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(54) **HOT WORK TOOL STEEL**

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(57) **ABSTRACT**

A matrix type hot work tool steel, in use, has an improved abrasive wear resistance in demanding applications. The steel is suited for applications in hot forging, die casting or hot extrusion. It is also suitable for press hardening, in particular for press hardening of Advance High Strength Steel (AHSS) and has a high hot wear resistance. The hot work tool steel has a composition including, in weight % (wt. %): C 0.65-0.85; Si 0.03-0.8; Mn 0.1-1.8; Cr 4.5-6.6; Mo 1.8-3.5; V 1.3-2.3; Al≤0.1; N≤0.12; Ni≤1; W≤0.5; Co≤2; Cu≤1; Nb≤0.1; Ti≤0.05; Zr≤0.05; Ta≤0.05; B≤0.01; Ca≤0.01; Mg≤0.01; REM≤0.2; and balance Fe and impurities.

HOT WORK TOOL STEEL

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This is a National Stage Entry into the United States Patent and Trademark Office from International Patent Application No. PCT/SE2021/050562, filed on Jun. 11, 2021, which relies on and claims priority to Swedish Patent Application No. SE 2050705-9, filed on Jun. 12, 2020, the entire contents of both of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention relates to a matrix type hot work tool steel.

BACKGROUND OF THE INVENTION

[0003] Vanadium alloyed matrix tool steels have been on the market for decades and attained a considerable interest because of the fact, that they combine a high wear resistance with an excellent dimensional stability as well as a good toughness. A matrix tool steel is a steel which does not contain any primary carbides or only an extremely low content of small primary carbides and which has a matrix consisting of tempered martensite.

[0004] U.S. Pat, No. 3,117,863 is probably the first patent directed to a matrix steel. The basic idea in the U.S. Pat. No. 3,117,863 was to create a steel having the composition of the matrix of a known high speed steel (HSS). The structure of this type of steel was developed in order to improve the toughness and the fatigue strength of the steel by refining the microstructure.

[0005] WO 03/106727 A1 of the present applicant discloses a hot work matrix steel having an excellent toughness and ductility as well as a good hot strength and wear resistance. The material is known in the market under the name UNIMAX®.

[0006] EP1 300 482 A1 discloses another matrix steel having a high hardness and wear resistance in combination with a very high toughness and is therefore particularly suited for tools that are stressed at elevated temperatures such as tools for hot and warm forming. This steel is known in the market under the name W360 ISOBLOC ® and has a nominal composition of 0.50% C, 0.20% Si, 0.25% Mn, 4.5% Cr, 3.00% Mo and 0.60% V.

[0007] Matrix steels are normally produced by vacuum arc re-melting (VAR) or electro slag re-melting (ESR) in order to improve the chemical homogeneity and the micro-cleanliness. Further examples of hot work tool matrix steels are given in JP2003226939A, EP3050986A1, US2004/0187972 Al and US2005/0161125A1.

[0008] Modern matrix steels are being developed with the aid of software for the calculation of phase diagrams and equilibrium phase balances as a function of temperature. Themo-Calc® (TC) is a user-friendly and frequently used software for this purpose in order to find out compositions resulting in a large austenitic single phase area at soaking temperatures, because of the fact that the dissolution of possibly existing MC carbides formed by segregation during casting is of prima importance.

[0009] Hot work matrix steels have a wide range of applications such as die casting and forging. The steels are generally produced by conventional metallurgy followed by Electro Slag Remelting (ESR). However, a drawback of the known steels is the limited wear resistance. In particular, the abrasive wear resistance may limit the life of the known steels in demanding hot work operations such as hot forging, extrusion and press hardening. These tools are expensive and often need to be welded for repair. Accordingly, the weldability is of importance. However, the weldability of tool steel with high carbon contents is usually considered to be poor and requiring special measures such as high preheating temperatures. It would therefore be useful if the steel could be welded with standard welding consumables, preferable without preheating.

SUMMARY OF THE INVENTION

[0010] The object of the present invention is to provide a matrix type hot work tool steel, in use having an improved abrasive wear resistance in demanding applications. In particular, the steel should be suited for applications in hot forging, die casting or hot extrusion. It should also be suitable for press hardening, in particular for press hardening of Advanced High Strength Steel (AHSS). For these applications, the hot wear resistance needs to be high.

