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(54) **Title:** STEEL MATERIAL CONTAINING CARBIDES AND USE OF THE MATERIAL

(57) **Abstract:** The invention concerns a steel material having a good corrosion resistance and the following chemical composition in weight -%: 0.7-1.6 (C + N), of which max. 0.8 N, 0.1-2.0 Si, 0.1-1,5 Mn, 14-19 Cr, from traces to max. 2.0 Ni, from traces to max. 2.0 Co, 1.5-4.0 (Mo + W/2), however at least 1.0 Mo och max. 1.0 W, 0.5-3,0 V, <0.1 Nb, from traces to max. 0.2 S, balance iron and impurities in normal amounts. The steel is suitable to be used for construction elements, fixtures in eroding machines, and moul tools.

STEEL MATERIAL CONTAINING CARBIDES AND USE OF THE MATERIAL

TECHNICAL FIELD

The invention relates to a steel material intended to be used for construction elements in environments which require a good corrosion resistance. Particularly, the invention concerns a steel material which also has a good abrasive wear resistance in the hardened and the tempered condition of the steel. The invention also concerns the use of the steel material for construction elements, particularly fixtures or fixture details for workpieces to be machined in eroding machines, such as spark machining machines, in the liquid bath of which the fixture or the fixture details are subjected to abrasive wear. Mould steels for plastic moulding tools and holder steels for plastic moulding tools are other conceivable applications.

BACKGROUND OF THE INVENTION

The machining of the engraving, i.e. the mould cavity of mould tools, to a large extent is performed in a water bath in eroding machines, such as spark machining machines. The water bath can gradually become very corrosive because of the electrochemical currents which are generated in the bath. In connection with the machining operation, metal fragments of the workpiece can be released and form a slurry in the water bath which therefore also becomes strongly abrasive. During the machining operation, the workpiece is secured by means of fixtures, the details of which are repeatedly used. They are therefore subjected to prolonged influence by the corrosive and abrasive environment in the water bath. Among known steels which are employed as materials for fixtures or fixture details in connection with the manufacturing of mould tools, there can be mentioned, the steels which are manufactured by the applicant and which are known under the applicant's registered and/or well known trademarks RIGOR®, STAVAX®, RAMAX® AND ELMAX®. For the mould tools, i.a. the said steels RIGOR®, STAVAX® and ELMAX® are employed.

When engineering plastics are moulded, the mould steel is subjected to high tensions and wear as well as corrosion. Therefore high hardness, good wear resistance, corrosion resistance and sufficient ductility are important features of the mould steel. Also the holders for the plastic mould tools are subjected to similar stresses, for which reason also the holder material should possess the above mentioned product features.

The nominal compositions of the said steels in weight-% are given in Table 1. Besides the elements mentioned in the table, the steels contain iron and normally occurring impurities and accessory elements.

Table 1

Steel	C	Si	Mn	Cr	Mo	V	S
RIGOR	1.0	0.2	0.8	5.3	1.1	0.2	
STAVAX	0.38	0.9	0.5	13.6		0.3	
RAMAX	0.33	0.3	1.3	16.7			0.12
ELMAX	1.7	0.8	0.3	18.0	1.0	3.0	

RIGOR® is a steel having a good wear resistance but insufficient corrosion resistance. STAVAX® has a comparatively good wear resistance, however not sufficient. The corrosion resistance is good for the fields of use which are interesting. RAMAX® has a corrosion resistance which is sufficiently good for the field of use for that steel, but has an insufficient wear resistance. ELMAX® has a good corrosion resistance and a good wear resistance, but not a sufficiently good machineability. It also requires a powder metallurgy manufacturing and may therefore be said to be too exclusive and too qualified to be defined as a volume product for fixture materials.

DISCLOSURE OF THE INVENTION

It is the purpose of the invention to provide a steel material having an optimal combination of features for the above-mentioned fields of use. The steel material thus in the first place shall satisfy some or all of the following criteria:

- Excellent corrosion resistance, particularly good resistance against pitting when the material is used for fixtures or fixture details submerged in a bath in an eroding machine, such as a spark machining machine, as well as when the material is used for moulds for plastic moulding and for holders for mould tools for plastic moulding.
- Sufficient wear resistance for the said applications, e.g. a wear resistance which is comparable with that of steels of type RIGOR®.
- A hardness of 52-64 HRC, preferably 58-63 HRC or about 59-62 HRC in the hardened and tempered condition.
- Good manufacturing economy.

Other features which are desirable are:

- Good machineability
- Good dimension stability
- High fatigue resistance
- Good ductility/toughness
- High pressure strength in order to resist plastic deformation when used for plastic moulding moulds, fixtures and fixture details
- Versatility, which makes the steel possible to employ for a plurality of different fields of use.

The above mentioned primary objectives and also any or several of the other desirable features can be achieved therein that the invention is characterised by what is stated in the appending patent claims.

As far as the individual alloy elements are concerned, the following applies.

