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(54) **MANUFACTURING METHOD FOR COLD-WORKING DIE**

HERSTELLUNGSVERFAHREN FÜR EINE KALTBEARBEITUNGSMATRIZE

PROCÉDÉ DE FABRICATION DE MATRICE POUR FORMAGE À FROID

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method of manufacturing a cold-work, for example, for forming parts of home electric appliances, mobile phones or automobiles.

BACKGROUND ART

[0002] In a field of cold-work tools for use in press forming such as bending, squeezing or punching of a plate material at a room temperature, a steel material has been proposed that can obtain a hardness of not lower than 55 HRC by quenching and tempering (hereinafter, quenching and tempering are referred to as "hardening process") in order to improve wear resistance (see Patent Literatures 1 to 3). Since it is difficult to machine the steel material having such a high hardness into a die shape after the hardening process, the steel material is usually roughly worked in an annealed state after hot worked where the hardness is low, and then is subjected to the hardening process to a hardness of not lower than 55 HRC for use. In this case, since the die is deformed due to the heat treatment of the hardening process, the die is again subjected to finish machining to correct the deformed portion after the hardening process, and finished in a final tool shape. The main reason for the heat treatment deformation of the tool due to the hardening process is because the steel material transforms from a ferritic structure in the annealed state to a martensitic structure and thus volume expansion generates.

[0003] Besides the above steel material, many pre-hardened steels have been proposed, which are subjected to the hardening process to a used hardness in advance. No hardening process is necessary after the pre-hardened steels are machined to a final tool shape. Thus, it is free of the heat treatment deformation of the tool due to the hardening process and thus the finishing machining is not necessary. Thus, it is effective techniques. With respect to the pre-hardened steels, a cold-work tool steel has been proposed which has good machinability and a hardness of more than 55 HRC through the hardening process, by optimizing an amount of insoluble carbides in a quenched steel material since the insoluble carbides deteriorate machinability (see Patent Literature 4). Also, a cold-work tool steel has been proposed for suppressing tool wear caused by a friction between a cutting tool and a steel material at a time of machining. The steel has self-lubricating properties by adding an element forming an oxide having a melting point of 1200°C or lower ($(FeO)_2 \cdot SiO_2$, Fe_2SiO_4 or $(FeSi)Cr_2O_2$) to form the oxide on a surface of a die by heat generated at the time of machining (Patent Literature 5). Furthermore, Patent Literature 6 discloses a cold die steel having a property of suppressing a dimensional change through tempering, wherein the dimensional change and deformation is suppressed by the choice of a specific base material.

CITATION LIST

PATENT LITERATURES

[0004]

Patent Literature 1: JP-A-2008-189982
Patent Literature 2: JP-A-2009-132990
Patent Literature 3: JP-A-2006-193790
Patent Literature 4: JP-A-2001-316769
Patent Literature 5: JP-A-2005-272899
Patent Literature 6: JP 2006 152356 A

SUMMARY OF THE INVENTION

[0005] Recently, use conditions of a cold-work die have been increasingly severe, and it is requested that a cold-work tool steel has a hardness after quenched and tempered of not lower than 58HRC, further not lower than 60HRC. Therefore, it is preferable that a pre-hardened steel stably achieves the hardness of not lower than 60HRC, as a matter of course not lower than 58HRC, as well as superior machinability in the state having such a high hardness. The cold-work tool steel disclosed in Patent Literature 4 is a superior pre-hardened steel simultaneously satisfying machinability at the time of machining and wear resistance as a die. However, with respect to the wear resistance, since an amount of defined insoluble carbides is small and a quenching temperature is restricted, the compositional range is limited for having a hardness of not lower than 60 HRC. Patent Literature 4 discloses that Nb and V are preferably added for suppressing grain growth at a time of heating for quenching. However, the elements are likely to form insoluble MC carbides at the above quenching temperature. Since the MC carbides are hard, there is a problem that machinability after the hardening process is deteriorated in the composition disclosed in Patent Literature 4.

[0006] In addition, the cold-work tool steel disclosed in Patent Literature 5 utilizes a low melting point oxide as a self-lubricating film. However, the lubricating effect is not obtained when the machining temperature is below the melting point of the oxide. On the contrary, when the machining temperature rises too high, there is a problem that a viscosity of the oxide is remarkably reduced and the oxide will not serve as the lubricating film.

[0007] An object of the present invention is to provide a method of manufacturing a cold-work die, including machining a cold-work tool steel having a composition for stably achieving a high hardness of not lower than 60 HRC, as a matter of course of not lower than 58 HRC, and also preferably having remarkably improved machinability after the hardening process without depending on a machining temperature even if an amount of insoluble carbides are further increased.

[0008] The present inventors have studied to improve machinability of a cold-work tool steel. As a result, the inventors have found that Al_2O_3 which is an oxide having a high melting point is positively introduced to form a complex lubricating protective film including Al_2O_3 and MnS, which is a high ductility inclusion, on a surface of a cutting tool by heat generated at a time of machining. The inventors has found a compositional range for the steel material that is capable of forming the complex lubricating protective film as well as having a hardness of not lower than 60 HRC, as a matter of course not lower than 58HRC, thereby reaching the present invention.

[0009] The present invention provides a method of manufacturing a cold-work die as defined in claim 1. In an embodiment, the method includes annealing the hot worked base material before the quenching and tempering. In another embodiment, the quenching is direct quenching that is conducted in cooling from the hot working. Preferably, the hardness after the hardening is not lower than 60 HRC.

[0010] The cold-work tool steel may include not greater than 1.0% of Ni, or may further include not greater than 1.0% of Cu.

[0011] Then, the cold-work tool steel may further include not greater than 1.0% of V, or may further include not greater than 0.5% of Nb.

