STAINLESS PM STEEL SUITABLE FOR PLASTIC MOULDING

TECHNICAL FIELD

The invention relates to a stainless tool steel suitable for plastic moulding, which steel is produced by Powder Metallurgy (PM).

BACKGROUND OF THE INVENTION

There are a number of plastic mould steels available on the market for the manufacturing of moulds for the plastic processing. The commonly used steels can be classified as pre-hardened steels, through-hardening steels, case hardening steels, precipitation hardening steels, corrosion resistant steels and powder metallurgy steels. Steels for plastic moulding need sufficient corrosion resistance, wear resistance and a high hardness.

The present invention is directed to a corrosion resistant martensitic stainless steel produced by powder metallurgy. Steels of this type are generally provided in the soft annealed condition, wherein the carbides are embedded in a soft ferritic matrix for best machinability. The steels are used in the hardened and tempered condition.

Stainless PM steels suitable for plastic moulding have been on the market for decades and have attained a considerable interest, because of the fact that they combine a high wear resistance with a good corrosion resistance. ELMAX SuperClean of the applicant is a powder metallurgy produced stainless steel with high wear and corrosion resistance. The nominal composition of ELMAX SuperClean is 1.7 %C, 0.8 %Si, 0.3 %Mn, 18.0 %Cr 1.0 %Mo and 3 %V. Other materials of this type include Böhler M390, BÖHLER M398, Crucible CPM S90V, Crucible S110V as well as the materials described in US5900560, US 5936169 and US2004/0094239.

The known stainless PM steels have a wide range of applications and, apart for being used for plastic moulding, they may also be used in other demanding applications where high wear resistance and corrosion resistance is required such as for screws, barrels, powder pressing, knives for food processing and custom knives.

Although the known PM stainless steels have better properties than conventionally produced tool steels, there is a need for further improvements of PM stainless steels due to the increased use of plastics containing more aggressive additives, which causes abrasive wear and severe corrosion problems.

Accordingly, it would be beneficial to further improve the composition of the steel in order to obtain a steel having improved properties, in particular improved wear and corrosion resistance as well as improved toughness.

DISCLOSURE OF THE INVENTION

The general object of the present invention is to provide a stainless PM steel having a working hardness in the hardened and tempered condition of 55 – 62 HRC, in combination with an improved corrosion resistance. In particular, an improved resistance against pitting corrosion is highly desirable. The claimed stainless tool steel is suitable for plastic moulding as well as for many other applications including, but not restricted to, screws, barrels, powder pressing, knives for food processing and custom knifes. The steel is in particular very well suited for use in high quality knifes because of the high corrosion resistance in combination with a high wear resistance giving the steel a superior edge durability and an excellent sharpness and ease of edge rejuvenation.

A particular object of the present invention is to provide a steel composition, which has an improved corrosion resistance as compared to the steel ELMAX SuperClean.

In addition, it is desirable that the stainless PM stainless steel, in addition to a good resistance against pitting corrosion, also has an improved resistance against abrasive wear.

The foregoing objects, as well as additional advantages, are achieved to a significant measure by providing a powder metallurgy produced steel having the composition as set out in claim 1.

The invention is defined in the claims.

DETAILED DESCRIPTION

The importance of the separate elements and their interaction with each other as well as the limitations of the chemical ingredients of the claimed alloy are briefly explained in the following.

All percentages of the chemical composition of the steel are given in weight % (wt. %) throughout the description. The amounts of hard phases are given in volume % (vol. %).

The broadest aspect of the invention is set out in claim 1. The inventive idea is valid for the whole scope of claim 1. Upper and lower limits for one or more of the chemical elements may be freely combined within the limits set out in claim 1, in order to form a more limited range for the one or more elements. This may be necessary in order to delimit the invention over the prior art. Accordingly, multiple combinations are expressly allowable for all elements defined in claim 1 and there is no need or pointer for a certain combination, since such a combination solely leads to a limitation of the scope of protection and not to a new invention. It is also allowable to form a new range for an element by the combination of two different values of an upper range or by the combination of two different values of a lower range.