[0011] The tempering resistance is an important property, because in use the steel may be subjected to high temperatures for long times. Accordingly, it is preferred that the steel not only has a high hardness after hardening but also that the hardness decrease is small. Further important properties include high ductility and toughness, which implies that the steel should have a high cleanliness with respect to microslag, a complete freedom from grain boundary carbides as well as a uniform hardness for thicknesses up to 300 mm.

[0012] It should be possible to adjust the hardness over a large interval in order to optimize the steel for the intended use. It should also be possible to obtain a high tensile strength and yield strength in combination with a sufficient ductility.

[0013] The foregoing objects, as well as additional advantages are achieved to a significant measure by providing a hot work tool steel having a composition as set out in the claims.

[0014] The invention is defined in the claims.

DETAILED DESCRIPTION OF EMBODIMENT(S) OF THE INVENTION

[0015] 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 for the chemical composition of the steel are given in weight % (wt. %) throughout the description. The amount of the hard phases is given in volume % (vol. %). Upper and lower limits of the individual elements can be combined freely within the limits set out in the claims. The arithmetic precision of the numerical values can be increased by one or two digits. Hence, a value given as e.g. 0.1% can also be expressed as 0.10% or 0.100%.

Carbon (0.5-0.9%)

[0016] is to be present in a minimum content of 0.5%, preferably at least 0.55, 0.60, 0.66, 0.67, or 0.68%. The upper limit for carbon is 0.9% and may be set to 0.85, 0.80, 0.75, 0.74, 0.73, or 0.72%. Preferred ranges are 0.6-0.8% and 0.65-0.75%. 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 (0.03-0.8%)

[0017] 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. Silicon is also prone to interfacial segregation, which may result in decreased toughness and thermal fatigue resistance. Si is therefore limited to 0.8%. The upper limit may be 0.7, 0.6, 0.5, 0.40, 0.35, 0.30, 0.28, 0.27, 0.26, 0.25, 0.24, 0.23 and 0.22%. The lower limit may be 0.05, 0.10, 0.11, 0.12, 0.13, 0.14 or 0.15%.

Manganese (0.1-1.8%)

[0018] 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 0.1%, preferably at least 0.2, 0.3, 0.35 or 0.4%. At higher sulphur contents manganese prevents red brittleness in the steel. Mn may also cause undesirable micro-segregation resulting in a banded structure. The steel shall contain maximum 1.8%, preferably maximum 0.8, 0.75, 0.7, 0.6, 0.55 or 0.5%.

Chromium (4.0-6.6%)

[0019] Chromium is to be present in a content of at least 4% in order to provide a good hardenability in larger cross sections during heat treatment. If the chromium content is too high, this may lead to the formation of high-temperature ferrite, which reduces the hot-workability. The lower limit may be 4.5, 4.6, 4.7, 4.8 or 4.9%. The upper limit may be 6.0, 5.9, 5.8, 5.7, 5.6, 5.5, 5.4, 5.3, 5.2 or 5.1%.

Molybdenum (1.8-3.5%)

[0020] Mo is known to have a very favourable effect on the hardenability. Molybdenum is essential for attaining a good secondary hardening response. The minimum content is 1.8%, and may be set to 1.9, 2.0, 2.1, 2.15 or 2.2%. Molybdenum is a strong carbide forming element and also a strong ferrite former. The maximum content of molybdenum is therefore 3.5%. Mo may be limited to 2.9, 2.7, 2.6, 2.5, 2.4 or 2.3%.

Tungsten (W≤0.5%)

[0021] Tungsten is not an essential element in the present invention. The upper limit is 0.5% may be set to 0.4, 0.3, 0.2 or 0.1%.

Nickel (≤1%)

[0022] Nickel is not an essential element in the present invention. The upper limit may be set to 0.5, 0.4, 0.3 or 0.25%.

