Martensitic stainless steel, characterised in that it comprises, in percentages by weight:

- 0.22% ≤ C ≤ 0.32%
- 0.05% ≤ N ≤ 0.15%, with 0.33% ≤ C + N ≤ 0.43%
- 10% ≤ Cr ≤ 12.4%
- 0.10% ≤ V ≤ 0.40%
- 0.10% ≤ Mn ≤ 1.0%
- trace levels ≤ Ni ≤ 1.0%
- trace levels ≤ Mn ≤ 1.0%
- trace levels ≤ Si ≤ 1.0%
- trace levels ≤ W ≤ 1.0%
- trace levels ≤ Co ≤ 1.0%
- trace levels ≤ Cu ≤ 1.0%
- trace levels ≤ Ti ≤ 0.010%
- trace levels ≤ Nb ≤ 0.050%
- trace levels ≤ Al ≤ 0.050%
- trace levels ≤ S ≤ 0.020%
- trace levels ≤ Cr ≤ 0.0040%
- trace levels ≤ P ≤ 0.03%
- trace levels ≤ B ≤ 0.0050%
- trace levels ≤ Ca ≤ 0.020%
- trace levels ≤ Se ≤ 0.010%
- trace levels ≤ La ≤ 0.040%
- trace levels ≤ Ce ≤ 0.040%

the remainder being iron and impurities resulting from the production operation.

Method for producing a component from this steel, and component obtained in this manner, such as a mould element for the production of articles of plastics material.
FIG. 1

Control

INV. 1

INV. 2
The present invention relates to steelmaking, more precisely martensitic stainless steels which are intended, for example, for the production of moulds for producing plastics materials by means of injection.

In order to produce moulds for material injection, the industry uses stainless steels of the family AISI 420 which have a chromium content of from 12 to 15% (in percentages by weight, as is the case for all the contents indicated in the remainder of the text), a silicon content of less than 1%, a manganese content of less than 1%, a carbon content of from 0.16 to 0.45% and a nitrogen content which is the one which results naturally from the production operation and which is generally up to 0.03%. Generally, the content of vanadium does not exceed 0.1% and is the result of simple fusion of the raw materials. In the same manner, the content of molybdenum is the result of the fusion of the raw materials and does not exceed 0.2%, unless from 0.2 to 1.0% is added in order to improve the corrosion resistance. More specifically, the steel with the reference X40Cr14 which is capable, owing to its carbon content of from 0.36 to 0.45%, of exceeding a hardness of 50 HRC, provides significant abrasion resistance.

Taking into account the application envisaged, the effectiveness of the material must be evaluated by obtaining a good compromise between the following properties:

- the wear resistance desired in order to be able to produce the maximum number of components with guaranteed geometric regularity, including with plastics materials which are made abrasive by the integration of fibres or other reinforcement additives; this wear resistance is provided by a high level of hardness;
- sufficient toughness to prevent fractures during thermal processing, assembly/disassembly operations, or service; for these steels which are particularly brittle, this property is found to contradict the above one, the toughness decreasing as the hardness increases;
- good polishability which allows a surface polishing quality to be readily achieved on the surface of the mould in order to produce components of plastics materials with a smooth and uniform surface appearance; the steel must also be able to maintain this polished state for as long as possible;
- sufficient corrosion resistance to prevent pitting, tarnishing, alteration of the polish state during storage of the moulds and during service, in the context of production of plastics materials which are slightly or moderately chemically aggressive; the most active substances, for example, by means of salting out chloride ions, require steels or alloys from other families.

After machining a blank to approximate dimensions of the final shape, the moulds are subjected to the following thermal processing operation in an oven under a controlled atmosphere:

- raising to quenching temperature in the range of from 1000 to 1050° C., followed by maintaining in this range for some tens of minutes;
- quenching under gas pressure down to a temperature in the order of 80° C.;
- raising the temperature for two tempering cycles.

Two temperature ranges are generally proposed for tempering:

- low temperature tempering: 150 to 250° C.,
- tempering at 490/530° C. in the secondary hardening zone of the steel.

Theoretically, the two successive tempering operations are both carried out in the same range.

Careful consideration must be given as to the precise selection of the processing parameters.

For the quenching, it is metallurgically recommended to seek high quenching temperatures in order to achieve a favourable martensitic microstructure. However, high quenching temperatures promote deformation and produce residual stresses which are capable of leading to fractures. In practice, the gas pressures are limited to values of from 2 to 4 bar.