Carbon shall be present to a sufficient amount in the steel in order to be able to form, together with nitrogen and carbide and nitride formers existing in the steel, in the hardened and tempered condition of the steel, 3-12 vol-% carbides, nitrides and/or carbonitrides, including 2-10 vol-% M_7C_3-carbides, nitrides and/or carbonitrides, where M mainly is chromium, and 0.1-2.0 vol-%, preferably at least 0.3 vol% MC-carbides, nitrides and/or carbonitrides, where M mainly is vanadium, in a matrix which essentially consists of tempered martensite. The total amount of carbon in the steel, i.e. the carbon that is dissolved in a matrix of the steel and the carbon which is bound in carbides shall be at least 0.5 %, preferably at least 0.6 %, suitably at least 0.7 %, while the maximal content of carbon may amount to 1.3 %, preferably max. 1.14 %, suitably max. 1.0 %. The most preferred carbon range depends on the specific application of the steel, which in the first place is fixtures and fixture details and moulds for plastic moulding and holders for mould assemblies, respectively, as above mentioned, and the specific application in turn, according to an aspect of the invention, should have great importance when the most suitable chromium content is selected. Therefore, as far as the most preferred carbon content range is concerned, reference is made to the below discussion in connection with the chromium content of the steel.

According to a preferred embodiment of the invention, **nitrogen** exists as an unavoidable element because the manufacturing of the steel comprises spray forming using nitrogen as an atomising gas. According to a first preferred embodiment of the invention, the steel thus contains max. 0.15 N, typically 0.06-0.12 % N. It is also conceivable, according to an embodiment of the invention, to increase the nitrogen content to at least 0.3 %, preferably at least 0.8 %, by means of any known technique, i.e. by pressurising the steel melt in a nitrogen gas atmosphere, addition of chromium nitride to the melt under advanced pressure, or by any other mode. When nitrogen exists in the mentioned amounts, nitrogen is not a harmful ingredient. To the contrary, nitrogen may have a favourable effect by forming vanadium- and chromium-carbonitrides together with carbon. Therefore, also a minor fraction of carbonitrides may be included in the above mentioned volume contents of MC- and M_7C_3-carbides. Also powder metallurgy manufacturing of the steel in principle is conceivable, which could include gas atomising of a metal melt using nitrogen as an atomising gas, but that technique also requires hot isostatic compaction and is expensive, which makes it difficult or impossible to satisfy the requirement as far as a good manufacturing economy is concerned.

Silicon exists as a residue from the manufacturing of the steel and exists in an amount of at least 0.1 %. Silicon increases the carbon activity in the steel and can therefore contribute to the provision of an adequate hardness of the steel without creating embrittlement problems. Preferably, the steel therefore contains at least 0.15 % and suitably at least 0.3 % Si. Silicon, however, is a strong ferrite former and must therefore not exist in amounts exceeding 1.5 %. Preferably, the steel does not contain more than 1.0 %, preferably max. 0.8 % Si. The nominal silicon content is about 0.5 %.

Manganese is also present as a residual from the manufacturing of the steel and binds the amounts of sulphur which may exist in low contents in the steel, by the formation of manganese sulphide. Manganese therefore exists in an amount of at least 0.1 %. Manganese also promotes the hardenability, which is favourable. Manganese, however, must not exist in amounts above 1.5 % in order to avoid embrittlement problems. Preferably, the steel does not contain more than max. 1.0 %, preferably max. 0.6 % Mn. Most conveniently, the content of manganese is in the range 0.2-0.5 % Mn. The nominal manganese content is 0.30 %.

Chromium shall exist in an amount of at least 14 %, preferably in an amount of at least 14.5 %, suitably at least 15.0 % in order to afford the steel a desirable corrosion resistance. Chromium also is an important carbide- and nitride former and forms, together with carbon and existing nitrogen M7C3-carbides, -nitrides, and/or

-carbonitrides, which together with the MC-carbides, -nitrides, and/or –carbonitrides, contribute to the desired wear resistance. Chromium, however, is a strong ferrite former. In order to avoid ferrite after hardening from 1000-1150°C, the chromium content must not exceed 19 %, preferably not exceed max. 18.0 %, suitably max. 17.0 %.

As mentioned in the foregoing, the most preferred carbon- and chromium contents are related to the specific use of the steel. In the case when the steel shall be used for fixtures or fixture detail for workpieces which are machined in eroding machines, initial experiments indicated that the most preferred range of carbon content is 14-15 % Cr and that the most preferred range of the carbon content is 0.55-0.75 % C. The nominal content for that application therefore should be 14.5 % Cr, and 0.65 % C, respectively. For the second main application, mould steels for mould tools for moulding plastic materials and holders for such tools, the initial experiments indicated that the most preferred content ranges should be 16-17 % Cr and 0.8-1.0 % C, respectively. The nominal contents in that case should be 16.5 % Cr and 0.9 % C, respectively. Later experiments, however, have modified the most preferred ranges for said application to 14.8-16.0 % Cr, nominally 15.6 % Cr, and 0.80-0.90 % C, nominally 0.85 % C, respectively, at the same time as the nitrogen content should rest in the range 0.06-0.12 % N, nominally at about 0.09 % N.

