) **EP 2 503 015 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
26.09.2012 Bulletin 2012/39

(21) Application number: **10830975.8**

(22) Date of filing: **10.11.2010**

(51) Int Cl.:
C22C 38/20 *(2006.01)* ***C21D 1/25*** *(2006.01)*

(86) International application number:
PCT/BR2010/000376

(87) International publication number:
WO 2011/060517 (26.05.2011 Gazette 2011/21)

(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: **17.11.2009 BR PI0904608**

(71) Applicant: **Villares Metals S/A**
SP - CEP 13177-900 (BR)

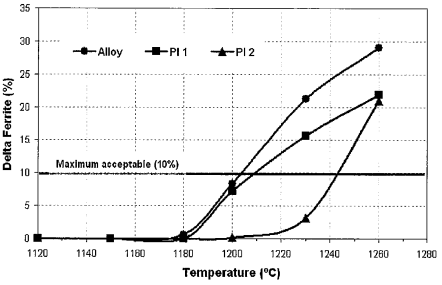
(72) Inventors:
- **BARBOSA, Celso Antonio**
Parque Nova Campinas- Campinas- SP- CEP 13085-910 (BR)
- **MESQUITA, Rafael Agnelli**
SP-CEP 13472-060 (BR)

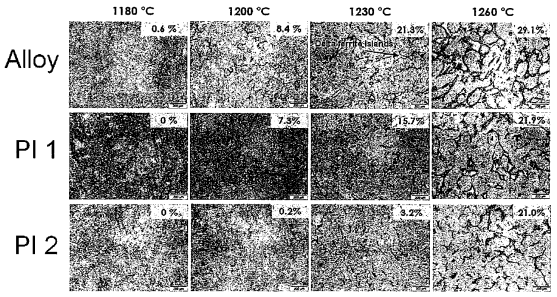
(74) Representative: **Earnshaw, Geoffrey Mark**
Murgitroyd & Company
Scotland House
165-169 Scotland Street
Glasgow G5 8PL (GB)

(54) STAINLESS STEEL FOR MOLDS HAVING A LOWER DELTA-FERRITE CONTENT

(57) "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", characterized by a composition of alloying elements consisting essentially of, in percentage by mass, Carbon between 0.01 and 0.20; Nitrogen between 0.01 and 0.07; Manganese between 2.0 and 4.0; Nickel between 0.01 and 1.0; Chromium between 11.0 and 13.0; Molybdenum + Tungsten lower than 1.0; Copper between 0.01 and 1.5; Vanadium between 0.01 and 1.0; Sulfur between 0.01 and 0.20; Calcium at maximum 0.01; Aluminum lower than 0.05; Silicon lower than 1.0; the remainder consisting essentially of Fe and inevitable impurities to the preparation process.

Figure 1





EP 2 503 015 A1

Description

[0001] This invention is a stainless steel for general applications in plastic-forming molds, particularly, but not limited, to hot chambers molds. Its main feature is the combination of properties related to the mold fabrication, such as machinability, weldability and low cost (associated with low nickel (Ni) content) and for being easy to process, in terms of control of an undesirable microstructural phase called delta-ferrite. Due to these mold- and steel-making advantages, this invention allows a considerable reduction of the mold cost.

[0002] The tools and molds are usually operated to form other materials, either thermoplastic polymer materials (commonly known as plastic materials) or metallic materials. Depending on the properties of the material used to make the tools, these are used in processes at room or high temperatures, around 700°C. The steel of this invention is especially applied to molds or mold devices, which are exposed to room temperature or temperatures below 500°C and must be corrosion-resistant. A typical example of such applications is the hot chambers used in plastic-forming molds, which do not exceed 300°C. For such cases, the combined temperature/water-cooling effect may lead to corrosion, which explains the need for stainless steels. And, due to the high content of machined material, the machinability property should be optimized.

[0003] In addition to these two features, corrosion resistance and machinability, welding is many times applied on mold steels, minor repairs and mold modifications. However, conventional martensitic stainless steels with high content of chromium (12 to 17%) and medium content of carbon (approx. 0.4%) have an extremely high hardenability causing significant hardness and potential cracking in welded areas (see Table 1). Thus, the development of a low-carbon alloy is something desirable.

Table 1: Typical chemical composition of traditional steels approached in the state of art. The approximate hardness of martensite is shown in order to highlight the difficult weldability caused by the high content of carbon. Content in mass percentage and Fe balance.