When quenching stops, before continuing with the tempering operations, fractures are possible if the cooling continues down to ambient temperature. However, the usual selection of stopping the cooling at approximately 80° C. involves the risk of retaining residual austenite, in particular if the subsequent tempering operations are fixed below 500° C., and consequently not being able to obtain the desired nominal hardness.

For the tempering operations, the selection of low temperatures only allows the constraints to be partially overcome, and if the composition of the steel and the quenching cycle have allowed residual austenite to remain, with the tempering operation not decomposing it, the desired hardness is not achieved. High-temperature tempering operations decompose the austenite and relax the residual stresses, but reduce the strength and the corrosion resistance.

There is also the problem of the cost of these steels, owing to the high contents of alloy elements which they require and which it would be necessary to be able to minimise without impairing the desired properties.

The object of the invention is to define an economic steel composition for applications involving moulds for the production of articles of plastics materials which have, with respect to the references AISI 420 and X40Cr14, the following properties:

- preferential equivalent hardness of from 49 to 55 HRC in the processed state in order to withstand abrasion;
- equivalent corrosion resistance;
- improved strength with equal hardness;
- improved polishability;
- and to have these properties under industrial thermal processing conditions which are comparable with conventional conditions.

To this end, the invention relates to a martensitic stainless steel, characterised in that it comprises, in percentages by weight:

- 0.22% ≤ C ≤ 0.32%,
- 0.05% ≤ N ≤ 0.15%, with 0.33% ≤ C + N ≤ 0.43%,
- 10% ≤ Cr ≤ 12.4%,
- 10% ≤ V ≤ 0.43%,
- 10% ≤ Mo ≤ 1.0%,
- 0.33% ≤ N ≤ 1.0%,
- 0.34% ≤ Mn ≤ 1.0%,
- 0.35% ≤ Si ≤ 1.0%,
- 0.36% ≤ W ≤ 1.0%,
- 0.37% ≤ Co ≤ 1.0%,
- 0.38% ≤ Cu ≤ 1.0%.
The invention relates to a method for producing a martensitic stainless steel, characterised in that:

- a steel of the above type is produced, cast, forged or rolled and annealed;
- the steel is machined in order to confer thereon the shape of the component;
- the machined steel is austenitised at a temperature of from 990-1040°C, preferably 1000-1030°C;
- the austenitised steel is quenched at a rate of between 10 and 40°C/min in the temperature range of from 800 to 400°C;
- two tempering operations are carried out on the quenched steel, in order to confer thereon its final hardness.

The tempering operations can each be carried out at a temperature of from 200 to 400°C, preferably from 300 to 380°C for a minimum of 2 hours whilst ensuring that the nominal temperature is maintained in the core for at least 1 hour, in order to obtain a hardness of from 49 to 50 HRC.

The tempering operations can each be carried out at a temperature of from 530 to 560°C for a minimum of 2 hours whilst ensuring that the nominal temperature is maintained in the core for at least 1 hour, in order to obtain a hardness of between 42 and 50 HRC.

The invention also relates to a component of martensitic stainless steel, characterised in that the element produced using the method is produced in accordance with the preceding method.

This may be a mould element which is intended for the production of articles of plastics materials.

As will be appreciated, the invention is based on a steel composition whose contents of carbon and chromium are simultaneously at the lower end of the ranges generally required, or even sometimes below in the case of the chromium content, with the imposition of precise conditions on other elements which are present or which must be limited or avoided. A production method is associated with this composition.

The inventors concentrated on actually taking into consideration the properties of the steel following the production operation, and in particular the industrial processing as described above, and not in accordance with laboratory conditions. The research was carried out with the intent of optimising the action of the alloy elements in order to limit the quantity thereof introduced.

The main considerations which have led to the invention are as follows:

- The polishability and the surface quality of the polished state of the steel are degraded by:
  - the presence of non-metal oxide inclusions which do not reflect light and which further disintegrate or become bare in contact with abrasives, and form leaving streaks or “comets tails” at the surface of the mould;
  - the interdendritic segregations which form naturally during solidification of the bar and generate on the surface of the moulds hard zones or lines which alternate with softer zones or lines, bringing about undulations during polishing, owing to the fact that the soft zones yield more quickly than the hard zones;
  - the presence of non-dissolved micrometric chromium carbides during the quenching operation.