The arithmetic precision of the numerical values can be increased by one or two digits for all values given in the present application. Hence, a value reported as e.g. 0.1 % can also be expressed as 0.10 or 0.100 %.

The steel may also contain conventional amounts of undesirable residual elements or impurities, which are not intentionally added but originate from the raw materials, the refractories or from the atmosphere during steelmaking. The upper limits of the impurities can be specified but need not be specified as long as they do not deviate from conventional impurity amounts.

Conventional martensitic stainless steels for plastic moulding generally contain high amounts of chromium. However, these steels have relatively low toughness from the relatively large chromium carbides in the microstructure. In addition, the formation of chromium carbides reduces the amount of Cr dissolved in the hardened matrix, thereby impairing the corrosion resistance.

The present invention aims at attaining a good balance between the corrosion resistance, wear resistance and the toughness. This object is achieved by balancing the steel composition in order to avoid the formation of chromium carbides and to replace said carbides with much harder and smaller vanadium carbides. Accordingly, the amount of the chromium carbides M_7C_3 and $M_{23}C_6$ should be prevented as far as possible.

Carbon (1.2 – 1.8 %)

Carbon is to be present in a minimum content of 1.2 %, preferably at least 1.25, 1.30, 1.35, 1.40, 1.45 or 1.5 %. The upper limit for carbon is 1.8 % and may be set to 1.75, 1.70, 1.65, 1.60 or 1.55 %. In any case, the amount of carbon should be controlled such that the amount of primary carbides of the type $M_{23}C_6$, M_7C_3 and M_6C in the steel is limited, preferably the steel is free from such primary carbides.

Silicon (0.05 – 0.8 %)

Silicon is used for deoxidation. Si is present in the steel in a dissolved form. Si is a strong ferrite former and increases the carbon activity and therefore the risk for the formation of undesired carbides, which negatively affects the impact strength. A low content of Si may result in the presence of finer carbides, which is beneficial for the ductility and toughness of the steel. Si is therefore limited to 0.8 %. The upper limit may be 0.7, 0.6, 0.5, 0.45 or 0.4 %. The lower limit may be 0.10, 0.15, 0.20, 0.25, 0.30 or 0.35 %.

Manganese (0.05 – 0.9 %)

Manganese contributes to improving the hardenability of the steel and together with sulphur manganese contributes to improving the machinability by forming manganese sulphides. Manganese shall therefore be present in a minimum content of 0.05 %, preferably at least 0.1 % or 0.2 %. The steel shall contain a maximum content of 0.9 %. The upper limit may be 0.8, 0.7, 0.65, 0.60, 0.55, 0.50 or 0.45 %.

Chromium (10.0 – 12.2 %)

Chromium is to be present in a content of at least 10.0 % in order to provide a good hardenability and a good corrosion resistance. If the chromium content is too high, this may lead to the formation of high-temperature ferrite, which reduces the hot-workability. Moreover, chromium has a negative effect on the tempering resistance because it counteracts

the formation of cubic carbides of the type MX such as VC. The lower limit may be 10.1, 10.2, 10.3, 10.4, 10.5, 10.6 or 10.7 %. The upper limit may be 12.1, 12.0, 11.9, 11.8, 11.7, 11.6, 11.5, 11.4, 11.3, 11.2, 11.1, 11.0 or 10.9 %.

Nickel (≤1.1 %)

Nickel may be present in an amount of up to 1.1 %. It gives the steel a good hardenability and toughness. The presence of nickel may also result in an improved machinability, possibly by reducing the amount of carbon in the martensite. However, because of the expense, the nickel content of the steel is limited to 1.1 %. The upper limit may be 1.0, 0.9, 0.8, 07, 0.6, 0.5 or 0.4 %. Ni need not be deliberately added to the inventive steel and is then present at conventional impurity levels. If added, then the lower limit may be set to 0.05, 0.1, 0.2, 0.3, 0.4 or 0.5 %.