Denomination	C	S	Mn	Ni	Cr	Mo	V	Martensite Hardness
AISI 440 C	1.0	0.003*	0.30	-	17.5	0.5	-	65 HRC
AISI 420 mod. (DIN 1.2083)	0.40	0.003*	0.30	-	13.5	-	0.25	55 HRC
DIN 1.2316	0.38	0.005*	0.60	0.80	16.0	1.0	-	55 HRC
DIN 1.2085	0.35	0.15	1.0	-	15.0	-	-	55 HRC
*Typical values; not specified by standard								

[0004] In addition to these metallurgical properties, the cost issues have become even more critical. Strong competitiveness, especially considering low-cost molds available worldwide, makes the mold manufacturers look for low-cost options. Under these conditions, a negative metallurgical factor is the microstructural stability in terms of absence of delta-ferrite. Carbon and nickel are the most important elements to promote the austenitic phase and the elimination of delta-ferrite in martensitic steels. However, there is a limitation for carbon, as mentioned above, with regard to weldability problems. And, in case of nickel, cost limitation is significant. The higher the carbon content, the lower the need for nickel and, thus, the higher the alloy cost.

[0005] New developments are under way to solve such problem. For instance, patents US 6.358.334 and US 6.893.608 B2 address the production of low- nickel and carbon stainless steels employing high levels of copper and nitrogen (see Table 2). However, the occurrence of delta-ferrite is significant for both of them, with levels of up to 10% being common. On the other hand, the control of delta-ferrite in these alloys influences the alloy forging and laminations temperatures. Table 2 shows the equilibrium temperature calculated by the "Thermocalc" thermodynamic calculation software for these alloys. When combined with high sulfur content, low temperatures may easily create cracking or excessive power in the forming equipment (usually a forging press or lamination mill). So, considering all those items, there are some state-of-the-art low- carbon and nickel steels, but processing them is not an easy task, which results in costlier processes and consequent increase of the alloy cost.

[0006] Therefore, the need for a stainless steel with high machinability, low- nickel and carbon content and increased processing capacity is evident. In order to allow the reduction of the steel-making process cost, the forming temperatures of the material should be significantly higher than those of state-of-the-art steels.

[0007] The steel of this invention will fulfill all those needs.

Table 2: State-of-the-art steels developed more recently than the steels shown in Table 1. Content in mass percentage and Fe balance. The hardness of martensite in these alloys, due to the low content of carbon, is about 35 HRC.

Patent	C	N	Mn	S	Ni	Cr	Mo	Cu	V	Maximum Forming Temperature*
US 6358334	0.05	0.04	1.3	0.12	0.10	12.6	0.05	0.95	0.08	1150 °C
US 6893608	0.05	0.04	0.30	0.15	0.70	13.5	0.40	0.25	0.06	1100 °C
* For AISI 420 steel, the forming temperature may reach up to 1260°C.										

[0008] The stainless steel for molds, proposed by this invention, can be produced with a lower content of delta-ferrite and at temperatures about 30° C higher during forging or lamination processes. Its chemical composition also lacks high-cost elements such as nickel and molybdenum, but the chromium content is sufficient to ensure inoxidability. And, as previously mentioned, weldability requirements can be achieved due to lower carbon content.

[0009] In order to satisfy the abovementioned conditions, the alloys of this invention have a composition of alloying elements, which, in percentage by mass, consist of:

* Carbon: between 0.01 and 0.2, preferably, and between 0.03 and 0.10, typically 0.05.
* Nitrogen: between 0.01 and 0.07, preferably between 0.03 and 0.06, typically 0.055.
* Manganese: between 2.0 and 4.0, preferably between 2.2 and 3.0, typically 2.5
* Nickel: between 0.01 and 1.0, preferably between 0.1 and 0.5, typically 0.3
* Chromium: between 11.0 and 13.0, preferably between 11.5 and 12.5, typically 12.0
* Molybdenum and Tungsten: the sum should be below 1.0, preferably below 0.5, typically below 0.2.
* Copper: between 0.01 and 1.5, preferably between 0.1 and 0.8, typically 0.55.
* Vanadium: between 0.01 and 1.0, preferably between 0.02 and 0.10, typically 0.05.
* Sulfur: between 0.01 and 0.20, preferably between 0.05 and 0.14, typically 0.09.
* Calcium: below 0.010, preferably between 0.001 and 0,003, typically 0.002.
* Aluminum: below 0.50, typically below 0.10, preferably below 0.050.
* Silicon: below 0.1, preferably below 0.05, typically between 0.1 and 0.6.

[0010] Balance by Fe and metallic or non-metallic impurities are inevitable to the steel-making process.

[0011] Next, we present the ratios of the specification of the composition of the new material and a description of the effect of each of the alloying elements. The percentages listed refer to percentage by mass.

[0012] C: carbon is the main responsible for the response to the heat treatment, and also for the hardness of martensite produced by quenching. Due to the intense heating and quick cooling, the welding process can be considered similar to quenching. Thus, the carbon content controls the final hardness created in the welded zone of the steel of this invention. Therefore, to achieve the required hardness, the carbon content should be at least 0.01 %, preferably above 0.03%. However, the carbon content should be below 0.2%, preferably below 0.1%, such that hardness in the welded zones is below 40 HRC to prevent cracking and facilitate the machining process.