Generally, the strength, which is moderate for this family of steels, becomes lower for a given hardness, as the chromium content increases. It could be improved by balancing the composition, in particular with additions of nickel and manganese which allow a residue of austenite to be retained during the quenching operation. This solution which further no longer has an effect if the tempering operations are carried out above 500°C is, however, found to be unstable and impedes the production of the hardness. It has not been retained, partially since it was not compatible with the desired reduction of the content of alloy elements.

In order to achieve the set objectives, it has been decided:

- on the one hand to produce the steel in accordance with known methods which limit the presence of oxidised non-metal inclusions, therefore conferring on the steel a low content of O,
- and on the other hand to globally reduce the alloy elements, introduce nitrogen, and optimise the equilibriums between elements in order to increase the strength, reduce the interdendritic segregation and limit the density of micrometric precipitates.

The invention will be better understood from the following description, given with reference to the following appended Figures:

- FIG. 1 which illustrates micrographs of samples of a reference steel and two steels according to the invention, illustrating the density and the distribution of the micrometric carbides in the state for use of these steels;
- FIG. 2 which illustrates the influence of the temperature of the two tempering operations on the corrosion resistance of a steel according to the invention;
- FIG. 3 which illustrates the influence of the temperature of the tempering operations on the corrosion resistance;
- FIG. 4 which illustrates the interactions of the content of Cr and the quenching rate on the corrosion resistance;
- FIG. 5 which illustrates the hardness of the steels according to the invention and a reference steel in accordance with the temperature of the tempering operations.

Table 1 sets out the compositions of the samples examined. The sample “reference” corresponds to a steel of the conventional type X40Cr14. The samples Exp. 1 to Exp. 5 were produced by the conventional method of casting, rolling and heat treatment, and were then tempering treated following the conditions of the invention given above.
7 are not in accordance with the invention but allow the disadvantages to be overcome which are involved in not complying with all the conditions required by the invention. The samples Inv. 1 and Inv. 2 are in accordance with the invention.

The samples Inv. 1 and Inv. 2 are in accordance with the invention.

<table>
<thead>
<tr>
<th>Chemical composition of the steels examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Reference</td>
</tr>
<tr>
<td>Exp. 1</td>
</tr>
<tr>
<td>Exp. 2</td>
</tr>
<tr>
<td>Exp. 3</td>
</tr>
<tr>
<td>Exp. 4</td>
</tr>
<tr>
<td>Exp. 5</td>
</tr>
<tr>
<td>Exp. 6</td>
</tr>
<tr>
<td>Exp. 7</td>
</tr>
<tr>
<td>Inv 1</td>
</tr>
<tr>
<td>Inv 2</td>
</tr>
</tbody>
</table>

[0088] An object of the invention is therefore to provide an optimised steel which is intended to be processed in accordance with the range of industrial quenching rates, preferably with a subsequent dual tempering operation at low temperature (~400°C.) for a hardness of 52 HRC with a strength and a corrosion resistance which are equal to or greater than those of the reference steel AISI 420 or X40Cr14 in its usual application.

[0089] Furthermore, an object of the invention is to limit to the greatest possible extent the additions of alloy elements, in particular metal elements, in order to reduce the production cost, prevent the presence of residual austenite after the quenching operation and reduce the extent of interdendritic segregation which is detrimental to the strength and the quality of the polishing.

[0090] To this end, the inventors have arrived at the following results relating to the definition of the composition of the steels of the invention.

[0091] The nitrogen content must be between 0.05% and 0.15% and preferably between 0.08% and 0.12%. This element is therefore systematically present with a high content since it is indispensable in order to form carbonitrides of the type V(C,N) which are capable of preventing grain enlargement during austenitisation after the chromium carbides have dissolved. However, an excessive content would be detrimental if exceeding the solubility limit in the solid state and would be a source of metallurgical defects. The carbon and nitrogen in carbon can confere the hardness and is involved in the corrosion resistance. The content of nitrogen can be adjusted by insufflation of gaseous nitrogen when the liquid steel is produced.

[0092] Carbon contributes mainly to conferring the hardness required, associated with the nitrogen. Taking into account the hardness required after tempering at low temperature, the percentage must be between 0.22% and 0.32%. Furthermore, the total C+N must be between 0.33% and 0.43% in order to allow the desired hardness to be achieved after tempering.