Vanadium (1.3-2.3%)

[0023] Vanadium forms evenly distributed primary precipitated carbides and carbonitrides of the type VC and V(C,N) in the matrix of the steel. These carbides and carbonitrides may also be denoted MX, wherein M is mainly V but Cr and Mo may be present and X is one or more of C, N and B. However, in the following only VC will be used with the same meaning as MX. Vanadium is used in order to form a controlled amount of relatively large VC and shall therefore be present in an amount of 1.3-2.3%. The lower limit may be set to 1.35, 1.4, 1.45, 1.5 or 1.55%. The upper limit may be set to 2.2, 2.1, 2.0, 1.9, 1.8, 1.7 or 1.65%.

Aluminium (≤0.1%)

[0024] Aluminium may be used for deoxidation in combination with Si and Mn. The lower limit is set to 0.001, 0.003, 0.005 or 0.007% in order to ensure a good deoxidation. The upper limit is restricted to 0.1% for avoiding precipitation of undesired phases such as A1N. The upper limit may be 0.05, 0.04 or 0.3%.

Nitrogen (≤0.12%)

[0025] Nitrogen is an optional element. N is restricted 0.12% in order to avoid too high an amount of hard phases, in particular V(C,N). However, the nitrogen content may be balanced against the vanadium content in order to form primarily precipitated vanadium rich carbonitrides. These will partly be 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 and the resistance against grain growth at high austenitizing temperatures may be enhanced. If the nitrogen content is deliberately controlled for the above reason then the lower limit may be set to 0.006, 0.007, 0.08, 0.09, 0.01, 0.012, 0.013, 0.014 or 0.015%. The upper limit may be 0.11, 0.10, 0.09, 0.08, 0.07, 0.06, 0.05, 0.04 or 0.03%.

Copper (≤1%)

[0026] Cu is an optional element, which may contribute to increase the hardness and the corrosion resistance of the steel. However, it is not possible to extract copper from the steel once it has been added. This drastically makes the scrap handling more difficult. For this reason, copper is normally not deliberately added. The upper limit may be restricted to 0.5, 0.4, 0.3, 0.2 or 0.15%.

Cobalt (≤5%)

[0027] Co is an optional element. Co causes the solidus temperature to increase and therefore provides an opportunity to raise the hardening temperature. During austenitization it is therefore possible to dissolve larger fraction of carbides and thereby enhance the hardenability. However, Co is expensive and a large amount of Co may also result in a decreased toughness and wear resistance. The maximum amount is therefore 5%. However, a deliberate addition of Co is generally not made. The maximum content may be set to 2, 1, 0.5 or 0.2%.

Niobium (≤0.1%)

[0028] Niobium is similar to vanadium in that it forms carbonitrides of the type M(N,C). However, Nb results in a more angular shape of the M(N,C) and may reduce the hardenability at high contents. The maximum amount is

therefore 0.1%, preferably 0.05%. Nb precipitates are more stable than V precipitates and may therefore be used for grain refinement, since the fine dispersion of NbC plays the role of pinning the grain boundaries leading to grain refinement and improved toughness as well as improved resistance to softening at high temperatures. For this reason, Nb is an optional element and may be present in an amount of ≤0.1%. The upper limit may be set to 0.06, 0.05, 0.04, 0.03 0.01 or 0.005%. The lower limit may be set to 0.005, 0.006, 0.007, 0.008, 0.009 or 0.01%.

Ti, Zr and Ta

[0029] These elements are carbide formers and may be present in the alloy in the claimed ranges for altering the composition of the hard phases. However, normally none of these elements are added. The amount of each element is preferable ≤0.5%, 0.1% or ≤0.05%, more preferably 0.01% or 0.005%.

Boron (≤0.01%)

[0030] B may be used in order to further increase the hardness of the steel. The amount is limited to 0.01%, preferably ≤0.006% more preferably 0.005%.

Ca, Mg and REM (Rare Earth Metals)

[0031] These elements may be added to the steel in the claimed amounts for modifying the non-metallic inclusion and/or in order to further improve the machinability, hot workability and/or weldability. The amount of Ca and Mg is preferably ≤0.01%, more preferably ≤0.005%. The amount of REM is preferably ≤0.2%, more preferably ≤0.1% or even 0.05%.