[0012] The present invention uses a mechanism for improving machinability, which can be widely applied to a number of steel compositions. Thus, even if an alloy is designed to have a hardness of not lower than 60 HRC, as a matter of course not lower than 58HRC, and to include a large amount insoluble carbides, the cold-work tool steel can have remarkably improved machinability after the hardening process without depending on a machining temperature. Therefore, the hardness of the cold-work tool steel and the amount of the insoluble carbides can be widely selected depending on various functions. When the steel is thermally refined to have a hardness of 58-62HRC and then machined, a die can be manufactured without the problems of the deformation during heat-treatment and the finishing machining. Thus, the invention provides an essential technique for practical use of a cold work die, in particular made of the pre-hardened cold-work tool steels.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

[Fig. 1A] Fig. 1A is a digital microscope photograph showing a rake face and a flank face of a machining tool used for machining of Sample No. 3 according to the present invention. The upper side in the figure shows the rake face, and the lower side shows the flank face.

[Fig. 1B] Fig. 1B is a digital microscope photograph showing a rake face and a flank face for a machining tool used in machining of Sample No. 5 according to the present invention. The upper side in the figure shows the rake face, and the lower side in the figure shows the flank face.

[Fig. 1C] Fig. 1C is a digital microscope photograph showing a rake face and a flank face of a machining tool used for machining of Sample No. 15 according to the present inventive example. The upper side in the figure shows the rake face, and the lower side shows the flank face.

[Fig. 1D] Fig. 1D is a digital microscope photograph showing a rake face and a flank face of a machining tool used for machining of Sample No. 22 according to comparative example. The upper side in the figure shows the rake face, and the lower side shows the flank face.

[Fig. 1E] Fig. 1E is a digital microscope photograph showing a rake face and a flank face of a machining tool used for machining of comparative Sample No. 30. The upper side in the figure shows the rake face, and the lower side shows the flank face.

[Fig. 2A] Fig. 2A is a mapping photograph of Al (upper left), O (upper right), Mn (lower left) and S (lower right) in a belag on a surface of the cutting tool in Fig. 1A (for Sample No. 3), analysed by EPMA (electron probe microanalyzer).

[Fig. 2B] Fig. 2B is a mapping photograph of Al, O, Mn and S in a belag on a surface of the cutting tool in Fig. 1B (for Sample No. 5), analysed by EPMA.

[Fig. 2C] Fig. 2C is a mapping photograph of Al, O, Mn and S in a belag on a surface of the cutting tool in Fig. 1B (for Sample No. 15), analysed by EPMA.

[Fig. 2D] Fig. 2D is a mapping photograph of Al, O, Mn and S in a belag on a surface of the cutting tool in Fig. 1D (for Sample No. 22), analysed by EPMA.

[Fig. 2E] Fig. 2E is a mapping photograph of Al, O, Mn and S in a belag on a surface of the cutting tool in Fig. 1E (for Sample No. 30), analysed by EPMA.

[Fig. 3A] Fig. 3A is a cross sectional TEM (transmission electron microscope) photograph showing the belag in Fig. 2A (for Sample No. 3) together with a TiN coating.

[Fig. 3B] Fig. 3B is a cross sectional TEM (transmission electron microscope) photograph showing the belag in Fig. 2D (for Sample No. 22) together with a TiN coating.

[Fig. 3C] Fig. 3C is a cross sectional TEM (transmission electron microscope) photograph showing the belag in Fig. 2E (for Sample No. 30) together with a TiN coating.

DESCRIPTION OF EMBODIMENTS

[0014] The present invention realizes a cold-work tool steel having not only an improved hardness but also good machinability after the hardening process without depending on a machining temperature even if a large amount of insoluble carbides are formed to, for example, control a grain size, and the invention has characterization of machining the steel after hardening. Specifically, the hardening is conducted before the machining of the steel material designed so that a hardness of not lower than 58HRC, preferably not lower than 60 HRC, is achieved, as well as a complex lubricating protective film of Al_2O_3 as a high melting point oxide and MnS as a high ductility inclusion are formed on a surface of a cutting tool in order to suppress wear of the cutting tool.

[0015] First, the present inventors have studied to improve machinability, which can be widely applied to a composition of a cold-work tool steel. As a result, the inventors have noticed on effectiveness of self-lubricating properties. Then, the inventors have studied the effect of self-lubricating properties of the oxide having a low melting point as Patent Literature 5, and consequently have found a problem that the low melting point oxide depends on a machining temperature. The low melting point oxide having self-lubricating properties is generally a complex oxide including Fe and Cr which are included in a steel material in a large amount. Thus, when the machining temperature changes, a composition and an amount of the complex oxide change and a stable lubricating effect is not obtained.

[0016] Then, intensive studies have been made for improving machinability of a cold-work tool steel without using the low melting point oxide, and it has been found that Al_2O_3 which is an oxide having a high melting point is introduced positively to form a complex lubricating protective film including Al_2O_3 and MnS as a high ductility inclusion on a surface of a cutting tool by heat generated at a time of machining. The complex lubricating protective film can provide stable effects in response to a wide range of the machining temperatures, and also ensure good machinability even in a case where elements for forming hard MC carbides, such as Nb and V, are added. Then, a composition of the steel material has been specified that enables to form the complex lubricating protective film while achieving a hardness of not lower than 60 HRC, as a matter of course of not lower than 58HRC, thereby reaching the present invention. Hereinafter, the composition of the cold-work tool steel for the method of the present invention will be described.

Carbon: 0.6 to 1.2 mass% (hereinafter, simply expressed as %)

[0017] Carbon is an important element for forming carbides in a steel to make a cold-work tool steel hard. If the carbon content is too small, an amount of the carbides is insufficient, and it is difficult to provide a hardness of not lower than 58HRC, preferably not lower than 60 HRC. On the other hand, if an excessive amount of carbon is included, an amount of insoluble carbides increases in quenching, and toughness is likely to be decreased. Therefore, the carbon content is defined as 0.6 to 1.2%. Preferably, the content is not less than 0.7% and/or not greater than 1.1%. Not greater than 1.0% is further preferable.