[0013] N: nitrogen is necessary in the alloy of this invention because it is a powerful austenitizer and reduces the amount of delta-ferrite. Moreover, nitrogen increases pitting corrosion resistance. On the other hand, a nitrogen surplus may generate gases, given that delta-ferrite is the first solid phase in the steel of this invention, considering limited nitrogen solubility. Thus, the nitrogen content should lie between 0.01% and 0.08%, preferably between 0.02% and 0.06%, typically around 0.05%.

[0014] Mn: as Mn is not a costlier element, but is a powerful austenitizer, it should be employed at high levels in the steel of this invention. Therefore, its content should be above 2.0%, preferably above 2.2%, typically 2.5%. However, when employed in excess, manganese increases the content of retained austenite, as well as the coefficient of material hardening, decreasing the machinability, besides increasing hydrogen solubility and promoting flake formation; thus, the manganese content should not exceed 4.0%, preferably below 3.0%.

[0015] Ni: nickel is a powerful austenitizer, but makes the alloy to become costlier. In order to get both aspects under control, the nickel content should remain between 0.01 and 1.0%, preferably between 0.10 and 0.50%, and typically, 0.30%.

[0016] Cr: chromium confers inoxidability to the steel of this invention, being the most important element as far as this

property is concerned (due to the low content of Mo and Ni in this alloy). Thus, the chromium content should be above 11.0%, typically above 12.0%. However, chromium is also a major ferritizer, contributing to increase the delta-ferrite content and to reduce the austenitic field. In order to counterbalance such effects, the Cr content should be lower than 13.0%, preferably below 12.5%.

[0017] Molybdenum and Tungsten: when combined, the total content should be below 1.0% because they increase the cost of the alloy and the ferrite content. Preferably, the sum should be below 0.5%, typically below 0.2%.

[0018] Copper: it is an austenitizer and also promotes precipitation hardening required for the response to heat treatment. However, if employed in excess, copper may have a negative effect on the cost and is a major scrap contaminant. Thus, the copper content should lie between 0.01% and 1.5%, preferably between 0.1 % and 0.8%, and typically, 0.55%.

[0019] Vanadium: vanadium plays an important role in secondary hardening that, despite not being intense in the steel of this invention, is essential for reaching the post-tempering hardness required at high temperature. However, as vanadium is also a ferritizer and has a negative impact on the cost of the alloy, its content should be controlled. Thus, the vanadium content should lie between 0.01 % and 1.0%, preferably between 0.05% and 0.50%, typically around 0.1 %.

[0020] S: in the steel of this invention, sulfur forms manganese sulfide (MnS) inclusions that become elongated through the hot forming process. As the inclusions become malleable at temperatures developed in the machining process, they facilitate the chip-breaking process and lubricate the cutting tool, thus improving machinability. In order to produce this effect, the sulfur content must be higher than 0.01%, preferably above 0.05%, typically above 0.09%. Despite being beneficial to the machining process, the MnS inclusions have a negative effect on the mechanical properties, especially toughness and corrosion resistance. Hence, the sulfur content should be limited to 0.20%, preferably below 0.15%.

[0021] Ca: calcium also has an effect on inclusions by modifying hard alumina inclusions that hinder machinability and by reducing the size (spheroidal) of inclusions in general. This effect is mostly important for the control of MnS inclusions, making them more distributed and less elongated, thus favoring the machining process and the mechanical properties. However, controlling the calcium content is quite complex due to its high reactivity. Thus, the use of calcium can be considered optional for those cases in which high machinability and polishability are required. If employed, the calcium content should not exceed 100 ppm (0.01 %) because its solubility in the molten metal and high reactivity (when in contact with refractories) limit higher values. Preferably, the Ca content should lie between 10 and 30 ppm (0.001 and 0.003%), typically 20 ppm (0.002%).

[0022] Al: due to the formation of hard alumina inclusions, the Al content should not be excessively high to hinder machinability. It should be below 0.5%, typically below 0.1 %, preferably below 0.05%.

[0023] Si: silicon is used as a deoxidizer, an important agent in situations of low Al content, which is the case of the steel of this invention. However, this element is a ferritizer and if used in excess, favors the formation of delta-ferrite. Thus, the silicon content should remain between 0.1% and 1.0%, preferably between 0.2% and 0.7%, typically 0.40%.

[0024] The figures attached herein have been referenced to in the description of the experiments carried out, and their contents are listed below:

Figure 1 shows the increase of the amount of delta-ferrite for state-of-the-art alloy 1 and alloys PI 1 and PI 2 of this invention. Representative microstructures have also been added.

Figure 2 shows the tempering curves obtained for the three alloys, alloy 1, PI 1 and PI 2 - the alloys' hardness is low after quenching, changing from 30 to 34 HCR after tempering.