Impurity Elements

[0032] Impurity elements cannot be avoided during the manufacturing of the steel. Impurity elements are therefore included in the balance and the level of said elements is not essential to the definition of the present invention.

[0033] P, S and O are the main impurities, which generally have a negative effect on the mechanical properties of the steel. These elements are unavoidable and may occur in in the steel at common impurity contents. However, since these elements may have a negative effect on the properties in steel, the impurity contents thereof may be further limited. Preferred limitations are set out as follows. P may be limited to 0.1, 0.05 or 0.03%. S may be limited to 0.5, 0.1 0.05 0.0015, 0.0010, 0.0008, 0.0005 or even 0.0001%. O may be limited to 0.01, 0.003, 0.0015, 0.0012, 0.0010, 0.0008, 0.0006 or 0.0005%.

Steel Production

[0034] The tool steel having the claimed chemical composition can be produced by conventional metallurgy including melting in an Electric Arc Furnace (EAF) and further refining in a ladle, optionally followed by a vacuum treatment before casting. The ingots may also be subjected to Electro Slag Remelting (ESR) in order to further improve the cleanliness and the microstructural homogeneity of the ingots. In addition the steel may also be subjected to Vacuum Induction Melting (VIM) and/or Vacuum Arc Remelting (VAR). An alternate processing route for the claimed steel is gas atomizing followed by hot isostatic pressing (HIP) to form a HIPed ingot, which also may be used in the condition as-HIPed. The ingots may be subjected to further hot working to final dimension as well as to soft annealing to a Brinell hardness of ≤360 HBW, preferably ≤300 HBW. The Brinell hardness is measured with a 10 mm diameter tungsten carbide ball and a load of 3000 kgf (29400N) and may also be denoted $HBW_{10/3000}$. The steel may be subjected to hardening and tempering before being used.

[0035] The steel is normally delivered to the customer in the soft annealed condition having a ferritic matrix with an even distribution of carbides therein. The soft annealed steel has uniform properties also for large dimensions and according to a preferred embodiment the uniformity in hardness should have a mean hardness of ≤360 HBW and for a thickness of at least 100 mm and the maximum deviation from the mean Brinell hardness value in the thickness direction measured in accordance with ASTM E10-01 is less than 10%, preferably less than 5%, and wherein the minimum distance of the centre of the indentation from the edge of the specimen or edge of another indentation shall be at least two and a half times the diameter of the indentation and the maximum distance shall be no more than 4 times the diameter of the indentation.

[0036] The atomized powder may also be used for additive manufacturing.

[0037] Hereinafter, the present invention will be described in more detail.

[0038] The hot work steel according to the present invention consists of in weight % (wt. %):

C	0.5-0.9
Si	0.03-0.8
Mn	0.1-1.8
Cr	4.0-6.6
Mo	1.8-3.5
V	1.3-2.3
Al	≤0.1
N	≤0.12
Ni	≤1
W	≤1
Co	≤5
Cu	≤1
Nb	≤0.1
Ti	≤0.05
Zr	≤0.05
Ta	≤0.05
B	≤0.01
Ca	≤0.01
Mg	≤0.01
REM	≤0.2

balance Fe and impurities.

[0039] Preferably, the hot work tool steel fulfils at least one of the following requirements:

C	0.6-0.8
Si	0.05-0.6
Mn	0.2-0.8
Cr	4.4-5.6
Mo	2.0-2.5
V	1.5-1.9
Al	≤0.05
N	≤0.08
Ni	≤0.5
W	≤0.5
Co	≤2
Cu	≤0.5
Nb	≤0.05

-continued

Ti	≤0.01
Zr	≤0.01
Ta	≤0.01
B	≤0.006
Ca	≤0.005
Mg	≤0.005
REM	≤0.1

[0040] More preferably the composition of the steel fulfils one or more of the following requirements:

C	0.65-0.75
Si	0.15-0.5
Mn	0.4-0.5
Cr	4.9-5.1
Mo	2.2-2.3
V	1.5-1.7
Al	≤0.03
N	≤0.05
Ni	0.25
W	≤0.2
Co	≤1
Cu	≤0.2
Nb	≤0.005
Ti	≤0.005
Zr	≤0.005
Ta	≤0.005
REM	≤0.05

[0041] Preferably the steel fulfils at least one of the following requirements:

C	0.66-0.75
Si	0.15-0.25
V	1.52-1.68
Al	0.001-0.03
N	≤0.05
W	≤0.1
Cu	≤0.15

[0042] In a particular preferred embodiment all of these requirements are fulfilled.