Nickel is an optional element and may as such optionally exist as an austenite stabilising element in an amount of max. 2.0 %, preferably max. 1.0 %, suitably max. 0.7 %, in order to balance the high contents in the steel of chromium and molybdenum, which are ferrite forming elements. Preferably, however, the steel according to the invention does not contain any intentionally added amount of nickel. Nickel, however, may be tolerated as an unavoidable impurity, which as such may be as high as about 0.3 or 0.4 %.

Cobalt also is an optional element and may as such optionally exist in an amount of max. 2.0 %, preferably max. 0.7 %, in order to further improve the tempering resistance. Normally, however, no addition of cobalt is required in order to achieve the desired properties of the steel. Suitably, the steel therefore does not contain any intentionally added cobalt, which however may exist as an impurity in an amount up to 0.1 %, emanating from used raw materials for the manufacturing of the steel.

Molybdenum shall exist in an amount of at least 1.0 % in order to afford the steel a desired corrosion resistance, particularly a good pitting corrosion resistance, as well as a good hardenability. Molybdenum also is a valuable carbide former and should therefore exist in the steel in an amount exceeding said content of at least 1.0 %, which is required from reasons which have to do with corrosion resistance. In principle, however, molybdenum in its capacity as carbide former may be replaced by twice the amount of **tungsten.** If tungsten exists in the steel, the content of the steel of Mo + W/2 shall amount to at least 1.5 %, preferably at least 1.8 % and suitably at least 2.0 % in order on one hand to afford the steel a desired corrosion resistance, particularly a good pitting corrosion resistance, and on the other hand to form, together with carbon, a desired amount of carbides. However, molybdenum and tungsten are strong ferrite formers. Therefore the steel must not contain more than max. 4.0 % (Mo + W/2), preferably max. 3.0 % (Mo + W/2), suitably max. 2.8 % (Mo + W/2). A suitable range is 2.1-2.6 % (Mo + W/2). The nominal content of Mo + W/2 is 2.3 %.

Tungsten, however, does not provide the same improvements of the corrosion resistance and of the hardenability as molybdenum does. Besides, because of the atomic weight conditions, twice as much tungsten is required in comparison with molybdenum, which is a drawback. The content of tungsten in the steel therefore is limited to max. 1.0 %W. Another drawback with tungsten is that the taking care of any produced scrap is made difficult, i.e. the utilisation of rest products (scrap) which are produced in connection with the manufacturing and working of the steel to a final product. Therefore, according to a preferred embodiment of the invention, the steel should not contain any intentionally added amount of tungsten, but can be tolerated as an unavoidable impurity in an amount of max. 0.4 %, preferably max. 0.3 %, in the form a residual element emanating from the raw materials used for the manufacturing of the steel.

Vanadium shall exist in the steel in an amount of at least 0.1 %, normally in an amount of 0.5-3.0 %, in order, together with carbon and existing nitrogen, to form said MC-carbides, -nitrides and/or –carbonitrides in the martensitic matrix of the steel in the hardened and tempered condition of the steel. Preferably, the steel contains at least 0.6 % V, suitably at least 0.7 % V and max. 2.0, suitably max. 1.5 % V. Most preferably, the vanadium content should rest in the range 0.8-1.2 % V. A nominal content of vanadium is 1.0 % V.

Niobium is also an element which can form MC-carbides, -nitrides and/or – carbonitrides, but for this purpose twice as much niobium is required in comparison with vanadium, which is a drawback. Further, niobium causes the carbides, nitrides, and/or carbonitrides to get a more edgy shape and they will also be larger than pure vanadium carbides, -nitrides, and/or –carbonitrides which may initiate ruptures or chippings, which reduces the toughness of the material. This may be particularly harmful in the steel of the invention, the composition of which is optimised for the purpose of, as far as the mechanical features of the steel are concerned, providing a good wear resistance in combination with high hardness and good ductility. The steel therefore must not contain any intentionally added amount of niobium, which means that niobium may exist only as an unavoidable impurity in an amount of < 0.1 % Nb, preferably max. 0.05 % Nb, in the form of a residual element emanating from used raw materials in connection with the manufacturing of the steel.

In addition to the said alloy elements, the steel need not and should not, contain any further alloy elements in significant amounts. Some elements are explicitly undesired because they have an influence on the features of the steel in an undesired way. This is true, e.g. as far as **phosphorus** is concerned, which should be kept at as low level as possible, preferably at max. 0.05 %, most conveniently at max. 0.03 %, in order not to influence on the toughness of the steel in an unfavourable way. Also **sulphur,** in most respects is an undesired element, but its unfavourable impact in the first place on the toughness, essentially can be neutralised by means of manganese, which forms essentially harmless manganese sulphides, allowing it to be tolerated in a maximal amount of 0.2 % in order to improve the machineability of the steel. Preferably, however, the steel normally does not contain more than max. 0.1 %, preferably max. 0.05 %, and most conveniently max. 0.025 % S.