[0093] Chromium confers on the steel the corrosion resistance thereof. Taking into account the industrial quenching rates used, and the tempering range selected, and in accordance with the mechanisms set out above, the content thereof must be between 10 and 12.4% and preferably between 11.0 and 12.4%.

[0094] Vanadium must be present at a content of between 0.10% and 0.40% and preferably between 0.15% and 0.35%. The presence thereof is indispensable for forming with the carbon and the nitrogen a sufficient density of micro- and nano-particles which are capable of preventing the grain enlargement. An excessive content would be detrimental owing to the excessive fixing of carbon which would impair the hardening and owing to the formation, during solidification, of carbides which are isolated or in a cluster which are unfavourable for the strength and the polish state quality.

[0095] Molybdenum complements the action of the chromium for the corrosion resistance; it is present owing to the recycling operations or by intentional addition, at percentages of between 0.10 and 1.0%. A greater content would be detrimental owing to the increase in the extent of the interdendritic segregation and owing to the risk of forming delta ferrite.

[0096] Nickel may be present at contents of less than 1.0%, in particular owing to the contribution by the raw materials. No beneficial effect of an addition within this limit has been found in terms of the toughness. However, a greater content would be capable of maintaining the residual austenite in the processed state.

[0097] Manganese is an element which is naturally present in this family of steel owing to the production methods and the raw materials available. No beneficial effect has been found and it has been found to be necessary to limit the concentration thereof to 1.0% in order to prevent residual austenite after thermal processing.

[0098] Silicon is naturally present for the production and the deoxidation of the steel. The content thereof must be limited to 1.0% and preferably 0.5% since it acts on the process of solidification and the delta/gamma conversion and consequently can bring about the presence of delta ferrite or local segregations owing to the presence of this phase at the end of solidification before forging.

[0099] Tungsten may be present at contents of less than 1.0% without having any favourable or detrimental effect on the product. Nonetheless, owing to its individual action or synergy with molybdenum, it may promote the presence of delta ferrite in the state for use or local precipitations or segregations resulting from the presence of delta ferrite at any stage of the thermomechanical process. It will be preferable to comply with the condition 0.10%≤Mo+W/2≤1.20%.
[0100] Cobalt and copper have no beneficial effect which has been identified but may be present at contents of less than or equal to 1.0%. Higher contents could promote the presence of residual austenite.

[0101] It is preferable for the total of the contents of Mn, Cu, and Co to be ≤1.8% in order to limit the risks of the presence of residual austenite.

[0102] Titanium and niobium are very reactive elements which form very hard precipitates which are detrimental to the quality of polystahl. The content thereof must be kept as low as possible: a maximum of 0.010%, preferably a maximum of 0.003% for Ti and a maximum of 0.050%, preferably a maximum of 0.010% for Nb.

[0103] The aluminium added for the deoxidization of the steel may remain present in oxide inclusions which are very detrimental to the polystahl state. The level of addition must be adapted to the production methods used. A maximum content of 0.050% is tolerable, on condition that it does not lead to the presence of inclusions of aluminium oxide or silico aluminates in large quantities which would lead to the acceptable content of O being exceeded (0.0040%, preferably 0.001%).

[0104] Sulphur is preferably limited to a content of less than 0.003% in order to prevent the formation of sulphur inclusions. Optionally, however, it is possible to elect to carry out a voluntary addition in the range of from 0.003 to 0.020% associated preferably with another element (Se up to 0.010%, Ca up to 0.020%, La up to 0.040%, Ce up to 0.040%) promoting the formation of globular sulphides in order to improve the machinability, to the detriment to a certain extent of the quality of the polystahl state.

[0105] The maximum content of oxygen is 0.0040%, preferably 0.0015%. This element is an indicator of the inclusion density, which is detrimental to the polystahl state of the surface when it is too high. This content must be kept as low as possible, and the production method of the steel must be selected as a result. In practice, known methods allow values as low as 0.5 ppm under economically acceptable conditions.

[0106] The content of phosphorus is limited to 0.03% which is a common content in this class of steels. No detrimental effect of P has been noted in this range.

[0107] Boron can be added in order to improve the quenchability; at a content which does not exceed 0.005%.

[0108] The preferable contents indicated for some elements may be imposed alone and not necessarily in combination with the other preferred contents indicated.

[0109] The non-cited elements may be present at contents of the level of impurities resulting from the production which do not modify the properties which the invention seeks to optimise.