[0043] In order to enhance the resistance against abrasive wear the composition can be adjusted such that the steel in the hardened and tempered condition contains a small and controlled amount of vanadium carbides having a size of larger than or equal to 1 μm. The size is given as Equivalent Circular Diameter (ECD), which is calculated from the image area (A) obtained in an image analysis. The ECD has the same projected area as the particle and it is equal to $2\sqrt{(A/\pi)}$.

[0044] The steel should preferably contain 0.2-4 volume % VC, preferably 0.5-3 volume % and more preferably 1.5-2.3 volume %.

[0045] The amount of M_6C and M_7C_3 should be restricted to 2 volume %, preferably 0.5 volume %, and more preferably 0.1 volume %, each.

[0046] The hardness of the steel can be adjusted by selecting a proper combination of the austenitizing time and temperature, the cooling rate expressed as cooling time in the temperature interval from 800° C. to 500° C. ($t_{5/8}$) as well as the tempering temperature. Generally, the steel is tempered twice for two hours (2×2 h) in order to reduce the amount of retained austenite to less than 2 volume %.

[0047] The mechanical properties of the steel after hardening and tempering to a hardness of 55-57 HRC should preferably at least one of the following requirements:

[0048] Yield strength (Rp0.2): ≥1700 MPa, preferably ≥1725 MPa, more preferably ≥1750 MPa.

[0049] Tensile strength (Rm): ≥1950 MPa, preferably ≥2050 MPa, more preferably ≥2050 MPa, most preferably ≥2100 MPa.

[0050] Elongation (A5): ≥3%, preferably ≥4, more preferably ≥5%, most preferably ≥6%.

[0051] Reduction of area (Z): ≥5%, preferably ≥10, more preferably ≥15%, most preferably ≥20%.

EXAMPLE 1

[0052] Table 1 discloses the hardness in Rockwell C (HRC) as a function of the hardening parameters austenitizing time and temperature. It can be seen that the hardness easily can be adjusted in the range from 49 to 61 HRC. The composition of the ESR ingot was as follows: C 0.71%, Si 0.22%, Mn 0.46%, Cr 5.01%, Mo, 2.24%, V 1.62%, Al 0.007%.

TABLE 1

Hardness (HRC) in the hardened and tempered condition. For all samples cooling in vacuum with t8/5 = 300 s and tempering 2 × 2 h.

Aust. T (° C.)	Time (min)	540° C.	560° C.	580° C.	600° C.	610° C.
1050	30	57.3	56.2	54.9	52.4	48.9
1100	30	59.1	58.1	57.5	54.5	52.0
1130	10	60.4	59.1	58.4	55.9	53.7
1150	10	61.2	61.0	59.6	56.7	54.8

[0053] The temper resistance was examined for the steel austenitized at 1130° C. and tempered at 580° C. and 600° C., respectively. The steel samples were subjected to heating at 600° C. for 10 hours. In the first case the hardness decreased from 58.4 HRC to 53.6 HRC and for the second sample the hardness decreased from 55.9 HRC to 52.8 HRC. Hence, the loss in hardness was 4.8 HRC and 3.1 HRC, respectively.

[0054] These values can be compared with the corresponding values for the steel UNIMAX® mentioned in the beginning. A sample of said steel having the nominal composition C 0.5%, Si 0.2%, Mn 0.5%, Cr 5.0%, Mo 2.3% and V 0.5% was prepared. The steel was hardened to 57.8 HRC by austenitizing at 1050° C. for 30 min, with $t_{8/5}$=300 s and tempering 2×2 h at 540° C. The initial hardness was 57.8 HRC and the hardness after 10 hours at 600° C. was 49.4 HRC. Accordingly, the loss in hardness was 8.4 HRC for the known steel. It can thus be concluded that the inventive steel has a superior temper resistance as compared to the known steel.