Si: 0.8 to 2.5%

[0018] Si solid-solutes in a steel, and is an important element for making the cold-work tool steel hard. In addition, since Si has a stronger tendency to be oxidized than Fe and Cr and is also likely to form corundum-type oxides with Al_2O_3, Si has an important function to suppress a formation of Fe-based and Cr-based oxides which reduce a melting point of oxides, and to promote formation of an Al_2O_3 protective film. However, if an excessive amount of Si is included, quenching properties and toughness are remarkably deteriorated. Therefore, the Si content is defined as 0.8 to 2.5%. Preferably, the content is not less than 1.0% and/or not greater than 2.0%. Not less than 1.2% is further preferable.

Mn: 0.4 to 2.0%

[0019] Mn is an important element in the present invention. Mn acts as a good lubricating film on the Al_2O_3 protective film formed on a surface of a cutting tool. Mn forms austenitic phase and solid-solutes in the steel to enhance quenching properties. However, if the Mn content is too large, a large amount of retained austenite remains after the hardening process, which causes secular deformation during use of a die. In addition, since Mn is likely to form low melting point oxides with Fe and Cr, it becomes a factor of inhibiting the function of the Al_2O_3 protective film. Therefore, the Mn content is defined as 0.4 to 2.0% in the present invention. Preferably, the content is not less than 0.6% and/or not greater than 1.5%.

Sulfur: 0.03 to 0.1%

[0020] Sulfur is an important element in the present invention. Sulfur acts as a good lubricating film on the Al_2O_3 protective film formed on a surface of a cutting tool. When sufficient sulfur is included in the steel material, MnS is formed. Since MnS has good ductility we well as is compatible with Al_2O_3, it deposits on the Al_2O_3 protective film and acts as a good lubricating protective complex film. In order to sufficiently exert such a lubricating action, sulfur is required to be added in an amount of not less than 0.03%. However, sulfur deteriorates toughness of the steel, and therefore an upper limit thereof is defined as 0.1%. Preferably, the sulfur content is not less than 0.04% and/or not greater than 0.08%.

Cr: 5.0 to 9.0%

[0021] Cr forms an M_7C_3 carbide in a structure after the hardening process, thereby it makes a cold-work tool steel hard. In addition, Cr has an effect of suppressing grain growth since a part of Cr forms insoluble carbides at a time of quenching heating. When a Cr content is not less than 5.0%, a large amount of carbides is formed, and a hardness of not lower than 58HRC, preferably not lower than 60HRC, is obtained. Furthermore, when a surface of a cold-work die is subjected to various coating treatments, forming ability of a VC film with a TD treatment or a TiC film with a CVD treatment is enhanced. Cr is effective in ensuring corrosion resistance.

[0022] On the other hand, Cr, a main component of the cold-work tool steel, is likely to form an oxide having a low melting point. When excessive Cr is included, it becomes a factor of inhibiting the function of the Al_2O_3 protective film. As a result, it becomes a factor of inhibiting the function of the lubricating complex protective film including Al_2O_3 and MnS of the present invention. Accordingly, it is important to adjust the Cr content provided that a sufficient amount of Al described below is included. Then, the function of the above lubricating complex protective film is exerted by adjusting the corresponding sulfur content. Therefore, it is important that the Cr content is 5.0 to 9.0%. The content is preferably not less than 6.0%, and more preferably not less than 7.0%.

One or both of Mo and W: 0.5 to 2.0% in a form of (Mo + 1/2W)

[0023] Mo and W increase hardness by precipitation strengthening (secondary hardening) of fine carbides during tempering of the hardening process. However, Mo and W make the decomposition of retained austenite retard during the tempering. Thus, when excessive amount of Mo and W is contained, the retained austenite is likely to remain in the structure after the hardening process. In addition, since Mo and W are expensive, their addition should be reduced as much as possible in terms of practical use. Therefore, the amounts of the elements are defined as 0.5 to 2.0% in a form of relational expression (Mo + 1/2W).

Al: 0.04 to less than 0.3%

[0024] Al is an important element in the present invention. When sufficient Al is included in the steel, Al_2O_3, that is an oxide having a high melting point, is formed on a surface of a machining tool by heat generated at a time of machining. Since the melting point of Al_2O_3 is about 2050°C and is much higher than the machining temperature, Al_2O_3 serves as the protective film of the machining tool. An amount of not less than 0.04% Al forms the protective film having a sufficient thickness, and improves tool lifetime. However, when the Al content is large, Al_2O_3 is formed as a large amount of inclusions in the steel material, and thus machinability of the steel material is deteriorated. Therefore, the upper limit of the Al content is defined as less than 0.3%. Preferably, the Al content is not less than 0.05% and/or not greater than 0.15%.

Optionally Ni: not greater than 1.0%

[0025] Ni improves toughness and weldability of the steel. In addition, Ni precipitates as Ni_3Al in tempering of the hardening process and effects to increase hardness of the steel. Thus, it is effective to add Ni depending on the Al content in the cold-work tool steel of the present invention. On the other hand, since Ni is an expensive metal, it should be reduced as much as possible in terms of practical use. Therefore, not greater than 1.0% Ni is preferable even if it is added.

Optionally Cu: not greater than 1.0%

[0026] Cu precipitates as ε-Cu during tempering of the hardening process and effects to increase a hardness of the steel. However, Cu causes hot-shortness of the steel material. Therefore, in the present invention, not greater than 1.0% Cu is preferable even if it is added. The hot-shortness by Cu is suppressed by adding substantially same amount of Ni. Thus, when the steel according to the invention includes Ni, the limitation of the content may be extended.