Molybdenum (0.7– 2.5 %)

Mo is known to have a very favourable effect on the hardenability as well as on the resistance against pitting corrosion. Molybdenum is essential for attaining a good secondary hardening response by the formation of dispersive nano-sized Mo_2C, which prevents dislocation rearrangement and thereby prevents recrystallization and improves the tempering softening resistance. The minimum content is 0.7 % and may be set to 0.8, 0.9 or 1.0 % Molybdenum is a strong carbide forming element and also a strong ferrite former. The maximum content of molybdenum is therefore 2.5 %. Preferably Mo is limited to 2.4, 2.3, 2.2, 2.1, 2.0, 1.9, 1.8, 1.7, 1.6, 1.5, 1.4, 1.3, 1.2, 1.15, or 1.10 %.

Vanadium (6.7 – 8.7 **%**)

Vanadium forms evenly distributed primary precipitated vanadium carbides (VC) and carbonitrides of the type V(N,C) in the matrix of the steel. This hard phase may also be denoted MX, wherein M is mainly V but minor amounts of Cr and Mo may be present and X is one or more of C and N. However, in the following this phase is referred to as VC even if it contains other elements such as N and Nb. Vanadium shall therefore be present in an amount of 6.7 - 8.7 %. The lower limit may be set to 6.8, 6.9, 7.0 or 7.1 %. The upper limit may be set to 8.6, 8.5, 8.4, 8.3, 8.2, 8.1, 8.0, 7.9, 7.8, 7.7, 7.6, 7.5, 7.4 or 7.3 %.

Nitrogen (0.001 – 0.3 %)

Nitrogen may optionally be added in order to obtain the desired type and amount of hard phases, in particular V(C,N) and in order to increase the quantity and stability of undissolved V(C;N). An increase in the ratio of N in V(C,N) improves the stability of the carbo-nitride. As a result, it may lead to grain refinement as well as to allowing higher austenitizing temperatures, which, in turn, may lead to an improved secondary hardening response. Nitrogen is restricted to 0.001 – 0.3 %. The lower limit may be 0.005, 0.01, 0.02 or 0.03 %. The upper limit may be 0.2, 0.1, 0.05, 0.03, 0.01 %. When the nitrogen content is properly balanced against the vanadium content, vanadium rich carbonitrides V(C,N) will form. These will be partly dissolved during the austenitizing step and then precipitated during the tempering step as particles of nanometer size. The thermal stability of vanadium carbonitrides is considered to be better than that of vanadium carbides, hence the tempering resistance of the tool steel may be improved by additions of N. However, as pointed out above this phase is referred to as VC even if it contains N.

Sulphur (≤ 0.05 %)

S is an impurity in the steel and negatively affects the mechanical properties of the steel. The content of S is limited to 0.05 % and may be further limited to 0.04, 0.03, 0.01, 0.008, 0.006, 0.004, 0.002, 0.001, 0.0008, 0.0007 or even 0.0005 %.

Phosphorous (≤ 0.05%)

P is an impurity element, which has negative effects on the mechanical properties of the steel. P may therefore be limited to 0.05, 0.04, 0.03, 0.02, 0.01 or 0.008 %.

Copper (≤ 0.5 %)

Cu is considered as an impurity element. It is not possible to extract copper from the steel. This drastically makes the scrap handling more difficult. For this reason, the maximum content of Cu is set to 0.5 %. The upper limit may be set to 0.4, 0.3, 0.2, 0.15, 0.12, 0.10 or 0.08 %.