[0110] The products must be produced in accordance with the provisions of the prevailing art for special high-quality steels which are intended for the application of fo moulding articles of plastics materials with the objective of limiting the content of inclusions and the segregation in order to obtain a high-quality polystahl state. The production must comprise, after fusion, a step for deoxidisation and elimination of the inclusions in a metallurgical reactor. Preferably, in particular for the production of large moulds and in order to obtain the highest quality of polystahl state, a remelting operation using a consumable electrode under a slag will be carried out in order to improve the inclusion purity and distribute the alloy elements, and in particular nitrogen in a homogeneous manner in the entire mass.

[0111] A thermomechanical transformation by means of forging or rolling finishing with an annealing operation must follow in order to complement the homogeneity and the compactness of the microstructure.

[0112] After machining the component to the final shape and before operation, the products must, in accordance with the preferred operating method, be subjected to a thermal processing operation which comprises austenisation at approximately 1020°C (from 990 to 1040°C, preferably 1000-1030°C), a controlled quenching operation, for example, under neutral gas pressure, at a rate of between 10 and 40°C/minute adapted to the size of the component, then two tempering operations at a temperature of from 200 to 400°C, preferably between 300 and 380°C, in order to obtain a hardness of approximately 52 HRC ±2 HRC and generally between 49 and 55 HRC.

[0113] Optionally, for applications which do not require a hardness greater than 50 HRC, the steel defined by the invention could be processed by means of dual tempering at 530°C to 560°C for hardnesses which are less than or equal to 50 HRC and greater than or equal to ±42 HRC, under which conditions the corrosion resistance is found to be adequate.

[0114] For the reference steel, the chromium carbides (M23C6) which exist in the delivery state are dissolved during the austenisation which precedes the quenching operation, and the temperature to be maintained is limited to 1020-1030°C in order to prevent growth. However, at this dissolution temperature, a significant quantity of carbides which are distributed in a heterogeneous manner remains. By substituting from approximately 0.10 to 0.15% of the content of carbon with nitrogen, a reduction of approximately 2% of the content of chromium and a simultaneous introduction of vanadium, it is observed at the adequate quenching temperature that the grain which is fixed by means of nanometric precipitates of vanadium carbonitrides V(C,N) does not grow whilst the majority of the chromium carbides are dissolved.

[0115] For three of the compositions examined, the compared calculation of the equilibria at 1030°C by means of thermodynamic software THERMOCALC (commonly used by metallurgists) illustrates this mutation (see Table 2).

### Table 2

<table>
<thead>
<tr>
<th>Identification</th>
<th>Nominal composition</th>
<th>Molar % of</th>
<th>Molar % of</th>
<th>Matrix composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C (%)</td>
<td>N (%)</td>
<td>Cr (%)</td>
<td>Mo (%)</td>
</tr>
<tr>
<td>Reference</td>
<td>0.41</td>
<td>0.02</td>
<td>14.56</td>
<td>0.29</td>
</tr>
<tr>
<td>Inv. 1</td>
<td>0.28</td>
<td>0.10</td>
<td>12.38</td>
<td>0.29</td>
</tr>
<tr>
<td>Inv. 2</td>
<td>0.27</td>
<td>0.12</td>
<td>11.04</td>
<td>0.32</td>
</tr>
</tbody>
</table>
The effective density of the micrometric carbides observed on industrial products and illustrated in FIG. 1 effectively decreases in a significant manner between the reference composition and the compositions of the invention, which constitutes a favourable factor for the quality of the polish state.

For the reference steel, the capacity for corrosion resistance is, theoretically in accordance with basic knowledge, above all linked to the content of chromium available in the matrix; the thermodynamic calculations show that the carbides which are not dissolved during austenisation fix approximately 0.9% of chromium. This quantity of chromium which is not available for the corrosion resistance becomes lower than 0.1% for the experimental grades which are alloyed with vanadium and nitrogen. In accordance with the following formula:

\[ \text{P.R.E. (Pitting Resistance Equivalent)} = \% \text{Cr} + 3.3 \times \% \text{N} \]

which conventionally allows the compositions to be classified in accordance with their resistance to pitting and applied to the effective composition of the matrix, it is found according to Table 2 that the experimental compositions Inv 1 and 2 have a coefficient which is close to that of the reference.