Optionally vanadium: not greater than 1.0%

[0027] Vanadium forms various carbides and effects to increase hardness of the steel. In addition, the formed insoluble MC carbides effect to suppress grain growth. In particular, vanadium is added in combination with Nb described later to make the insoluble MC carbides fine and uniform at the time of quenching heating, and vanadium acts to effectively suppress grain growth. On the other hand, the MC carbides are hard and deteriorate machinability. The present invention forms the above-described complex lubricating protective film on the surface of the tool at the time of machining to make it possible to ensure good machinability even if a large amount of MC carbides are formed in the steel material. However, if vanadium is excessively added, coarse MC carbides are excessively formed to deteriorate toughness and machinability of the cold-work tool steel. Thus, even if vanadium is added, the vanadium content is preferably not greater than 1.0%. More preferably, the vanadium content is not greater than 0.7%

Optionally Nb: not greater than 0.5%

[0028] Nb forms MC carbides and effects to prevent coarse grains. However, when excess Nb is added, coarse MC carbides are excessively formed to deteriorate toughness and machinability of the steel. Thus, even if Nb is added, the Nb content is preferably not greater than 0.5%. More preferably, the Nb content is not greater than 0.3%.

[0029] The present invention resides in the machining of the cool tool steel having the above composition after the hardening of the steel so as to have a hardness of 58-62HRC. The cold-work tool steel according to the present invention can achieve a hardness of not lower than 58HRC by quenching and tempering. It is also possible to achieve a hardness of not lower than 60HRC. Since the steel has superior machinability while it has such a high hardness, there is no need to machine the steel in an annealed state followed by quenching and tempering. Since there is no need to undergo the annealed state, the steel can be directly quenched in the course of the cooling from hot working of the ingot. Same improved machinability can be obtained even when this direct quenching is applied, in place of the quenching after annealing. Therefore, when the cold-work tool steel of the present invention is used as a pre-hardened steel, it is possible to eliminate heat treatment deformation due to the hardening process and to omit finish machining, and may further omit the annealing step etc. for manufacturing the base material. The present invention defines an upper limit of the hardness is 62HRC in order to maintain sufficient mechanical properties other than the hardness of the steel and to stably conduct the machining.

[0030] A die produced through the method according to the present invention has a superior dimensional accuracy and wear resistance. When it is subjected to PVD treatment, the wear resistance is further improved while maintaining a high dimensional accuracy.

Example

[0031] Materials were melted with a high frequency induction furnace and ingots having chemical compositions shown in Table 1 were produced. The ingots were hot forged so as to have a forging ratio of about 10, and then cooled and annealed at 860°C. The annealed materials were quenched from 1030°C by air cooling. Then, they were tempered twice at 500 to 540°C so as to have an aimed hardness of 60HRC. Thus, test pieces for evaluating machinability were produced.

[Table 1]

Sample No.	Composition (mass%) C	Si	Mn	P	S	Ni	Cr	W	Mo	V	Cu	Al	Nb	Fe	Hardness (HRC)	Remarks
1	0.800	1.98	1.01	0.004	0.0530	<0.1	7.73	<0.1	1.51	0.26	<0.1	0.059	0.12	Bal.	60.6	Example according to the invention
2	0.785	2.01	1.04	0.006	0.0554	<0.1	7.68	<0.1	1.48	0.25	<0.1	0.070	0.12	Bal.	60.5	
3	0.773	1.96	1.01	0.006	0.0581	<0.1	7.68	<0.1	1.50	0.26	<0.1	0.099	0.12	Bal.	60.9	
4	0.820	1.48	0.83	0.025	0.0610	<0.1	7.16	<0.1	1.51	0.25	<0.1	0.117	0.12	Bal.	60.7	
5	0.706	2.01	0.98	0.028	0.0542	<0.1	6.89	<0.1	1.48	<0.1	<0.1	0.107	<0.1	Bal.	60.4	
6	0.770	1.99	1.02	0.025	0.0563	<0.1	7.60	<0.1	1.52	0.26	<0.1	0.250	0.12	Bal.	60.7	
7	0.782	2.02	1.01	0.024	0.0554	<0.1	8.64	0.63	0.62	0.21	<0.1	0.190	<0.1	Bal.	59.7	
8	1.012	2.42	1.49	0.027	0.0821	<0.1	8.56	<0.1	0.72	<0.1	<0.1	0.110	<0.1	Bal.	59.7	
9	0.626	2.00	0.99	0.025	0.0483	<0.1	5.13	<0.1	0.97	<0.1	<0.1	0.140	<0.1	Bal.	60.9	
10	0.626	1.52	0.70	0.025	0.0626	<0.1	5.14	<0.1	1.17	0.51	<0.1	0.090	<0.1	Bal.	60.8	
11	0.757	1.32	0.50	0.027	0.0450	0.2	5.24	<0.1	0.99	<0.1	0.20	0.065	<0.1	Bal.	60.8	
12	0.632	2.47	1.08	0.025	0.0820	0.2	5.49	0.41	0.50	<0.1	<0.1	0.230	<0.1	Bal.	60.1	
13	0.657	1.77	1.21	0.026	0.0815	<0.1	7.77	0.21	0.97	0.10	<0.1	0.047	<0.1	Bal.	60.8	
14	0.655	1.79	1.17	0.025	0.0772	<0.1	7.82	<0.1	0.98	0.10	<0.1	0.075	<0.1	Bal.	60.6	
15	0.607	0.99	0.42	0.026	0.0626	0.40	5.96	<0.1	0.98	0.25	0.34	0.111	<0.1	Bal.	61.7	
21	0.760	1.97	1.00	0.005	0.0014	<0.1	7.64	<0.1	1.47	0.24	<0.1	0.007	0.13	Bal.	60.2	Comparative example
22	0.770	2.00	1.05	0.004	0.0610	<0.1	7.56	<0.1	1.50	0.26	<0.1	0.016	0.12	Bal.	60.4	
23	0.819	2.01	1.04	0.005	0.0600	<0.1	7.04	<0.1	1.50	0.25	<0.1	0.010	0.13	Bal.	60.4	
24	0.804	1.97	0.96	0.006	0.0580	<0.1	6.95	<0.1	1.48	<0.1	<0.1	0.011	<0.1	Bal.	58.1	
25	0.810	1.17	0.57	0.006	0.0600	<0.1	6.96	<0.1	1.45	0.23	<0.1	0.012	0.12	Bal.	61.1	
26	1.020	1.53	0.82	0.008	0.0575	<0.1	5.02	<0.1	0.99	0.25	<0.1	0.021	0.12	Bal.	59.8	
27	0.997	1.49	0.49	0.008	0.0585	<0.1	5.07	<0.1	0.98	0.25	<0.1	0.012	0.12	Bal.	60.0	
28	1.016	1.55	0.86	0.007	0.0550	<0.1	4.14	<0.1	1.02	0.24	<0.1	0.016	0.12	Bal.	59.4	
29	1.015	1.54	0.85	0.008	0.0570	<0.1	4.12	<0.1	1.02	0.60	<0.1	0.014	0.12	Bal.	59.9	
30	0.580	0.97	0.40	0.027	0.0060	0.40	5.96	<0.1	0.96	0.29	0.34	0.009	<0.1	Bal.	60.1	
31	0.765	0.28	0.40	0.028	0.0624	<0.1	7.60	<0.1	1.02	0.26	<0.1	0.027	0.12	Bal.	60.2	
32	0.771	2.00	1.01	0.024	0.0025	<0.1	7.65	<0.1	1.49	0.25	<0.1	0.100	0.11	Bal.	62.0	
33	0.765	1.97	1.02	0.025	0.0298	<0.1	7.62	<0.1	1.51	0.26	<0.1	0.100	0.11	Bal.	60.7	
34	0.957	1.51	0.83	0.026	0.0550	<0.1	2.70	<0.1	0.97	0.48	<0.1	0.094	0.15	Bal.	59.9	
35	1.120	1.01	1.54	0.026	0.0529	<0.1	2.71	<0.1	1.00	0.58	<0.1	0.170	<0.1	Bal.	60.0	