Cobalt (≤ 5 %)

Co may be optionally present in amounts of up to 5 %. Co stabilizes austenite and reduces the risk for undesired ferrite. Co causes the solidus temperature to increase and therefore provides an opportunity to raise the hardening temperature, which may be 15 - 30 °C higher than without Co. During austenitization it is therefore possible to dissolve larger fractions of

carbides and thereby enhance the hardenability as well as the secondary hardening response. Co also increases the M_s-temperature. However, a large amount of Co may result in a decreased toughness and wear resistance. For practical reasons, such as scrap handling, deliberate additions of Co need not to be performed. The maximum content may be set to 4.5, 4.0, 3.5, 3.0, 2.5, 2.0, 1.5, 1.0, 0.5, 0.45, 0.40, 0.35, 0.30, 0.25, 0.20, 0.15 or 0.10 %. The minimum content may be set to 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1,5, 2.0, 2.5 or 3.0 %.

Tungsten (≤ 1 %)

In principle, molybdenum may be replaced with twice as much tungsten. However, tungsten is expensive and it also complicates the handling of scrap metal. The maximum amount is therefore limited to 1 %, preferably 0.5 %, more preferably 0.3 % and most preferably no deliberate addition is made. Tungsten is then accepted in an amount of up to 0.1 %.

Niobium (≤ 4 %)

Niobium is similar to vanadium in that it forms carbonitrides of the type M(N,C), where M is V and Nb. However, in the present invention this phase is referred to as VC even if it contains Nb and N, because the inventive alloy contain high amounts of V and C. Small additions of Nb may be used to increase the quantity and stability of undissolved VC and may lead to grain refinement, allowing higher austenitizing temperatures and an improved secondary hardening response. Thermodynamic calculations indicate that Nb decreases the solubility of Cr in the primary VC and results in a higher amount of dissolved Cr, Mo and N in the matrix. Larger additions of Nb may therefore be used in order to further increase the corrosion resistance of the alloy. Deliberate additions for grain refinement may be made with additions in the range of 0.005 to 0.1 %. However, Nb is optional and need not be added. The maximum amount is therefore 4 %. The upper limit may be 3.5, 3, 2, 1, 0.5, 0.1, 0.05 or 0.005 %. The lower limit may be set to 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08 or 0.09 %.

Ti, Ta, Zr and Hf

The elements Ti, Ta, Zr and Hf are strong carbide formers and may be present in the alloy in an amount of 1 % each. The upper limit may be set to 0.5, 0.3, 0.1 or 0.05 %.

Steel production

The stainless steel having the claimed chemical composition is produced by powder metallurgy. The tool steel having the claimed chemical composition can be produced by conventional gas atomizing followed by hot isostatic pressing (HIP). The nitrogen content in the steel after nitrogen gas atomizing is generally less than 0.3 %.

The steel to be atomized can have been produced in situ or by conventional metallurgy, including melting in an Electric Arc Furnace (EAF) and further refining in a ladle and optionally by vacuum treatment before casting into ingots, which may be further subjected to Electro Slag Remelting (ESR) in order to further improve the cleanliness of the steel.

Hardening and tempering

The steel is generally provided to the customer in the soft annealed condition for easy machining and the heat treatment is performed by the customer after the machining. The heat treatment comprises hardening and tempering to the desired hardness.
Austenitizing may be performed at an austenitizing temperature (T_A) in the range of 1050 - 1170 °C, preferably 1140 - 1160 °C. A typical T_A is 1150 °C with a holding time of 30 minutes followed by quenching. The tempering temperature is chosen according to the hardness requirement and is performed at least twice. The steel may be subjected to a low temperature tempering (LTT) at a temperature of 180 – 250 °C or to a high temperature tempering (HTT) at a temperature of 480 - 540 °C for 2 hours (2x2h) followed by cooling in air.

Microstructure after hardening and tempering

The microstructure after hardening and tempering comprises a martensitic matrix with less than 5 vol. % retained austenite. The amount of the retained austenite can be reduced to less than 2 vol. % by adjusting the tempering temperature and/or by subjecting the steel to deep cooling, preferably in liquid nitrogen. The hardness after hardening and tempering is typically in the range of 56 – 61 HRC, preferably 58 – 60 HRC. The main hard phase in the microstructure is vanadium carbide (VC), which may contain small amounts of Mo and Cr. A main feature of the present invention is that the amount of chromium rich carbides of the type M_7C_3 and $M_{23}C_6$ is low and that the hard phase mainly consists of very stable VC hard

particles after hardening and tempering in particular after LTT.