Figure 3 shows a comparison of the microstructure of alloys PI 1 and PI 2 for two contents of sulfur - note that the increase of the number of inclusions is directly proportional to the increase of the sulfur content.

EXAMPLE 1:

[0025] The "Thermo-calc" software was used to simulate the effect of N and Mn on the increase of the delta-ferrite formation temperature to allow defining the composition of the steel of this invention. Simulations 1 to 4 show the strong effect of nitrogen, at a composition equivalent to that of US 6358334. However, extremely high N content, above 0.06%, already anticipate the formation of gas during the solidification stage, which generates voids in the billets, making their use unfeasible. On the other hand, for simulation 5, the Mn effect associated with a higher and safe N content, can be analyzed. In this alloy steel, we estimate that there is a gain of 30 to 90°C in the maximum formation temperature in relation to state-of-the-art alloys. This indicates the possibility of better hot formation and elimination of delta-ferrite, (as mentioned above, by reducing the mechanical and corrosion resistance).

[0026] After this evidence of the strong effects of N and Mn, two compositions have been produced for pilot-scale billets and compared to the alloy of patent US 6358334, hereinafter called alloy 1. The alloys of the present invention will be called PI 1 and PI 2. The chemical compositions of the billets are shown in table 4. The principal variables in terms of matrix stability concerning ferrite formation are the Mn and N contents; however the S content of the alloys also varied, and the respective effects will be discussed further on.

Table 3: Equilibrium temperature required to produce 10% by volume of delta-ferrite, in several state-of-the-art alloys and those proposed by this invention, calculated via "Thermo-calc".

Designation	Approximate composition	Maximum Formation Temperature **
US 6358334	0.05C 0.04N 1.3Mn 0.1Ni 12.5Cr 1.0Cu	1150 °C
US 6893608	0.05C 0.04N 0.3Mn 0.7Ni 13.5Cr 0.25Cu	1100 °C
Simulation 1	0.05C **0.05N** 1.3Mn 0.1 Ni 12.5Cr 1.0Cu	1160 °C
Simulation 2*	0.05C **0.06N** 1.3Mn 0.1 Ni 12.5Cr 1.0Cu	1180 °C
Simulation 3*	0.05C **0.07N** 1.3Mn 0.1 Ni 12.5Cr 1.0Cu	1190 °C
Simulation 4*	0.05C **0.08N** 1.3Mn 0.1 Ni 12.5Cr 1.0Cu	1200 °C
Simulation 5*	0.05C **0.05N 2.5Mn** 0.1Ni 12.5Cr 1.0Cu	1190 °C
* formation of N_2 gas during solidification		

[0027] The results of the delta-ferrite content measured on rough-cast samples for the three alloys of Table 4 are shown in Table 5 ND Figure 6. The increase of the N content proposed results in significant gain (compare alloy 1 vs. alloy PI 1) in terms of increase of temperature required to form 10% delta-ferrite. However, the strongest effect takes place after combining the N and Mn effect, with a gain even higher than that calculated by the thermodynamic software. Apart from the values of Table 4, it is also worthy observing the evolution of the delta-ferrite content as a function of temperature. This is shown in Figure 1, with a clear reduction of the delta-ferrite content of alloy 1 if compared to alloy PI 1 and, especially, if compared to alloy PI 2.

Table 4: Chemical composition of pilot-scale billets that contain the state-of-the-art alloy defined in patent US 6358334, called alloy 1, and two alloys investigated in the present invention (PI 1 and PI2). Values in percentage by mass and balance by Fe.

Alloy:	Alloy 1	PI 1	PI 2
C	0.058	0.055	0.059
N	0.044	0.055	0.056
Si	0.39	0.39	0.40
Mn	1.05	1.05	2.46
P	0.025	0.026	0.025
S	0.085	0.097	0.140
Cr	12.2	12.3	12.3
Mo	0.06	0.06	0.06
Ni	0.3	0.3	0.3
Cu	0.55	0.56	0.55
V	0.04	0.04	0.04
W	0.03	0.04	0.03
Al	0.009	0.009	0.005

Table 5: Volume fraction of delta-ferrite in alloy 1 and alloys PI 1 and PI 2 calculated through quantitative metallography. The measurements have been performed after 24 hours at temperature specified.

Alloy:	1150 °C	1180 °C	1200 °C	1230 °C	1260 °C
Alloy 1	0%	0.6%	8.4%	21.3%	29.1%
PI 1	0%	0%	7.3%	15.7%	21.9%
PI 2	0%	0%	0.2%	3.2%	21.0%

[0028] In terms of the response to heat treatment as shown in Figure 2, alloys PI 1 and PI 2 are both capable of reaching the 30 to 34 HRC levels required for the applications. It is also worth being emphasized that alloys PI 1 and PI 2 have post-quenching hardness of about 35 to 40 HRC (value extracted from the chart, for quenching temperature = 0°C), far below the 55/65 HRC of state-of-the art conventional steels shown in Table 1.

