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(54) **Corrosion resistant steel having good cold-workability and machinability**

(57) Disclosed is a corrosion resistant steel suitable for the material of printer shafts. The steel has good machinability, corrosion resistance sufficient for ordinary indoor use without plating the product surfaces, and improved straightness after wire drawing and cold workability, and further, is less expensive. Alloy composition is, by weight percent, C: 0.005-0.200%, Si: up to 1.0%, Mn: up to 2.0%, P: up to 0.05%, Cu: up to 2.0%, Ni: up to 2.0%, Cr: 2.0-9.0%, one or both of Ti and Zr:

$[\text{Ti}\%]+0.52[\text{Zr}\%]=0.03-1.20\%$ , one or both of S: 0.01-0.50% and Se:0.01-0.40%, N: up to 0.050% and O: up to 0.030%, and the balance of Fe and inevitable impurities, with the conditions of  $[\text{S}\%] \geq 32[\text{C}\%]/12$ , and  $0 < L \leq 0.5$ , wherein  $L=4[\text{C}\%]/([\text{Ti}\%]+0.52[\text{Zr}\%])$ . The inclusions therein are, Ti-based, Zr-based, or Ti-Zr-based compound or compounds containing C and one or both of S and Se .

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**Description**

## BACKGROUND OF THE INVENTION

5 Technical Field

**[0001]** The present invention concerns a corrosion resistant steel, more specifically, a corrosion resistant steel having good cold workability and machinability.

10 Prior Art

**[0002]** Requisites for the material of parts of devices used indoor such as "OA" devices are good cold workability and machinability, and further, corrosion resistance of the level at which the parts can be used indoor environment. Production of such the parts is carried out by using a stainless steel or by plating parts made of a structural steel. 15  
Needless to say, stainless steel has good corrosion resistance but is expensive, while structural steel is less expensive but has lower corrosion resistance.

**[0003]** Recently, personal computers came into wide use and demand for printers is increasing. Printers contain plural shafts such as paper-feeding shafts and character-printing shafts, and reduction of costs for the printers depends on reduction of costs for the shafts. A common requisite for the shafts is high straightness.

20 **[0004]** Now the conventional materials for the printer shafts are outlined below. For laser printers stainless steels such as SUS420J2 or SUS410 are used. On the other hand, for ink-jet printers free-cutting steels such as SUM24L and SUM22 of structural steels are chosen, and after being machined, the shafts are Ni-plated for use. In the latter case, the straightness can be ensured by regulating hardness of the material before wire drawing.

25 **[0005]** The printer shafts should have, as mentioned above, the corrosion resistance of the level at which the device can be used under indoor environment, expensive stainless steels such as SUS420J2 or SUS410 are not appropriate materials from the viewpoint of cost-performance. On the other hand, in case of plating machined shafts of free-cutting steels such as SUM24L, quality of the products tends to disperse due to thickness differences of plated films and presence of surface defects, and the quality dispersion often result in lower product liability. To practice the plating it is necessary to consider treatment of the resulting waste liquid from the view to prevent environmental pollution. The 30  
expense for the treatment is getting higher, and thus, the costs for the shafts cannot be said low.

**[0006]** In order to solve the above problems the inventors have intended to establish a steel which has good machinability and straightness as well as corrosion resistance sufficient for use under indoor environment, and further, which is less expensive, and made research with some coworkers. As the result of the search we have learnt that a corrosion resistant steel containing specific inclusions is useful, and disclosed (Japanese Patent Disclosure 2002-339047). The 35  
disclosed corrosion resistant steel is the steel containing C: 0.005-0.200%, Si: up to 1.0%, Mn: up to 2.0%, P: up to 0.05%, Cu: up to 2.0%, Ni: up to 2.0%, and Cr: 2.0-9.0%, and in which Ti-based, Zr-based or Ti-Zr-based compounds containing C and one or both of S and Se, such as  $(Ti,Zr)_4(S,Se)_2C_2$ , are formed by addition of specific amounts of S, Se, Ti and Zr. The steel, because of fine dispersion of these compounds, has not only good machinability, but also good corrosion resistance, cold workability and hot-workability.

40 **[0007]** Upon further research we have discovered that, in the corrosion resistant steel of the above alloy composition, choice of the relations between S-amount and C-amount, C-amount and (Ti+Zr)-amount, and (S+Se)-amount and (Ti+Zr)-amount in specific ranges results in further improvement in the corrosion resistance and machinability, or, improvement in, of the cold workability, cold forgeability or machinability in drilling.

45 SUMMARY OF THE INVENTION

**[0008]** The basic object of the present invention is to provide a corrosion resistant steel suitable for the material of the shafts, which satisfies the strict standard of the straightness by regulating material hardness before wire drawing without heat treatment after wire rolling, which has corrosion resistance sufficient for use under indoor environment 50  
without plating and good cold workability and machinability, and is less expensive than stainless steels.