The amounts of hard phases in the microstructure after hardening and low temperature tempering are preferably as follows, in volume %:

VC	8 – 15	preferably 8 - 12	
M_7C_3	≤ 3,	preferably ≤ 2,	more preferably ≤ 1
$M_{23}C_6$	≤ 2,	preferably ≤ 1	

The low amount of chromium rich carbides of the type M_7C_3 and $M_{23}C_6$ results in that the amount of Cr in solid solution in the matrix is high after hardening and tempering, because little chromium is bound in the chromium rich carbides. Thereby, the thin passive chromium rich surface film is strengthened, which leads to an increased resistance to general corrosion and pitting corrosion. In addition, it would appear that the high content of vanadium in the steel positively influences the passive film, possibly by shifting the corrosion potential to a more positive value.

The hard phase particles in the tempered martensite may be determined by using a SEM (Scanning Electron Microscope) at a magnification of 1500 times. The retained austenite can be determined by an X-ray diffractometer using ASTM E975-13.

EXAMPLE 1

In this example, a steel according to the invention is compared to the premium PM stainless steel ELMAX SuperClean.

The steels had the following composition (in wt. %):

	Inventive steel	ELMAX SuperClean
C	1.5	1.7
Si	0.4	0.8
Mn	0.4	0.4
Cr	10.8	18.0
Mo	1.05	1.0
V	7.2	3.0

balance iron and impurities.

The inventive steel was heated to an austenitizing temperature (T_A) 1150 °C with a holding time of 30 minutes followed by quenching. The inventive steel was thereafter subjected to tempering twice for two hours at a temperature of 200 °C (2x2h).

The comparative steel was subjected to the recommended heat treatment, i.e. it was heated to an austenitizing temperature (T_A) 1080 °C with a holding time of 30 minutes followed by quenching and tempering twice for two hours at a temperature of 200 °C (2x2h).

The steels were subjected to a salt spray test (or salt fog test) according to ISO 9227:2022 as well as to a cyclic polarisation test in order to examine their respective resistance to pitting corrosion.

The salt spray test was performed with a modified 0.1 M NACl solution and it was found that the inventive steel did not show any sign of localized corrosion, whereas the comparative steel disclosed the formation of several pits, which indicated a breakdown of the passive film.

Both the inventive steel and the comparative steel were subjected to a cyclic polarisation test in order to examine the resistance to pitting corrosion. An electrochemical cell with a saturated Ag/AgCl reference electrode and a carbon mesh counter electrode were used for cyclic polarization measurements. The 500 mesh grounded sample was first open circuit potential (OCP) recorded with a 0.1 M NaCl solution to ensure that a stable potential was reached. Next, the cyclic polarization measurements were performed with a scan rate of 10 mV/min. The start potential was -0.2 V vs. OCP, and the final potential was set to the OCP. By choosing a setting in the software, the upward potential scan was automatically reversed when the anodic current density reached 0.1 mA/cm^2.

The cyclic polarisation test revealed that the inventive steel formed a passive film, which was stable to the breakdown potential of 174 mV, whereas the comparative steel did not form a passive film.

It can thus be concluded that the inventive steel has a better resistance against localized corrosion such as pitting and crevice corrosion.

These results were totally unexpected, because the inventive steel had a much lower content of Cr than the comparative steel. The reasons therefore are presently not fully clarified.

The pitting resistance equivalent (PRE) is often used to quantify pitting corrosion resistance of stainless steels. A higher value indicates a higher resistance to pitting corrosion. For high nitrogen martensitic stainless steels the following expression may be used

PRE= %Cr +3.3 %Mo + 30 %N

wherein %Cr, %Mo and %N are the calculated equilibrium contents dissolved in the matrix at the austenitising temperature (TA). The dissolved contents can be calculated with Thermo-Calc for the actual austenitising temperature (TA) and/or measured in the steel after quenching.