[0029] The S content of alloys PI 1 and PI 2 is not the same, and this can be positive or negative for the application, and thus, the S content should be specified depending on the application. This issue was investigated for the billets shown in Table 4, but after hot formation for 70 x 70 mm square section size (4x reduction by area). The low values are due to the low degree of reduction applied to the trial billets.

[0030] The higher S content of alloy PI 2 results in improved machinability but lower toughness and corrosion resistance. The results of such changes can be seen in Table 5 and, in microstructural terms, the different distribution of the S content of alloys PI 1 and PI 2 can be observed in Figure 3. The higher amount of sulfides (dark gray in Figure 3) and their persistence explain the lower values obtained for corrosion resistance and toughness, respectively. And, in terms of machinability, the preponderant factor is the higher sulfide content of alloy PI 2.

[0031] Therefore, for applications demanding high machinability and low toughness and corrosion requirements, high Si alloys (around 0.15%) are recommendable. For cases of stricter toughness and corrosion requirements, alloys with S content around 0.10% are more adequate.

Table 5: Values relative to machinability, corrosion resistance and toughness of alloys PI 1 and PI 2. The differences observed are associated with the different S content of the alloys.

Alloy:	PI 1(97 ppm S)	PI 2(140 ppm S)
Volume machined up to tool wear (cm^3), for cutting speed of 250 m/min and advance per tooth = 0.10mm	121	199
% corroded after 2-hour exposure to NaCl 5% at 35 °C (fog test as per ASTM B117) and NBR 8094	17	33
Izod Impact Test (Charpy V, cross test specimens, treated to 32 HCR)	4.8 ± 1,8	2.7 ± 0.3

EXAMPLE 2:

[0032] Due to increased stability in terms of delta-ferrite, the basic composition of alloy PI 2 has been privileged and made on an industrial scale. However due to the poorer mechanical and corrosion properties, the PI 1 sulfur content was applied to that industrialized product. Table 6 shows the chemical composition of the alloy, called PI 3, and also the chemical composition of a conventional 420 steel whose machinability can be compared to the PI 3's. The machining volume up to the end of the tool's lifespan is shown on the last row of Table 6; note the higher machined volume of alloy PI 3, pointing out to a significant gain in relation to the state-of-the-art 420 steel.

[0033] A key observation can be made with respect to alloy PI 3. Forging took place at temperatures of 1200°C and, even so, the delta-ferrite content remained below 10%.

[0034] Therefore, the two aforementioned examples show that the steel of the present invention, especially PI 3, is capable of meeting the weldability, machinability, corrosion resistance and toughness requirements without creating processing problems, for allowing higher hot forming temperatures.

Table 6: chemical composition of the steel of the present invention, produced on an industrial scale, and of steel 420, subjected to the machinability test (both with 32 HRC)

Alloy:	Steel 420	PI 3
C	0.37	0.046
N	0.008	0.040
Si	0.85	0.32
Mn	0.44	2.49
P	0.030	0.028
S	0.001	0.075
Cr	13.10	12.1
Mo	0.11	0.05
Ni	0.29	0.31
Cu	0.07	0.55
V	0.19	0.05
W	0.02	0.03
Al	0.025	0.005
Volume machined up to tool wear (cm^3), for cutting speed of 250 m/min and advance per tooth = 0.10mm	**148**	**261**

Claims

1. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", **characterized by** a composition of alloying elements consisting essentially of, in percentage by mass, Carbon between 0.01 and 0.20; Nitrogen between 0.01 and 0.07; Manganese between 2.0 and 4.0; Nickel between 0.01 and 1.0; Chromium between 11.0 and 13.0; Molybdenum + Tungsten lower than 1.0; Copper between 0.01 and 1.5; Vanadium between 0.01 and 1.0; Sulfur between 0.01 and 0.2; Calcium at maximum 0.01; Aluminum lower than 0.50; Silicon lower than 1.0; the remainder consisting essentially of Fe and inevitable impurities to the preparation process.

2. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", according to claim 1, **characterized by** a composition of alloying elements consisting essentially of, in percentage by mass, Carbon between 0.03 and 0.10; Nitrogen between 0.03 and 0.06; Manganese between 2.2 and 3.0; Nickel between 0.10 and 0.5; Chromium between 11.0 and 13.0; Molybdenum + Tungsten lower than 0.5; Copper between 0.1 and 0.8; Vanadium between 0.02 and 0.10; Sulfur between 0.05 and 0.14; Calcium between 0.01 and 0.003; Aluminum lower than 0.10; Silicon lower than 0.50; the remainder consisting essentially of Fe and inevitable impurities to the preparation process.

3. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", according to claim 2, **characterized by** a composition of alloying elements consisting essentially of, in percentage by mass, Carbon between 0.03 and 0.08; Nitrogen between 0.03 and 0.06; Manganese between 2.2 and 2.8; Nickel between 0.10 and 0.50; Chromium between 11.5 and 12.5; Molybdenum + Tungsten lower than 0.1; Copper between 0.3 and 0.7; Vanadium between 0.03 and 0.08; Sulfur between 0.08 and 0.12; Calcium between 0.0015 and 0.0025; Aluminum lower than 0.05; Silicon lower than 0.50; the remainder consisting essentially of Fe and inevitable impurities to the preparation process.

4. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", in accordance with any claims from 1 to 3, **characterized by** replacing Vanadium with Niobium or Titanium in a ratio corresponding to 1V:2Nb and 1V: 1 Ti.

5. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", in accordance with any claims from 1 to 3, **characterized by**: delta-ferrite content in the microstructure lower than 10%.

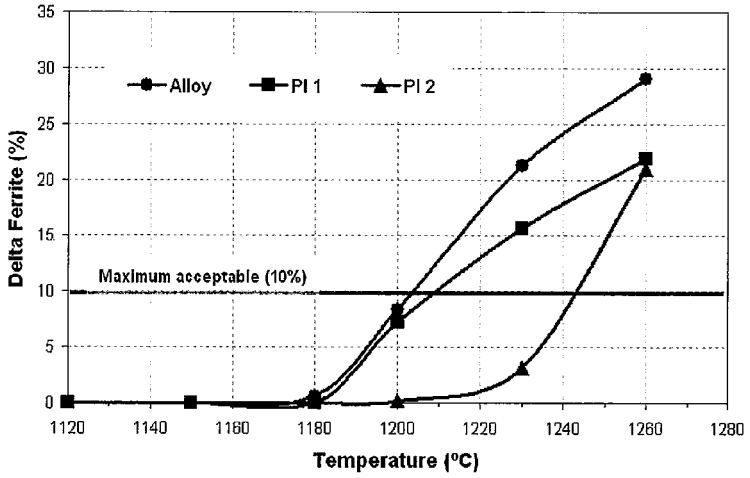
6. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", in accordance with any claims from 1 to 3, characterized for being homogenized, forged or hot rolled at temperatures higher than 1160°C, but with delta-ferrite content in the microstructure lower than 10%.

7. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", in accordance with any claims from 1 to 3, characterized for being applicable to molds, dies and multiple-use tools, for formation of solid or liquid materials, at room temperature or at temperatures up to 1300°C.

8. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT", in accordance with any claims from 1 to 3, characterized for being applicable to plastic molds and plastic mold components.

9. "STAINLESS MOLD STEEL WITH LOWER DELTA-FERRITE CONTENT" in accordance with any claims from 1 to 3, characterized for being applicable to hot chambers or other devices of plastic molds, in which high corrosion resistance and high machinability are required.

Figure 1


Alloy
PI 1
PI 2
Maximum acceptable (10%)
Delta Ferrite (%)
Temperature (°C)
35
30
25
20
15
10
5
0
1120
1140
1160
1180
1200
1220
1240
1260
1280

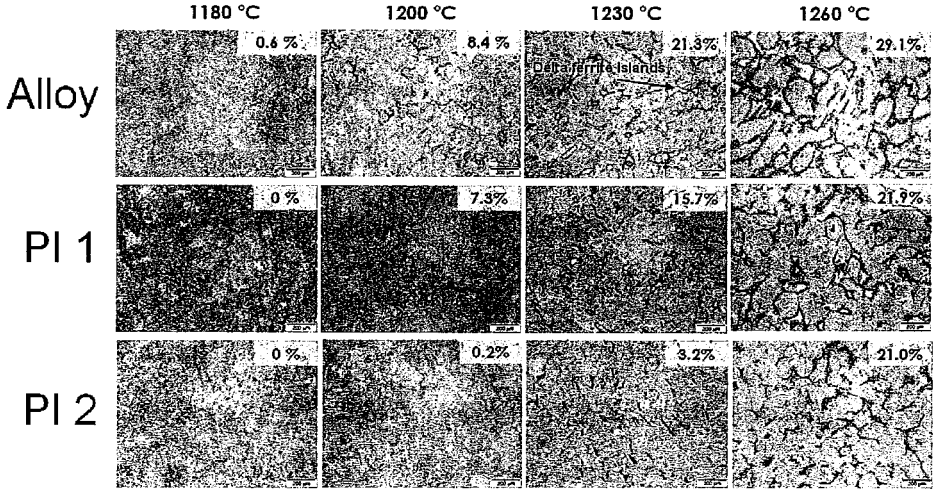

1180 °C
1200 °C
1230 °C
1260 °C
Alloy
PI 1
PI 2
0.6 %
8.4 %
21.3%
Delta ferrite islands
29.1%
0 %
7.3%
15.7%
21.9%
0 %
0.2%
3.2%
21.0%