Some preferred compositions of the steel according to the invention are given in Table 2 below. Steel A is conceived in a first place to be used specifically for fixtures and fixture parts according to what is mentioned above, while steels B and C are conceived in a first place to be used for mould tools for moulding articles of plastic materials and for holders for mould tools for moulding plastic materials.

Table 2

Chemical composition, weight-%, balance Fe and other impurities than those given in the table

	C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*W*	*V*	*Ni*	*Cu*	*N*
A	0.65	0.5	0.3	<.05	<.025	14.5	2.3	<.3	1.0	<.3	<.25	0.1
B	0.90	0.5	0.3	<.05	<.025	16.5	2.3	<.3	1.0	<.3	<.25	0.1
C	0.85	0.5	0.3	<.025	<.025	15.6	2.3	<.3	1.0	<.3	<.25	0.09

In the above table, the given contents of phosphorus, sulphur, tungsten, nickel, and copper are the maximally allowed contents of said elements in the form of impurities in the preferred compositions.

The manufacturing of the steel material comprises, as above mentioned, preferably spray forming of a steel melt to form an ingot, which is hot worked to desired dimensions. The delivery condition of the steel is the soft annealed condition, in which the steel material according to the invention has a hardness of 200-280 HB (Brinell-hardness), preferably 210-250 HB. After machining to desired shape, e.g. to the shape of fixtures or fixture details according to what has been mentioned above, or to the shape of moulds intended to be used for moulding, extrusion or injection moulding of plastic products, respectively, or to the shape of holders or construction details, the product is heat treated by austenitising at a temperature between 1000 and 1150°C, preferably at a temperature between 1080 and 1120°C. A suitable holding time at the austenitising temperature is 10-30 minutes. From the said austenitising temperature the steel is cooled to about ambient temperature or possibly lower, e.g. by sub-zero cooling down to -196°C in order to eliminate retained austenite. In order to achieve a desired secondary hardening, the product is tempered at least once, preferably twice, at a temperature between 150 and 650°C, preferably at a temperature between 200 and 250°C (low temperature tempering) or between 400 and 600°C (high temperature tempering). The product is cooled after each such tempering treatment. The holding time at the tempering temperature may be 1- 10 hours.

Although the steel material according to the invention has been developed in the first place to be used for specific products as mentioned above, it should be understood that the steel may be employed also within other fields, where the features of the steel material are advantageous, e.g. for wear parts and other construction elements than fixtures and holders of the mentioned kind.

Further characteristic features and aspects of the invention will be apparent from the appending patent claims and from the following description of performed experiments.

BRIEF DESCRIPTION OF DRAWINGS

In the following description of performed experiments, reference will be made to the accompanying drawings, in which

Fig. 1 shows the microstructure of a first steel according to the invention in 100x magnification,

Fig. 2 shows the same steel in 500x magnification,

Fig. 3 shows the microstructure of a reference steel in the same magnification as Fig. 2, and

Fig. 4 shows the microstructure of a second steel according to the invention in 100x magnification.

EXAMPLES

An ingot, size ∅ 500 mm, weight: 2408 kg, was made from a steel melt in a first series of experiments by spray forming. The composition of the ingot according to a control analysis is given in Table 3, steel No. 1. A steel melt having a lower chromium content and an unintentionally slightly higher carbon content was made in a second series of experiments, and from this melt there was made an ingot by spray forming, size ∅ 465 mm, weight: 2813 kg, steel No. 9 in Table 3. In the same table, also the compositions of studied reference materials are given.

Table 3
Chemical composition of studied steels, weight-%, balance Fe and other impurities than those given in the table in unavoidable contents

Steel No	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*W*	*V*	*Ni*	*Cu*	*N*
1	0.88	0.63	0.30	0.026	0.010	17.1	2.32	0.16	0.96	0.20	0.10	0.11
2	1.04	0.27	0.74	0.018	0.016	17.3	0.62	n.a.	0.05	0.09	0.03	0.02
3	0.89	0.52	0.54	0.026	0.001	17.4	0.97	n.a.	0.10	n.a.	n.a.	n.a.
4	1.7	0.8	0.3			18	1.0		3.0			0.12
5	1.3	0.3	0.4			18	1.0		1.0			0.06
6	2.2	0.15	0.3			18	2.4		0.9			0.05
7	1.6	0.4	0.5			16	0.8		0.5	0.4		0.11
8	2.7	0.3	0.3			17	2.1		3.4		Co 1.8	0.05
9	0.90	0.41	0.27	0.023	0.012	15.6	2.40	n.a.	1.26	0.19	Cu 0.11	0.05

Steels No's. 2-8 are commercially available reference materials. Steel No. 4 is a steel according to information from literature. In Table 3, the analysed compositions of steels No's. 1-3 and 9 and the nominal compositions of steels No's. 4-8, respectively, are given. The denomination *n.a.* indicates that the contents of the elements in question lie on an impurity level, but that they have not been analysed. Steels No's. 1 and 9 were, as mentioned, made by spray forming; steels No's. 2 and 3 in a conventional way, and the other steels powder metallurgically.