[0055] The cleanliness of the inventive steel was examined with respect to micro-slag according to ASTM E45-97, Method A, Plate I-r and the result is given in Table 2.

TABLE 2

Cleanliness according to ASTM E45-97, Method A, Plate I-r.

A T	A H	B T	B H	C T	C H	D T	D H
0.5	0	0.5	1.0	0	0	0.5	1.0

EXAMPLE 2

[0056] The ESR ingot of example 1 was hot rolled to a diameter of 196 mm from which three samples were taken in the LC2 direction and subjected examination for mechanical properties. This steel sample was hardened to a hardness of 56 HRC by austenitizing at 1050° C. for 30 minutes cooling in vacuum with $t_{8/5}$=300 seconds followed by tempering twice at 560° C. for 2 hours. The following mean value of the examination are given below:

[0057] Yield strength (Rp0.2): 1761 MPa

[0058] Tensile strength (Rm): 2117 MPa

[0059] Elongation (A5): 7%

[0060] Reduction of area (Z): 26%

EXAMPLE 3

[0061] In this example an inventive steel was compared to a standard matrix steel used or forging tools.

[0062] The alloys had the following compositions (in wt. %) was

	Inventive steel	Comparative steel
C	0.7	0.5
Si	0.2	0.2
Mn	0.5	0.5
Cr	5.0	4.2
Mo	2.3	2.0
V	1.6	1.2
W	0.01	1.6

balance Fe and impurities.

[0063] The alloys were subjected to standard heat treatment, forging and soft annealing to a hardness of about 300 HBW. Both steels were subjected to hardening and tempering by heating to 1100° C. for 30 minutes, quenching and tempering two times at 540° C. during two hours (2×2 h). The hardness of the inventive steel was 57 HRC and the hardness of the comparative steel was 56 HRC. The wear resistance of the steel was examined by the Pin on Disk method using 800 mesh Al-oxide papers from the same batch. The wear loss of the inventive steel was found to be 178 mg/min and that of the comparative steel was 219 mg/min.

[0064] A further sample of the inventive steel was prepared in order to obtain the same hardness as the comparative steel. This was achieved by heating to 1100° C. for 30 minutes and tempering 2×2 h at 540° C. The hardness was 56 HRC. As expected, the wear loss of this sample was somewhat higher (189 mg/min) as compared to the steel having a hardness of 57 HRC but substantially lower than that of the comparative steel having the same hardness.

EXAMPLE 4

[0065] Samples of a steel of the same composition as in example 1 were prepared for welding tests. Solid blocks of the steel were milled to have a sharp 90° inside corner, the samples were to two different hardening treatments. The first heat treatment consisted of austenitizing at 1050° C. for 30 minutes cooling in vacuum with $t_{8/5}$=300 seconds followed by tempering twice at 560° C. for 2 hours. The second heat treatment differed therefrom in that the austenitizing was performed at 1130° C. for 10 minutes.

[0066] The samples were then TIG-welded at room temperature (RT), 80° C., 225° C. and 325° C. using 1.6 mm diameter rod with three different standard welding consumables. The applicants own Caldie TIG and QRO 90 TIG as well as UTP A 696 TIG from UTP Schweissmaterial GmbH.

[0067] Cracking was experienced at all temperatures with the consumable Caldie TIG. However, surprisingly it was found that the two other consumables could be used to produce crack-free welding also at RT without cracking. Accordingly, the inventive steel possesses a surprisingly good weldability.

[0068] The steel of the present invention is useful for hot work applications where the tool is subjected to abrasive wear. In particular, the steel is suitable as a tool for hot forging, press hardening, die casting, high pressure die casting or hot extrusion.

1. A hot work tool steel for hot forging, press hardening, die casting or hot extrusion consisting in weight % (wt. %):

C	0.65-0.85
Si	0.03-0.8
Mn	0.1-1.8
Cr	4.5-6.6
Mo	1.8-3.5
V	1.3-2.3
Al	≤0.1
N	≤0.12
Ni	≤1
W	≤0.5
Co	≤2
Cu	≤1
Nb	≤0.1
Ti	≤0.05
Zr	≤0.05
Ta	≤0.05
B	≤0.01
Ca	≤0.01
Mg	≤0.01
REM	≤0.2, and

balance Fe and impurities.