Figure 2

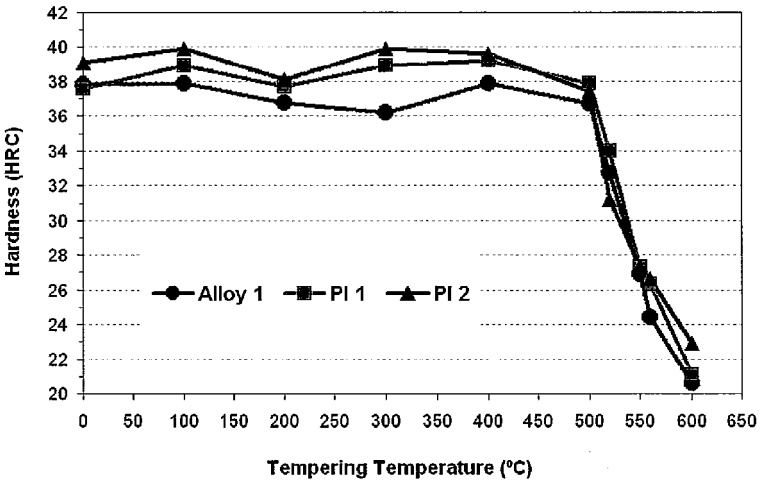
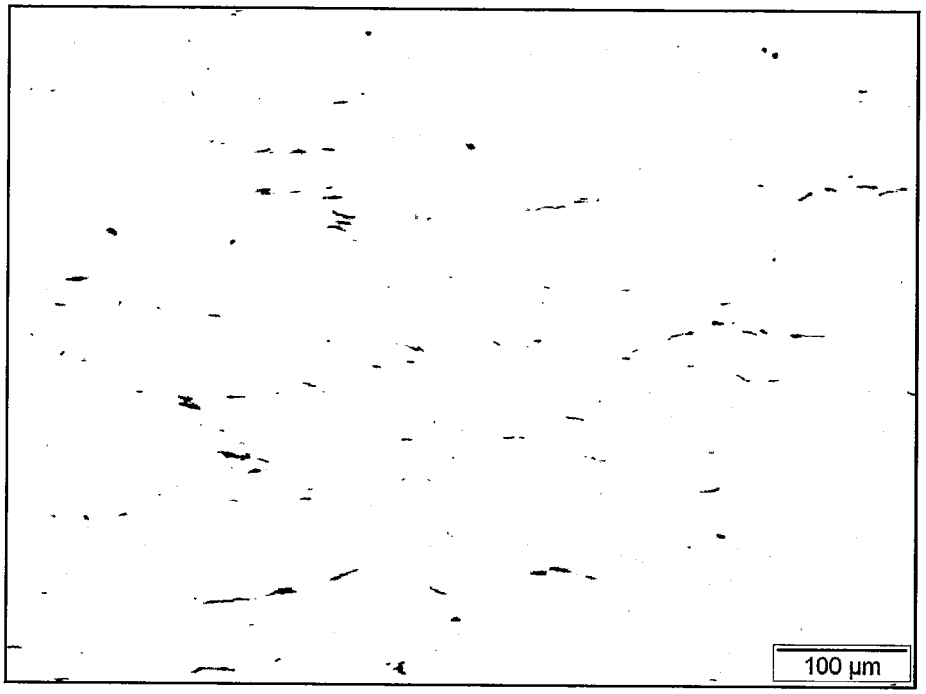
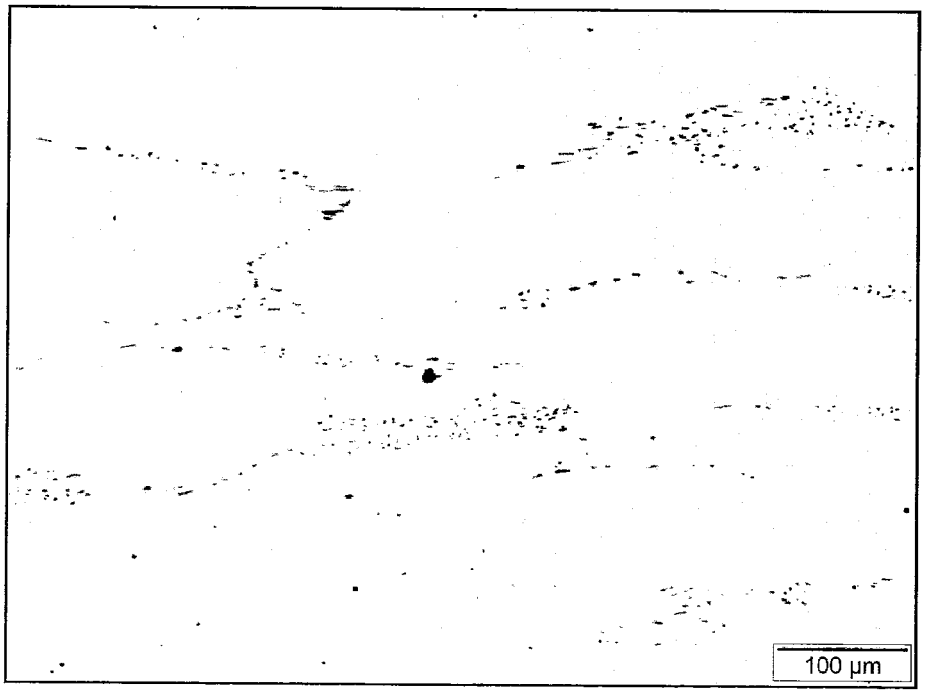