The PRE values were calculated based on the calculated equilibrium contents dissolved in the matrix at the austenitising temperatures (T_A). The inventive steel was found to have a PRE of 14.0 and the comparative steel had a PRE of 15.2. Accordingly, based on this difference, one should expect the comparative to have a better resistance against pitting corrosion but instead the inventive steel showed a better corrosion resistance.

As pointed out before, the reasons therefore are not fully resolved. However, the present inventors do not want to be bound by theory. Nevertheless, it is considered that the differences may be related to the type and amount of hard phases remaining in the steel after austenitizing and quenching and/or because of a positive effect of the much higher amount of vanadium in the inventive steel. For this reason, the dissolved contents of V were calculated with Thermo-Calc for both steels at their respective austenitising temperatures (TA). The calculated content of V in the comparative steel ELMAX SuperClean was 0.61 % at 1080 °C, whereas the calculated content of V in the comparative steel inventive steel was 1.91 % at 1150 °C. Accordingly, the inventors think it is likely that the improved corrosion resistance, at least partly, may be related to the higher amount of vanadium in the inventive steel, which leads to a shift of the pitting potential to a more positive value.

EXAMPLE 2

A full size industrial charge was prepared by melting and atomizing with nitrogen gas followed by HIPing. The steel had the following composition (in wt. %):

C	1.49
Si	0.40
Mn	0.47
Cr	10.81
Mo	1.08
V	7.17
N	0.10
Ni	0.60

balance iron and impurities.

The HIPed ingot was subjected to forging and rolling to a dimension of 245x102 mm. A sample of the steel was heated to an austenitizing temperature (T_A) 1150 °C with a holding time of 30 minutes followed by quenching and subjected to tempering twice for two hours at a temperature of 200 °C (2x2h).

Samples of the steel were prepared in the same way as described in example 1 and subjected to a cyclic polarisation test under the same conditions as for example 1. The cyclic polarisation test revealed that the inventive steel formed a passive film, which was stable to the breakdown potential (Epit) of 237 mV. Hence, the inventive material is not susceptible to pitting corrosion, which indicates that the steel is very suitable for use in corrosive environments such as for IC-moulding and for dish-machine proof knives.

The wear resistance of the inventive steel was examined and compared to the well known stainless steel Elmax SuperClean and the non-stainless steel Vanadis 8. The weight loss was measured using the pin-on-disc method with Al_2O_3-paper and it was found that the inventive steel had a remarkable good wear resistance with a weight loss of 47.6 g mg/min, whereas the stainless steel Elmax SuperClean had a weight loss of 112.8 mg/min and the non-stainless steel Vanadis 8 had a weight loss of 49.1 mg/min. Accordingly, the inventive steel is well suited for moulding fibre-reinforced plastics.

Other alloy compositions that can be used according to the present invention are reproduced in Table 1 below.