[0032] A machinability test was conducted by surface-grinding with an insert PICOmini manufactured by Hitachi Tool Engineering Ltd. as a cutting edge replaceable tool that can machine a high hardness material. The insert is made of a cemented carbide alloy as a base material coated with TiN. Machining conditions were as follows:

cutting speed: 70 m/min,
spindle speed: 1857rev/min,
feed speed: 743 mm/min,
feed per tooth: 0.4 mm/ tooth,
axial depth of cut: 0.15 mm,
radial depth of cut: 6 mm, and
number of teeth: 1.

[0033] Machinability was evaluated based on the following two points. First, an amount of the complex lubricating protective film including Al_2O_3 and MnS on the surface of the cutting tool was evaluated. The amount was determined as follows. When a machining length is 0.8m after the beginning of the machining, the insert was analysed from a rake face side with EPMA, and the amount was evaluated by average counts of Al and S. Then, the machining length was extended to 8 m and the tool wear at this time was measured using an optical microscope. These evaluation results are shown in Table 2.

[Table 2]

Sample No.	Average count of A1	Average count of S	Tool wear (mm)	Remarks
1	158	57	0.066	Example according to the invention
2	152	59	0.068	
3	167	50	0.065	
4	171	53	0.060	
5	153	69	0.040	
6	184	44	0.062	
7	155	41	0.062	
8	110	41	0.052	
9	162	111	0.048	
10	153	96	0.046	
11	125	77	0.049	
12	145	104	0.044	
13	90	70	0.064	
14	106	71	0.051	
15	138	122	0.058	
21	8	3	0.429	Comparative Example
22	57	9	0.106	
23	28	8	0.194	
24	19	5	0.071	
25	45	7	0.282	
26	86	24	0.082	
27	37	9	0.106	
28	57	26	0. 112	
29	77	10	0.235	
30	7	3	0.100	
31	87	8	0. 547	

(continued)

Sample No.	Average count of A1	Average count of S	Tool wear (mm)	Remarks
32	64	3	0.126	
33	101	22	0.118	
34	110	39	0.091	
35	109	25	0. 130	

[0034] In the machining of the cold-work tool steels of the present invention, the complex lubricating protective film is formed on the surface of the cutting tool to suppress the tool wear. Even in a case where Nb and V are added for forming insoluble carbides, good machinability is maintained. On the contrary, in the machining for the cold-work tool steels that do not satisfy the requirements of the present invention, the tool wear is larger than the steels of the present invention.

[0035] Figs. 1A to 1E are digital microscope photographs showing flank faces and rake faces of cutting tools used for, respectively, Samples Nos. 3, 5, 15, 22 and 30. Figs. 2A to 2E are analysis results of belag on the surfaces in, respectively, Figs. 1A to 1E with use of EPMA, in which a high concentration portion of each element is represented in white colour. Samples Nos. 3, 5 and 15 exhibit large average counts of Al and S in Table 2, and it has been confirmed that much Al and S are attached over a wide region in the EPMA analysis of Figs. 2A to 2C. On the contrary, Sample No. 22 having smaller amount of Al has smaller average counts of Al and S and smaller attached Al and S than Samples Nos. 3, 5 and 15. Since Sample No. 30 originally has small Al and S contents in the steel, the average counts of these elements are small and Al and S are hardly detected in the EPMA analysis (detected elements were mostly Fe and Cr which were likely transferred from the test piece).

[0036] It is seen from Figs. 1A to 1C showing wear states of the cutting tools that a belag is remarkably attached on the rake face of the tool of each Sample Nos. 3, 5 and 15 corresponding to the above results, and the wear of the tool is suppressed on both of the flank and rake faces. In addition, the wear progresses uniformly and stably. On the contrary, the tool wear of Sample No. 22 is nearly twice that of Sample No. 3, and chipping also occurs on the tool. Surface of the tool No. 30 is also severely damaged as Sample No. 22.