Hardness (HRC)
42
40
38
36
34
32
30
28
26
24
22
20
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Alloy 1
PI 1
PI 2
Tempering Temperature (°C)

Figure 3



a) PI 1, 0.097% S



b) PI 2, 0.14% S

INTERNATIONAL SEARCH REPORT

International application No.
PCT/BR2010/000376

A. CLASSIFICATION OF SUBJECT MATTER

IPC (2011.01) C22C 38/20 C21D 1/25

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)

IPC (2011.01) C22C 38/-- C21D 1/--

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

SINPI (BASE DE DADOS DO INPI)

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

EPODOC, ESPACENET, SCIENCE DIRECT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6893608 B2 (BOEHLER EDELSTAHL [AT]) 17 **May** 2005 (2005-05-17)	1-9
A	US 6358334 B2 (EDRO ENGINEERING INC [US]) 19 **March** 2002 (2002-03-19)	1-9
A	US 2002088513 A1 11 **July** 2002 (2002-07-11)	1-9
A	US 5089067 A (ARMCO INC [US]) 18 **February** 1992 (1992-02-18)	1-9
A	US 3767390 A (ALLEGHENY LUDLUM IND INC) 23 **October** 1973 (1973-10-23)	1-9

[X] Further documents are listed in the continuation of Box C. [X] 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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
26.JAN 2011 (26.01.2011)	**08 FEB 2011 (08.02.2011)**

Name and mailing address of the ISA/	Authorized officer
INSTITUTO NACIONAL DA PROPRIEDADE INDUSTRIAL Rua Mayrink Veiga nº 9, 18º andar cep: 20090-050, Centro - Rio de Janeiro/RJ	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/BR2010/000376

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to claim No.
A	US 5496421 A (NIPPON KOKAN KK [JP]) 05 **March** 1996 (1996-03-05)	1-9

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/BR2010/000376

US 6893608 B2	2005-05-17	AT 301731 T	2005-08-15
		AT 2302001 A	2002-02-15
		AT 409636 B	2002-09-25
		BR 0200003 A	2002-10-29
		CA 2371333 A1	2002-08-14
		CN 1370851 A	2002-09-25
		CN 101041885 A	2007-09-26
		CN 100558926 C	2009-11-11
		DE 50107038 D1	2005-09-15
		DK 1233080 T3	2005-12-19
		ES 2247052 T3	2006-03-01
		HK 1107123 A1	2010-07-23
		KR 20020066990 A	2002-08-21
		SI 1233080 T1	2006-02-28
		TW 528811 B	2003-04-21
		US 2002162614 A1	2002-11-07
US 6358334 B2	2002-03-19	CA 2237851 A1	1998-11-16
		US 6045633 A	2000-04-04
		US 2002014286 A1	2002-02-07
		US 2002088513 A1	2002-07-11
US 2002088513 A1	2002-07-11	CA 2237851 A1	1998-11-16
		US 6045633 A	2000-04-04
		US 2002014286 A1	2002-02-07
		US 6358334 B2	2002-03-19
US 5089067 A	1992-02-18	AT 135057 T	1996-03-15
		AU 645147 B2	1994-01-06
		AU 8788191 A	1992-07-30
		CA 2055154 C	2000-01-18
		DE 69208693 D1	1996-04-11
		EP 0496350 A1	1992-07-29
		ES 2084195 T3	1996-05-01
		JP 5043988 A	1993-02-23
		KR 100214401 B1	1999-08-02
		ZA 9109028 A	1992-08-26
US 3767390 A	1973-10-23	NONE	
US 5496421 A	1996-03-05	DE 69429610 D1	2002-02-14
		EP 0649915 A1	1995-04-26
		JP 7166303 A	1995-06-27
		JP 3228008 B2	2001-11-12

Form PCT/ISA/210 (patent family annex) (July 2009)

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

- US 6358334 B **[0005] [0025] [0026]**
- US 6893608 B2 **[0005]**
- US 6893608 B **[0026]**