The ingot of steel No. 1 was forged to the shape of bars of size 200x80 mm and size ∅ 125 mm, while the ingot of steel No. 9 was forged to the shape of a bar of size 280x135 mm. The other steels were forged to the shape of bars with sizes in the range ∅ 30- ∅ 125 mm. The materials were examined with reference to:

- Microstructure
- Hardness
- Ductility
- Wear resistance
- Corrosion resistance

Microstructure

The microstructures in the centre of the bars of steels No. 1 and No. 9 were studied in the hardened and tempered condition, T_A = 1120 °C/30 min. + 525 °C/2x2h, and were compared with the corresponding in the hardened and tempered condition of one of the reference materials, steel No. 2. Fig. 1 shows the microstructure of steel No. 1 in 100x magnification; a comparatively even structure, which contained about 10 vol-% of comparatively evenly distributed carbides, nitrides and/or carbonitrides, mainly chromium carbides, -nitrides and/or –carbonitrides, M_7C_3 (about 9 vol-%), and a smaller fraction of vanadium carbides, -nitrides, and/or –carbonitrides. Fig. 2, which shows the steel at a larger scale, however, shows that the structure contains regions having a higher carbide content, partly in the form of aggregates. Steel No. 9 had a more even microstructure with a desired carbide content and without aggregations, Fig. 4. The reference material, which is shown in Fig. 2, had a substantially more coarse carbide network which impairs the toughness/ductility.

Hardness

The hardness was measured in the soft annealed condition (Brinell-hardness, HB), in the hardened and tempered condition. The austenitising temperature varied between 1030 and 1120°C. All steels except steel No. 3 were high temperature tempered at 500 or 525°C. Steel No. 3 was tempered at 150°C because of the low tempering resistance of that steel which made higher temperature impossible. The values obtained from the performed experiments and from information in the literature are given in Table 5 below. In this table, also the relative values of the pressure strength which are proportional to the hardness, are given. In this relative comparison between the examined steels, the best value (excellent) has been given the value 5 and the lowest value (poor in the comparison between the steels) has been given the value 1. Reference is also made to the information below the table.

Ductility

Impact tests were carried out in the longitudinal direction with un-notched test specimens at room temperature after the above mentioned heat treatments. For steels

No. 1, No. 4 and No. 9 there were measured an absorbed impact energy of 26 J, 30 J and 17 J, respectively. These results have been given the values 2, 3 and 2 in the relative comparison between the examined steels. It is true that steel No. 9 has achieved a lower ductility than steel No. 1, but it can still be considered as acceptable for the intended use of steel. The other comparison values of the ductility given in Table 5 are estimates based on the microstructures and carbide contents of the examined steels.

Wear resistance

Abrasive wear tests were performed in the longitudinal direction of the material with SiO_2-paper according to the pin-against-pin method after the same heat treatments as above. For steel No. 1 there was measured a worn off quantity of material amounting to 8.9 mg/min. For steels No's. 2 and 4 the corresponding values were 11.0 mg/min and 14.0 mg/min, respectively, and for steel No. 9 22.5 mg/min. These results have been given the values 4, 1, 3 and 2, respectively in Table 5. Other values in Table 5 are estimates, based on the microstructures and carbide contents of the examined steels.

Corrosion resistance

The corrosion resistance of steels No's. 1, 2, 4-6, 8 and 9 was measured via generation of polarisation graphs in 0.05 M H_2SO_4 in the high temperature tempered, 525°, condition of the steels. The results are given in Table 4, which indicates measured corrosion current, i_{cr}, at the active peak of the polarisation graph. The smaller the current, the better the corrosion resistance.

Table 4

Measured polarisation current, i_{cr}, via generation of polarisation graphs.

Steel No	*1*	*2*	*4*	*5*	*6*	*8*	*9*
I_{cr}	2,5	53	12	15- 40	60	75	3.0

In Table 5, also the estimated, relative values of the corrosion resistance of steels No's. 3 and 4 are given, based on the content of carbon, chromium, vanadium, and molybdenum in the steels.