[0037] Furthermore, Figs. 3A to 3C are cross sectional TEM images showing belag confirmed on the surfaces of the tools of respectively Samples No. 3, 22 and 30, together with an underlying TiN coating. In the figures, reference number 1 denotes a protective film for preparing a sample, reference number 2 denotes a belag at the time of machining, reference number 3 denotes a plastically deformed TiN region, and reference number 4 denotes an undeformed TiN region. According to the above results, Sample No. 3 having large average counts of Al and S has a thick belag, and the belag becomes thinner as the counts decreases as Sample No. 22. Sample No. 30 was hardly observed to have a belag. Although Al_2O_3 and MnS are also attached on the surface of the tool for Sample No. 22 as Sample No. 3, the thicknesses thereof are thin and chipping occurred as described above. The belag of Sample No. 3 exerts a high lubricating protective function. It can be seen from the fact that the TiN coating on the surface of the tool is prevented from plastic deformation in Sample No. 3 having a thick belag (that is, the narrowest plastically deformed region), while the TiN coating is usually plastically deformed by a frictional stress at the time of machining.

Claims

1. A method of manufacturing a cold-work die, comprising:

hot working an ingot of a cold-work tool steel to produce a base material, wherein the cold-work tool steel comprises, in mass%,

0.6 to 1.2% of C,
0.8 to 2.5% of Si,
0.4 to 2.0% of Mn,
0.03 to 0.1% of S,
5.0 to 9.0% of Cr,

one or both of Mo and W being 0.5 to 2.0% in a form of (Mo + 1/2W),

0.04 to less than 0.3% ofAl, and
optionally not greater than 1.0% of Ni,

optionally not greater than 1.0% of Cu,
optionally not greater than 1.0% of V,
optionally not greater than 0.5% of Nb,

the balance being Fe and inevitable impurities;
quenching and tempering the base material as hardening so as to have a hardness of 58 to 62HRC; and
then machining the material in a die shape.

2. The method according to claim 1, comprising annealing the hot worked base material before the quenching and tempering.

3. The method according to claim 1, wherein the quenching is conducted in the course of cooling from the hot working.

4. The method according to any one of claims 1 to 3, wherein the die has a hardness of not lower than 60 HRC after the hardening.

Patentansprüche

1. Verfahren zum Herstellen einer kaltbearbeiteten Matrize, das Folgendes umfasst:

Warmarbeiten eines Rohblocks eines kaltbearbeiteten Werkzeugstahls, um ein Grundmaterial zu fertigen, wobei der kaltbearbeitete Werkzeugstahl Folgendes in Massenprozent umfasst:

0,6 bis 1,2 % von C,
0,8 bis 2,5 % von Si,
0,4 bis 2,0 % von Mn,
0,03 bis 0,1 % von S,
5,0 bis 9,0% von Cr,

entweder 0,5 bis 2,0 % von Mo oder W oder beides in einer Form von (Mo + 1/2W),

0,04 bis weniger als 0,3 % von Al und
wahlweise nicht mehr als 1,0 % von Ni,
wahlweise nicht mehr als 1,0 % von Cu,
wahlweise nicht mehr als 1,0 % von V,
wahlweise nicht mehr als 0,5 % von Nb,

wobei das Gleichgewicht Fe und unvermeidbare Unreinheiten sind;
Abschrecken und Anlassen des Grundmaterials zum Härten so, dass es eine Härte von 58 bis 62 HRC besitzt; und
dann maschinelles Bearbeiten des Materials in eine Matrizengestalt.

2. Verfahren nach Anspruch 1, das das Glühen des warmgearbeiteten Grundmaterials vor dem Abschrecken und Anlassen umfasst.

3. Verfahren nach Anspruch 1, wobei das Abschrecken im Laufe des Kühlens von dem Warmarbeiten durchgeführt wird.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei die Matrize nach dem Härten eine Härte von nicht weniger als 60 HRC besitzt.

Revendications

1. Procédé de fabrication d'une matrice pour travail à froid, comprenant :

le travail à chaud d'un lingot d'un acier à outils pour travail à froid pour produire un matériau de base, dans lequel l'acier à outils pour travail à froid comprend, en % en masse,

0,6 à 1,2 % de C,
0,8 à 2,5 % de Si,
0,4 à 2,0 % de Mn,
0,03 à 0,1 % de S,
5,0 à 9,0 % de Cr,

l'un ou les deux de Mo et W étant de 0,5 à 2,0 % sous forme de (Mo + 1/2 W),

0,04 à moins de 0,3 % d'Al, et
facultativement pas plus de 1,0 % de Ni,
facultativement pas plus de 1,0 % de Cu,
facultativement pas plus de 1,0 % de V,
facultativement pas plus de 0,5 % de Nb,

le solde étant du Fe et des impuretés inévitables ;
la trempe et le revenu du matériau de base en tant que durcissement de manière à avoir une dureté de 58 à 62 HRC ; et
puis l'usinage du matériau sous forme de matrice.

2. Procédé selon la revendication 1, comprenant un recuit du matériau de base travaillé à chaud avant la trempe et le revenu.

3. Procédé selon la revendication 1, dans lequel la trempe est réalisée au cours du refroidissement à partir du travail à chaud.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel la filière a une dureté de pas moins de 60 HRC après le durcissement.