2. The hot work tool steel according to claim **1**, wherein the steel fulfils at least one of the following requirements:

C	0.65-0.8
Si	0.05-0.6
Mn	0.2-0.8
Cr	4.5-5.6
Mo	2.0-2.5
V	1.5-1.9
Al	≤0.05
N	≤0.08
Ni	≤0.5
W	≤0.5
Co	≤2
Cu	≤0.5
Nb	≤0.05
Ti	≤0.01
Zr	≤0.01
Ta	≤0.01
B	≤0.006
Ca	≤0.005
Mg	≤0.005, and
REM	≤0.1.

3. The hot work tool steel according to claim **1**, wherein the steel fulfils at least one of the following requirements:

C	0.65-0.75
Si	0.15-0.5
Mn	0.4-0.5
Cr	4.9-5.1
Mo	2.2-2.3
V	1.5-1.7
Al	≤0.03
N	≤0.05
Ni	0.25
W	≤0.2
Co	≤1
Cu	≤0.2
Nb	≤0.005
Ti	≤0.005
Zr	≤0.005
Ta	≤0.005, and
REM	≤0.05.

4. The hot work tool steel according to claim **1**, wherein the steel comprises carbides having a size of ≥1 μm and fulfils at least one of the following requirements concerning the amounts of carbides in volume %:

VC	0.2-4
M_6C	≤2, and
M_7C_3	≤2.

5. The hot work tool steel according to claim **4**, wherein the steel comprises carbides having a size of ≥1 μm and fulfils at least one of the following requirements concerning the amounts of carbides in volume %:

VC	0.5-3
M_6C	≤0.5, and
M_7C_3	≤0.5.

6. The hot work tool steel according to claim **5**, wherein the steel comprises carbides having a size of ≥1 μm and fulfils at least one of the following requirements concerning the amounts of said carbides in volume %:

VC	1.5-2.3
M_6C	≤0.1, and
M_7C_3	≤0.1.

7. The hot work tool steel according to claim **1**, wherein the steel after hardening and tempering has a hardness of 55-57 HRC and wherein the steel fulfils at least one of the following requirements:

Rp0.2	≥1750 MPa
Rm	≥2100 MPa
A5	≥6%
Z	≥20%, and

a cleanliness fulfilling the following maximum requirements with respect to micro-slag according to ASTM E45-97, Method A, Plate I-r:

A	A	B	B	C	C	D	D
T	H	T	H	T	H	T	H
1.0	0	1.5	1.0	0	0	1.5	1.0.

8. The hot work tool steel according to claim **1**, wherein the steel fulfils at least one of the following requirements:

C	0.66-0.75
Si	0.15-0.25
Mo	2.2-2.3
V	1.52-1.68
Al	0.001-0.03
N	≤0.05
W	≤0.1
Co	≤1
Cu	≤0.15
Nb	≤0.005
Ti	≤0.005, and
Zr	≤0.005.

9. The hot work tool steel according to claim **1**, wherein the steel fulfils at least one of the following requirements:

C	0.66-0.75
Si	0.15-0.25
Mo	2.2-2.3
V	1.52-1.68
Al	0.005-0.03
N	≤0.05
W	≤0.1
Co	≤0.5
Cu	≤0.15
Nb	≤0.005
Ti	≤0.005, and
Zr	≤0.005.

10. The hot work tool steel according to claim **1**, having a mean hardness of ≤360 HBW, wherein the steel has a thickness of at least 100 mm and the maximum deviation from the mean Brinell hardness value in the thickness direction measured in accordance with ASTM E10-01 is less than 10%, and wherein the minimum distance of the center of the indentation from the edge of the specimen or edge of another indentation shall be at least two and a half times the diameter of the indentation and the maximum distance shall be no more than 4 times the diameter of the indentation.

11. Use of the hot work tool steel according to claim **1** as a tool for hot forging, press hardening, die casting, high pressure die casting or hot extrusion.

12. The hot work tool steel according to claim **10**, wherein the maximum deviation from the mean Brinell hardness value in the thickness direction measured in accordance with ASTM E10-01 is less than 5%.

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