In Table 5, also the relative values of homogeneity, machineability, heat treatment response and production economy are given. The relative values of the homogeneity were calculated by microstructure studies. The machineability of a steel generally depends on the hardness of the steel in the soft annealed condition, carbide content, carbide size, and carbide type (carbide hardness). The relative machineability values were estimated based on the knowledge which was achieved by studies of these parameters. Heat response means such features as the capability of the steels to be hardened to the desired hardness from moderately high austenitising temperatures, the need of possible sub-zero cooling, as well as the level of the necessary temperature, which conveniently should be at least 250°C but not higher than 550°C, features which have been used as a basis for the relative evaluation of the heat treatment response given in Table 5. When estimating the production economy, not only the manufacturing of ingots, slabs, or blooms have been considered but the total costs included from start to finish. It should be beyond dispute that powder metallurgy manufacturing is most expensive, which therefore has been afforded the relative value 1. It has also been assessed that the total costs for the conventional manufacturing of the qualified steels in question are higher than the total costs for a manufacturing which includes spray forming of ingots. Conventional manufacturing therefore has been afforded value 2, while spray forming based manufacturing has the relative value 3.

Table 5

Hardnesses and relative comparison of the features of examined steels.

Steel No	*Soft annealed hardness (HB)*	*Hardness after hardening and tempering (HRC)*	*Pressure strength*	*Ductility*	*Abrasive wear resistance*	*Corrosion resistance*	*Homogeneity*	*Machineability*	*Heat treatment response*	*Production economy*	*Total*
1	230	60	3	2	4	5	4	4	3	3	28
2	240	57	1	1	4	2	1	4	2	2	17
3	220	57*	1	1	1	4*	1	4	1	2	15
4	240	60	3	3	3	3	5	3	4	1	25
5	270	58	2	5	2	3	5	4	4	1	26
6	255	61	3	4	3	2	5	4	4	1	26
7	240	<60	2	4	2	2	5	4	4	1	24
8	270	66	5	2	5	1	5	1	5	1	25
9	230	62	4	2	2	5	4	5	4	3	29

* Can not satisfy requirements on high temperature tempering

In Table 5 the following grades for the features of the steels mean:
5 = excellent for intended applications
4 = very good for intended applications
3 = good for intended applications
2 = approved for intended applications
1 = poor for intended applications

In the comparison between the steels, steels No. 1 and No. 9 obtained the highest total value of 28 and 29, respectively, and no feature has been estimated as poor, which indicates that these steels have a good combination of features. Their combination of features, however, is not identical, which indicates that there is a possibility to select materials within the scope of the invention, having features which are adapted to different applications.

PATENT CLAIMS

1. Steel material with good corrosion resistance, c h a r a c t e r i s e d in that it has the following chemical composition in weight-%:

0.7-1.6 (C + N), of which max. 1.0 %, preferably max. 0.3 % is nitrogen
0.1-2.0 Si
0.1-1,5 Mn
14-19 Cr
from traces to max. 2.0 Ni
from traces to max. 2.0 Co
1.5-4.0 (Mo + W/2), however at least 1.0 Mo and max. 1.0 W
0.5-3.0 V
< 0.1 Nb
from traces to max. 0.2 S
balance iron and impurities in normal amounts.

2. Steel material according to claim 1, c h a r a c t e r i s e d in that it after hardening and tempering has a hardness of 52-64 HRC and a microstructure which contains 5-12 vol-% carbides, nitrides and/or carbonitrides, including 4-10 vol-% M_7C_3-carbides, -nitrides, and/or –carbonitrides, where M mainly is chromium and 0.1-3.0 vol-% MC-carbides, -nitrides, and/or –carbonitrides, where M mainly is vanadium, in a matrix which essentially consists of tempered martensite.

3. Steel material according to claim 1 or 2, c h a r a c t e r i s e d in that it contains 0.16-1.14 C, preferably 0.7-1.0 C.

4. Steel material according to any of claims 1-3, c h a r a c t e r i s e d in that it contains 0.15-1.0, preferably 0.3-1.0, suitably 0.3-0.8 Si.

5. Steel material according to any of claims 1-4, c h a r a c t e r i s e d in that it contains max. 1.0, preferably max. 0.6, suitably 0.2-0.5 Mn.

6. Steel material according to any of claims 1-5, c h a r a c t e r i s e d in that it contains 14-18 Cr.

7. Steel material according to any of claims 1-6, c h a r a c t e r i s e d in that it contains 14-15 Cr and 0.55-0.75 C.

8. Steel material according to any of claims 1-6, c h a r a c t e r i s e d in that it contains16-17 Cr and 0.8-1.0 C.

9. Steel material according to claim 8, c h a r a c t e r i s e d in that it contains 14.8-16.0 Cr and 0.80-0.90 C.

10. Steel material according to any of claims 1-9, c h a r a c t e r i s e d in that it contains 1.8-3.0, preferably 2.0-2.8, suitably 2.1-2.6 (Mo + W/2).

11. Steel material according to any of claims 1-10, c h a r a c t e r i s e d in that it contains max. 0.4 W.

12. Steel material according to any of claims 1-11, c h a r a c t e r i s e d in that it contains 0.6-2.0, preferably 0.7-1.5, suitably 0.8-1.2 V.