FIG.1A

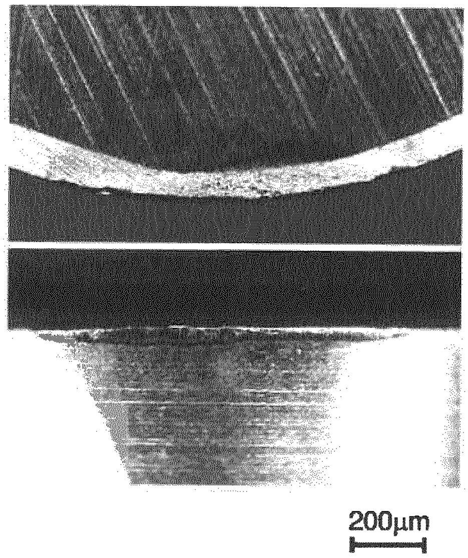


FIG.1B

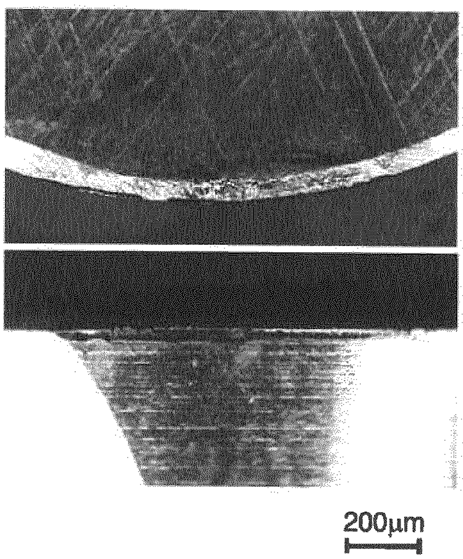


FIG.1C

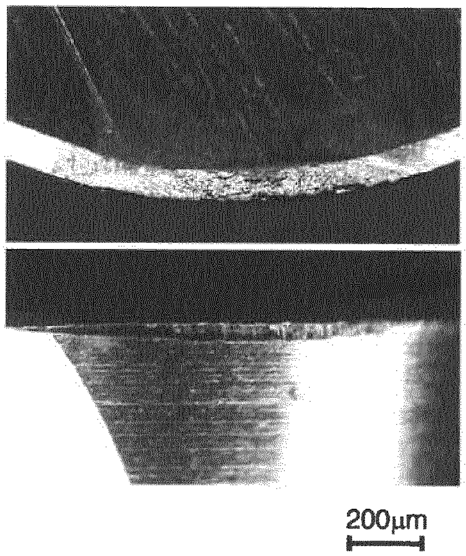


FIG.1D

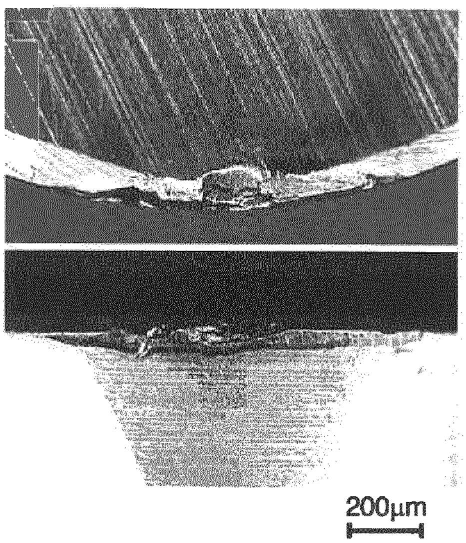


FIG.1E

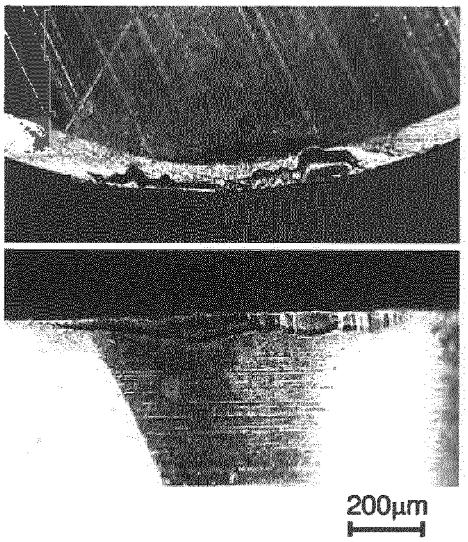


FIG.2A

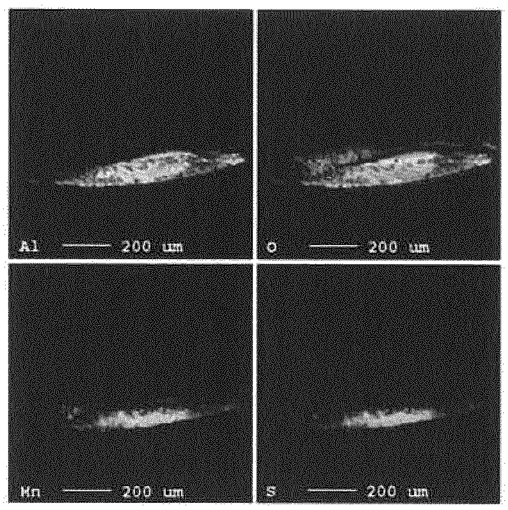


FIG.2B

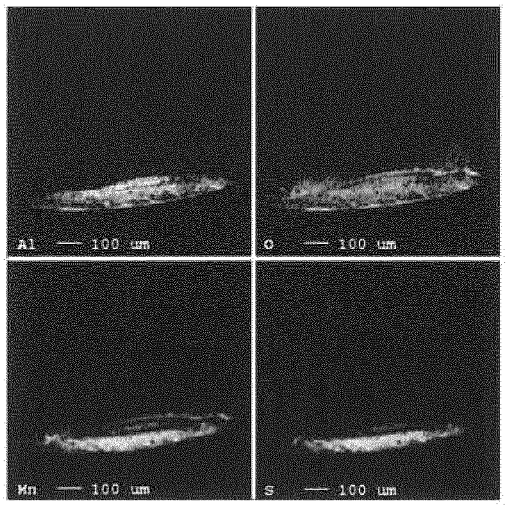

Al 100 um
O 100 um
Mn 100 um
S 100 um

FIG.2C

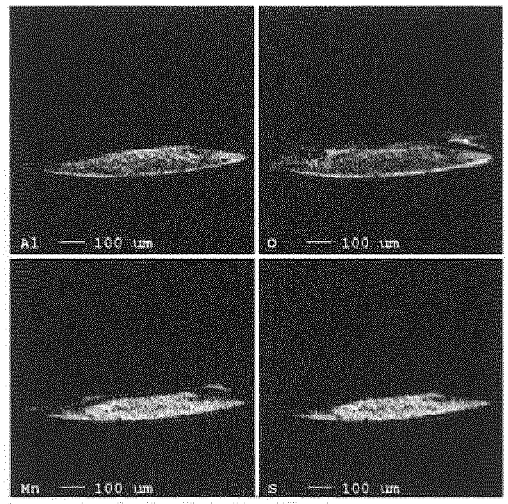

Al 100 um