In addition to the considerations set out above expressing a potential in the crude quenching state, it is advantageous to carry out measurements in the effective state of the metal at the stage of use. The electrochemical method carried out from the standard ASTM G 108 involves polarising the sample for 15 minutes in an aqueous solution of \( \text{H}_2\text{SO}_4 \) at 1% by weight, at a potential of -550 mV/ECS then carrying out a scanning operation back and forth at 60 mV/mm from -550 mV to +500 mV. The characteristic lines intensity/potential on return may have two peaks, one (peak 1) owing to the dissolution of the matrix, the second (peak 2), at a higher potential, linked to the dissolution in the region of the precipitates of chromium carbides. The steel becomes more sensitive to corrosion as the dissolution current becomes more intense. Characteristic lines are set out in FIGS. 2 and 3.

According to current practices for reference steels, whilst obtaining the desired hardness of approximately 52 HRC, two parameters of the thermal processing are found to be influential for the corrosion resistance: the tempering temperature and the quenching rate.

These effects have been set out by laboratory tests:

**Tempering Effect:**

FIG. 2 illustrates for the casting INV1 that the steel becomes highly sensitive with respect to corrosion for tempering operations which are carried out in the hardening zone of approximately 500°C. If the corrosion resistance is a characteristic which must imperatively be prioritised for the applications envisaged, low-temperature tempering operations will therefore be preferred (200-380°C).

This tendency is confirmed for all the compositions tested, as illustrated in FIG. 3. This shows the influence of a dual tempering operation of 2 hours at 380°C, or at a temperature close to 500°C, on the corrosion resistance taking into account the corrosion current at the peak 2 of FIG. 2. The precise temperature of the dual tempering operations at approximately 500°C has been adjusted so that it allows the same hardness to be obtained as after a dual tempering operation at 380°C. It has been found in particular that the sample according to the invention has a corrosion resistance which is very comparable to that of the reference sample for a dual tempering operation at 380°C.

For low tempering temperatures, it has further been verified that the corrosion resistance decreases slightly between 200°C and 380°C and degrades rapidly above 400°C.

So that the tempering operations have the intended effect, they must last at least 2 hours, and their nominal temperature must be maintained at the core of the component for at least 1 hour.

**b) Effect of the Quenching Rate:**

Unexpectedly, as illustrated in FIG. 4 which compares two experimental castings which are distinguished from each other only by their chromium content, the increase of the content of this element does not improve the corrosion resistance under industrial quenching conditions with a cooling rate in the order of 20°C/minute in the range 900/400°C. The low cooling rate brings about the development of the peak 2 which indicates the precipitation of carbides or nitrides and whose extent becomes greater as the content of chromium increases and amplifies the corrosion current of the matrix (peak 2).

These results are confirmed for the various compositions examined.

According to the invention, a quenching rate is selected which is compatible with the technical knowledge of the thermal processing operation and between 10 and 40°C/minute in the temperature range from 800 to 400°C.

In conclusion, in the context of an industrial quenching operation the best corrosion resistance is obtained with the low-temperature tempering operations and, in this configuration, the variation of the chromium content in the range from 10.5 to 15% does not confirm the beneficial effect normally recognised for this alloy element.

The same unfavourable effects of reducing the quenching rate and increasing the tempering temperature are found with respect to the toughness. This property is commonly simply appreciated from the conventional mechanical characteristics of elongation and reduction of area during the traction and impact flexion energy test on non-notched bars having dimensions of 55x10x7 mm. For the tests concerned, a quenching operation of 16°C/minute was carried out on all the samples then a dual tempering operation of 2 hours. The results set out in Table 3 illustrate:

- for the composition Inv. 2, taken as an example, the negative effect of reducing the quenching rate;
- the embrittling effect of the dual tempering operation at approximately 500°C;
- for the dual tempering operation at low temperature (380°C), the superior nature of the hardness/toughness compromise of the two steels of the invention with respect to the reference.
TABLE 3

Mechanical characteristics measured for three compositions on samples representative of industrial products

<table>
<thead>
<tr>
<th>Composition</th>
<th>Quenching rate (°C/min)</th>
<th>Hardness HRC</th>
<th>A %</th>
<th>Z %</th>
<th>Impact flexion</th>
<th>Non-notched sample J</th>
<th>Tempering °C</th>
<th>Hardness HRC</th>
<th>A %</th>
<th>Z %</th>
<th>Impact flexion</th>
<th>Non-notched sample J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>16</td>
<td>51.3</td>
<td>4.5</td>
<td>9</td>
<td>110</td>
<td></td>
<td>500</td>
<td>51.3</td>
<td>3.0</td>
<td>3</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Inv. 1</td>
<td>16</td>
<td>53.2</td>
<td>7.5</td>
<td>21</td>
<td>210</td>
<td></td>
<td>520</td>
<td>53.0</td>
<td>3.5</td>
<td>5</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Inv. 2</td>
<td>16</td>
<td>53.9</td>
<td>6.5</td>
<td>17</td>
<td>130</td>
<td></td>
<td>520</td>
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<td>60</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