13. Steel material according to any of claims 1-12, c h a r a c t e r i s e d in that it contains max. 0.05 Nb.

14. Steel material according to any of claims 1-13, c h a r a c t e r i s e d in that it contains max. 0.15 N, preferably 0.04-0.12 N.

15. Steel material according to any of claims 1-14, c h a r a c t e r i s e d in that it contains max. 0.1 S.

16. Steel material according to claim 15, c h a r a c t e r i s e d in that it contains max. 0.05, preferably max. 0.025 S.

17. Steel material according to any of claims 1-16, c h a r a c t e r i s e d in that it contains max. 0.4, preferably max. 0.3 Ni.

18. Steel material according to any of claims 1-17, c h a r a c t e r i s e d in that it contains max. 0.7 Co, suitably max. 0.1 Co.

19. Steel material according to any of claims 1-18, c h a r a c t e r i s e d in that it after hardening and tempering contains at least 0.3 vol-% MC-carbides, -nitrides and/or –carbonitrides.

20. Steel material according to any of claims 2-19, c h a r a c t e r i s e d in that it has been hardened by austenitising at 1000-1150°C, preferably at 1080-1120°C, has been cooled and subsequently tempered at 150-650°C, preferably at a temperature between 200 and 250°C or between 400 and 600°C.

21. Steel material according to any of claims 2 and 20, c h a r a c t e r i s e d in that it has a hardness of 58-63 HRC, preferably 59-62 HRC.

22. Steel material according to claim 1 or any of claims 3-18, c h a r a c t e r i s e d in that it is soft annealed and that it in the soft annealed condition has a hardness of 200-300 HB (Brinell-hardness).

23. Use of a steel material according to claim 22 for manufacturing of construction elements intended, after hardening and tempering, to be used in corrosive and abrasively wearing environments.

24. Use according to claim 23 of a steel according to claim 7 for fixtures or fixture details for workpieces which are machined in a water bath in eroding machines, comprising spark machining machines.

25. Use according to claim 23 of a steel according to any of the claims 8 and 9 for manufacturing of mould tools for moulding plastic materials.

26. Use according to claim 23 of a steel according to any of claims 8 and 9 for manufacturing of holders for mould tools for moulding plastic materials.

27. Fixture or fixture detail for metallic workpieces intended to be machined in a water bath in eroding machines, comprising spark machining machines, c h a r a c t e r i s e d in that said fixture or fixture detail consists of a steel material according to claim 7 and any of claims 20-21.

28. Mould tool for moulding plastic materials, c h a r a c t e r i s e d in that it consists of a steel material according to any of claims 8 and 9 and any of claims 20-21.

29. Holder for mould tools for moulding plastic materials, c h a r a c t e r i s e d in that it consists of a steel material according to any of claims 8 and 9 and any of claims 20-21.