O 100 um
Mn 100 um
S 100 um

FIG.2D

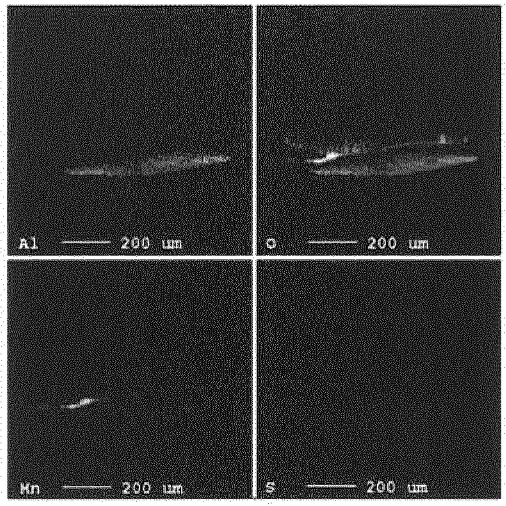

Al 200 um
O 200 um
Mn 200 um
S 200 um

FIG.2E

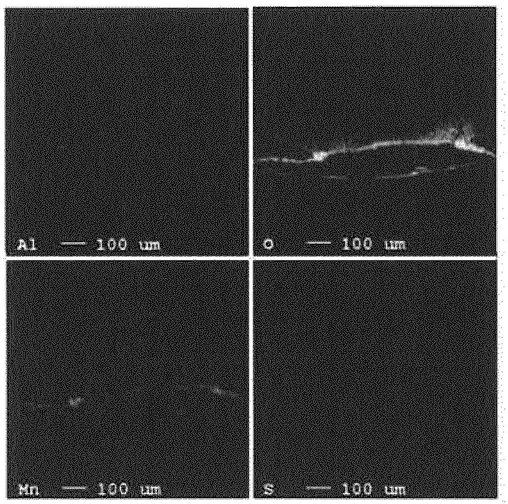

Al 100 um
O 100 um
Mn 100 um
S 100 um

FIG.3A

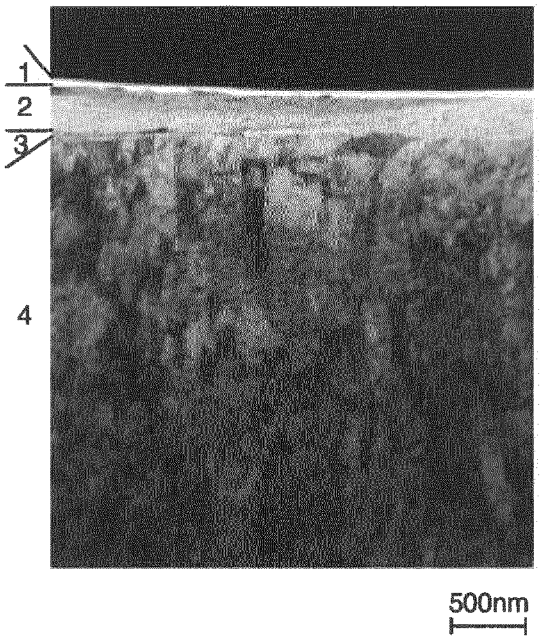


FIG.3B

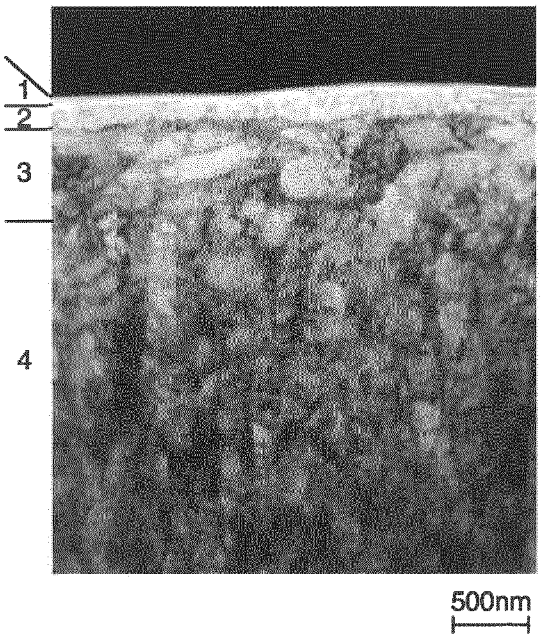
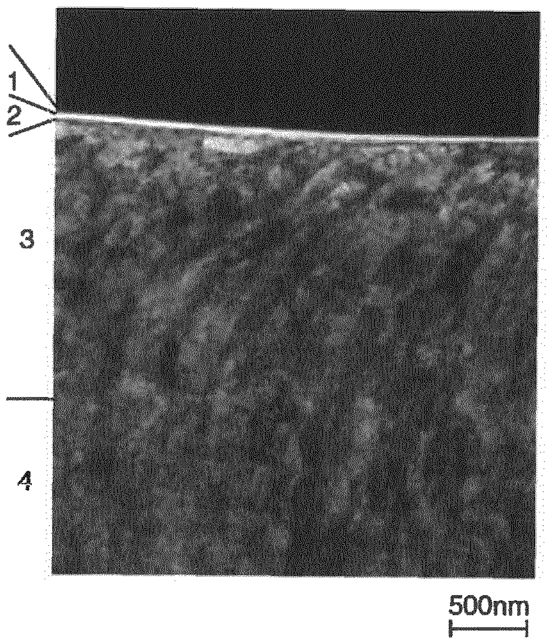


FIG.3C



REFERENCES CITED IN THE DESCRIPTION

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