[0133]: The compositions of the invention allow the hardness of 52 HRC or above to be obtained after quenching under industrial conditions and dual tempering at 380°C, in spite of the softening occurring in this range for this family of steels from the crude quenching material, as illustrated in FIG. 5.

1. Martensitic stainless steel, characterised in that it comprises, in percentages by weight:
   - 0.22% ≤ C ≤ 0.32%
   - 0.05% ≤ N ≤ 0.15%, with 0.33% ≤ C+N ≤ 0.43%
   - 10% ≤ Cr ≤ 12.4%
   - 0.10% ≤ V ≤ 0.40%
   - 0.10% ≤ Mo ≤ 1.0%
   - trace levels ≤ Ni ≤ 1.0%
   - trace levels ≤ Mn ≤ 1.0%
   - trace levels ≤ Si ≤ 1.0%
   - trace levels ≤ W ≤ 1.0%
   - trace levels ≤ Co ≤ 1.0%
   - trace levels ≤ Cu ≤ 1.0%
   - trace levels ≤ Ti ≤ 0.10%
   - trace levels ≤ Nb ≤ 0.050%
   - trace levels ≤ Al ≤ 0.050%
   - trace levels ≤ Si ≤ 0.020%
   - trace levels ≤ O ≤ 0.004%
   - trace levels ≤ P ≤ 0.03%
   - trace levels ≤ B ≤ 0.005%
   - trace levels ≤ S ≤ 0.020%
   - trace levels ≤ Se ≤ 0.010%
   - trace levels ≤ Mn ≤ 0.040%
   - the remainder being iron and impurities resulting from the production operation.

2. Steel according to claim 1, characterised in that 0.08% ≤ N ≤ 0.12%.

3. Steel according to claim 1, characterised in that 11.0% ≤ Cr ≤ 12.4%.

4. Steel according to claim 1, characterised in that 0.15% ≤ V ≤ 0.35%.

5. Steel according to claim 1, characterised in that trace levels ≤ Si ≤ 0.5%.

6. Steel according to claim 1, characterised in that 0.10% ≤ Mo+V/2 ≤ 1.20%.

7. Steel according to claim 1, characterised in that trace levels ≤ Ti ≤ 0.003%.

8. Steel according to claim 1, characterised in that trace levels ≤ Nb ≤ 0.010%.

9. Steel according to claim 1, characterised in that trace levels ≤ O ≤ 0.0015%.

10. Steel according to claim 1, characterised in that trace levels ≤ S ≤ 0.003%.

11. Steel according to claim 1, characterised in that trace levels Mn+Cu+Co ≤ 1.8%.

12. Method for producing a component of martensitic stainless steel, characterised in that:
   - a steel according to claim 1 is produced, cast, forged or rolled and annealed;
   - the steel is machined in order to confer thereon the shape of the component;
   - the machined steel is austenitised at a temperature of from 990-1040°C, preferably 1000-1030°C;
   - the austenitised steel is quenched at a rate of between 10 and 40°C/min in the temperature range of from 800 to 400°C;
   - two tempering operations are carried out on the quenched steel, in order to confer thereon its final hardness.

13. Method according to claim 12, characterised in that the tempering operations are each carried out at a temperature of from 200 to 400°C, preferably from 300 to 380°C for a minimum of 2 hours whilst ensuring that the nominal temperature is maintained in the core for at least 1 hour, in order to obtain a hardness of from 49 to 55 HRC.

14. Method according to claim 12, characterised in that the tempering operations are each carried out at a temperature of from 530 to 560°C, for a minimum of 2 hours whilst ensuring that the nominal temperature is maintained in the core for at least 1 hour, in order to obtain a hardness of between 42 and 50 HRC.

15. Component of martensitic stainless steel, characterised in that the element produced using the method is produced in accordance with claim 12.

16. Component according to claim 15, characterised in that it is a mould element which is intended for the production of articles of plastics materials.

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