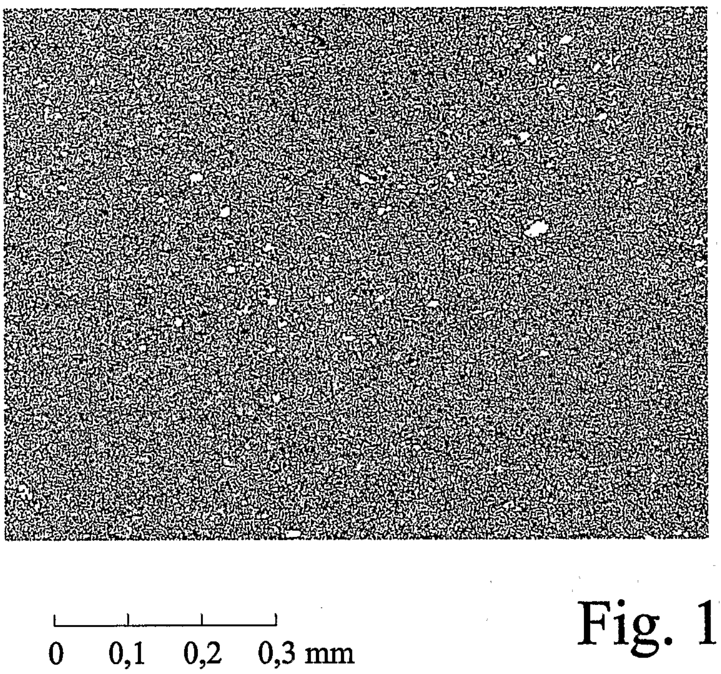


Fig. 1

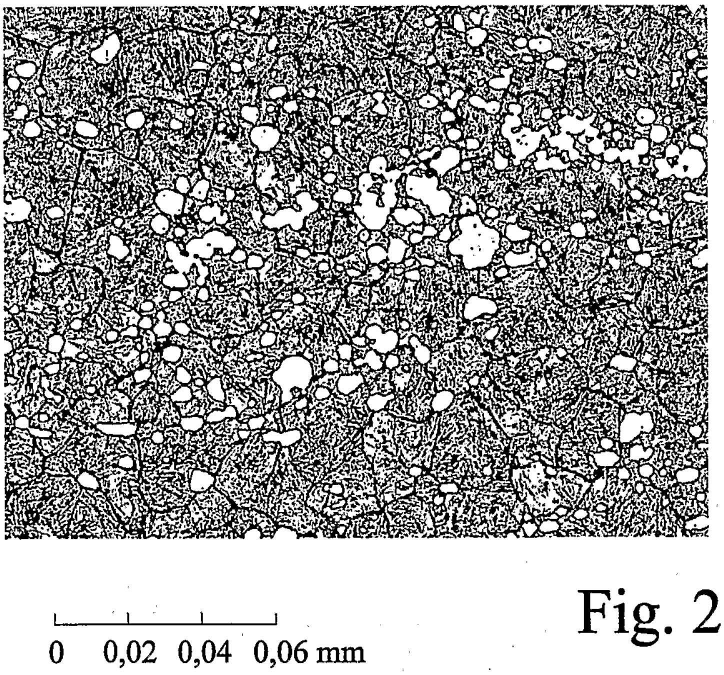
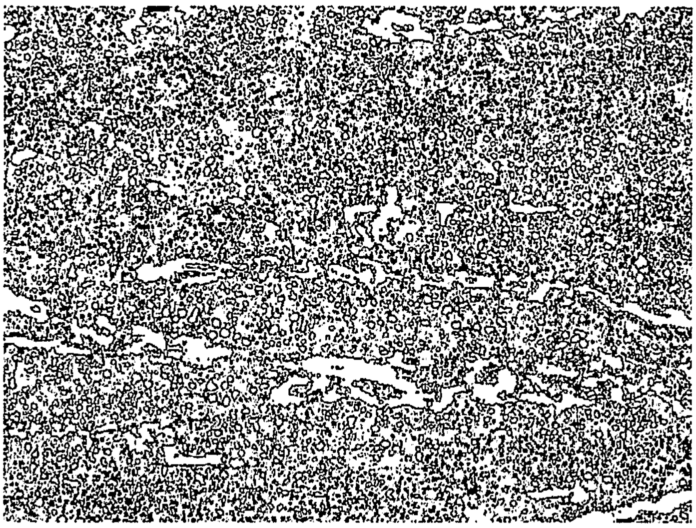
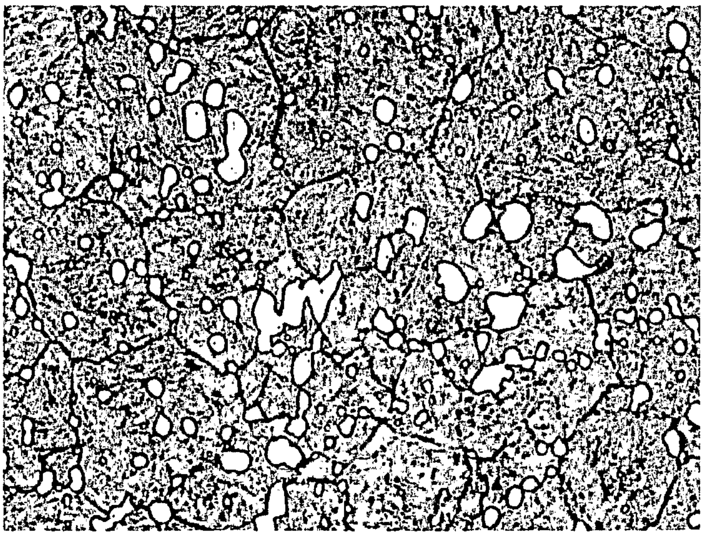


Fig. 2



0 0,02 0,04 0,06 mm

Fig. 3



0 0,1 0,2 0,3 mm

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/00224

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C22C 38/24, C22C 38/26
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)

IPC7: C22C

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	SE 518678 C2 (UDDEHOLM TOOLING AB), 5 November 2002 (05.11.02), abstract --	1-29
A	SE 516934 C2 (UDDEHOLM TOOLING AB), 26 March 2002 (26.03.02), abstract --	1-29
A	SE 514226 C2 (UDDEHOLM TOOLING AB), 22 January 2001 (22.01.01), abstract --	1-28
A	EP 0630984 A1 (HITACHI METALS, LTD.), 28 December 1994 (28.12.94), abstract, table 1, page 6 -- --------	1-25

☐ Further documents are listed in the continuation of Box C.   ☒ 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

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"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
25 April 2003	15 -05- 2003

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/00224

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
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				EP	1281239	A	05/02/03
				SE	0100737	A	07/09/02
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				CN	1378605	T	06/11/02
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				SE	9903580	A	06/04/01
				WO	0125499	A	12/04/01
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				CN	1348507	T	08/05/02
				CZ	20013818	A	16/10/02
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				JP	2002543290	T	17/12/02
				SE	9901554	A	31/10/00
				WO	0066801	A	09/11/00
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				US	5651842	A	29/07/97