Steel	C	Si	Mn	Cr	Mo	V	N	Other elements	Balance
1	1.2	0.4	0.3	11.8	1.0	7.1	0.12	Ni:0.8, Nb:1.1, Co:2.1	Fe
2	1.25	0.1	0.1	10.2	0.8	6.8	0.005	Ni:0.3	Fe
3	1.3	0.6	0.5	11.3	1.8	7.0	0.08		Fe
4	1.3	0.4	0.4	10.8	2.1	7.4	0.04		Fe
5	1.4	0.5	0.6	10.9	1.3	7.8	0.05	Nb:0.4	Fe
6	1.45	0.3	0.4	11.0	1.5	7.2	0.05	Ni:0.5, Co:0.2	Fe
7	1.5	0.6	0.2	10.5	1.2	8.0	0.01	Nb:2.2	Fe
8	1.5	0.05	0.5	11.3	1.7	8.3	0.25		Fe
9	1.55	0.15	0.4	11.4	2.1	7.3	0.15		Fe
10	1.55	0.3	0.3	10.5	2.0	7.3	0.1	Cu:0.2	Fe
11	1.6	0.5	0.55	11.5	1.4	7.5	0.03	Zr:0.2	Fe
12	1.6	0.8	0.6	10.5	1.1	6.9	0.08	Ni:0.8, Hf: 0.2	Fe
13	1.65	0.4	0.7	11.0	2.5	7.0	0.12		Fe
14	1.7	0.2	0.5	11.1	1.9	7.2	0.02	Nb: 0.05	Fe
15	1.7	0.5	0.2	11.5	1.6	7.7	0.06	Ni:0.1, Nb:0.3	Fe
16	1.7	0.1	0.4	11.2	1.8	7.5	0.05	Ti:0.1, Cu:0.3	Fe
17	1.75	0.7	0.8	12.1	2.4	8.6	0.2	W:0.2	Fe
18	1.8	0.3	0.4	10.3	1.2	8.0	0.1	Co:3.0	Fe
Elements not listed are within common impurity levels									

Table 1. Exemplary alloy compositions of the present invention.

INDUSTRIAL APPLICABILITY

The tool steel of the present invention is particular useful for the production of moulds for plastic forming.

CLAIMS

1. A stainless steel suitable for plastic moulding, wherein the steel is produced by powder metallurgy and comprises the following elements in weight %:

C	1.2 – 1.8
Si	0.05 – 0.8
Mn	0.05 – 0.9
Cr	10.0 – 12.2
Mo	0.7 – 2.5
V	6.7 – 8.7
N	0.001 – 0.3
Ni	≤ 1.1
Nb	≤ 4
Ti	≤ 1
Ta	≤ 1
Zr	≤ 1
Hf	≤ 1
S	≤ 0.05
P	≤ 0.05
Cu	≤ 0.5
Co	≤ 5
W	≤ 1

balance Fe apart from impurities.

2. The stainless steel as defined in claim 1, wherein the steel fulfills at least one of the following requirements:

C	1.3 – 1.7
Si	0.1 – 0.7
Mn	0.1 – 0.8
Cr	10.2 – 11.4
Mo	0.8 – 1.8
V	6.8 – 7.7

N	0.01 – 0.2
Ni	0.1 – 1.0
Nb	≤ 2
Ti	≤ 0.5
Ta	≤ 0.5
Zr	≤ 0.5
Hf	≤ 0.5
Co	1 – 4

3. The stainless steel as defined in claim 1 or 2, wherein the steel fulfills at least one of the following requirements:

C	1.4 – 1.6
Si	0.2 – 0.6
Mn	0.2 – 0.6
Cr	10.4 – 11.2
Mo	0.9 – 1.6
V	7.0 – 7.4
N	0.03 – 0.15
Ni	0.4 – 0.8
Nb	≤ 1
Ti	≤ 0.1
Ta	≤ 0.1
Zr	≤ 0.1
Hf	≤ 0.1
Co	2 – 3

4. The stainless steel as defined in any of the preceding claims, wherein the steel fulfills at least one of the following requirements:

C	1.45 – 1.55
Si	0.3 – 0.5
Mn	0.3 – 0.5
Cr	10.6 – 11.0

Mo	0.95 – 2.1
V	7.1 – 7.3
Ni	0.4 – 0.7
N	0.05 – 0.15

5. The stainless steel as defined in any of the preceding claims, wherein the steel fulfills at least one of the following requirements:

Volume % VC	8 – 15
Volume % M_7C_3	≤ 3
Volume % $M_{23}C_6$	≤ 2,
Hardness	58 – 60 HRC

6. The stainless steel as defined in any of the preceding claims, wherein the steel fulfills at least one of the following requirements:

Volume % VC	8 – 12
Volume % M_7C_3	≤ 2
Volume % $M_{23}C_6$	≤ 1

7. The stainless steel as defined in any of the preceding claims, wherein the steel is formed as a knife.