**[0009]** Additional object of the present invention is to provide, among the above-mentioned corrosion resistant steel, those having good cold forgeability, and those having good machinability in drilling, thus suitable as the material for production of not only the printer shafts but also the other parts.

55 **[0010]** The corrosion resistant steel of the invention achieving the above-noted basic object of the invention is the steel having good cold workability and machinability, which is characterized in that the steel consists essentially of the alloy components of, by weight percent, C: 0.005-0.200%, Si: up to 1.0%, Mn: up to 2.0%, P: up to 0.05%, Cu: up to 2.0%, Ni: up to 2.0%, Cr: 2.0-9.0%, one or both of Ti and Zr:  $[Ti\%]+0.52[Zr\%]=0.03-1.20\%$ , one or both of S: 0.01-0.50% and Se:0.01-0.40%, N: up to 0.050% and O: up to 0.030%, and the balance of Fe and inevitable impurities, and that

the steel contains, as the inclusions therein, Ti-based, Zr-based, or Ti-Zr-based compound or compounds containing C and one or both of S and Se in the conditions of  $[S\%] \geq 32[C\%]/12$ , and  $0 < L \leq 0.5$ , wherein  $L = 4[C\%]/([Ti\%] + 0.52[Zr\%])$ .

5 DETAILED EXPLANATION OF THE PREFERRED EMBODIMENTS

**[0011]** The steel of the invention achieving particularly good cold forgeability, one of the above-noted specific objects, has an alloy composition satisfying the condition:  
 $0 < H \leq 0.5$ , wherein  $H = 1.5([S\%] + 0.40[Se\%])/([Ti\%] + 0.52[Zr\%])$ .

10 **[0012]** The steel of the invention achieving particularly good machinability in drilling, the other of the above-noted specific objects, has an alloy composition satisfying the condition:  
 $0.5 < H \leq 1.2$ , wherein  $H = 1.5([S\%] + 0.40[Se\%])/([Ti\%] + 0.52[Zr\%])$ .

**[0013]** The corrosion resistant steel of the invention suitable as the material for the use such as printer shafts may contain, in addition to the above-defined alloy components, one or more of the members of the following groups.

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- (1) one or both of Mo: 0.1-4.0% and W: 0.1-3.0%,
  - (2) at least one of Pb: 0.01-0.30%, Te: 0.005-0.30% and Bi: 0.01-0.20%,
  - (3) at least one of Ca, Mg B and REM of 0.005-0.010%, and
  - (4) at least one of Nb, V, Ta and Hf of 0.01-0.50%.
- 20

**[0014]** The following explains the reasons for choosing the alloy components of the basic alloy composition as described above and restricting the ranges of the compositions.  
 C: 0.005-0.200%, preferably, 0.010-0.100%

25 **[0015]** Carbon is an important element for forming the compounds which improve the machinability of the steel. Unless the C-content reaches 0.005% or higher, there will not be formed sufficient amounts of the compounds to improve the machinability. If the C-content exceeds 0.200%, large amount of simple carbides will occur and damage the machinability. The amount of carbon should be chosen to an adequate level in view of the other elements which form the compounds improving the machinability. A preferable range of C-addition is 0.010-0.100%.  
 Si: up to 1.0%

30 **[0016]** Silicon is added as the deoxidizing agent at steelmaking. Too much addition of Si not only increases hardness of the steel after heat treatment for solid-solution and results in lowered cold workability, but also increases  $\delta$ -ferrite formation and results in lowered hot-workability and corrosion resistance. Thus, the upper limit of Si-content is set to be 1.0%. In case where the machinability and the straightness are particularly important, the Si-content should be limited to 0.15% or less.

35 Mn: up to 2.0%

**[0017]** Manganese, on one hand, is a deoxidizing agent of the steel, and on the other hand, improves the machinability by forming the compounds with S and Se. However, MnS, formed by combination of Mn and S, significantly lowers the corrosion resistance, cold workability and straightness. Thus, the upper limit of Mn-content is set to be 2.0%. In case where much importance is attached to the corrosion resistance and the straightness, it is preferable to restrict the Mn-content to 0.40% or less.

40 P: up to 0.05%

**[0018]** Phosphor is an impurity of the steel, which segregates at grain boundaries to heighten intergranular corrosion sensitivity. Therefore, the lower the P-content is, the better. However, dephosphorization to an extremely low level causes increase in the manufacturing cost, and 0.05% is set as the allowable upper limit. Preferably, the P-content is 0.030% or less.

45 Cu: up to 2.0%

**[0019]** Copper is an element effective for improving corrosion resistance, particularly in the atmosphere of reducing acid. Because excess amount of Cu lowers the hot workability, the content should be restricted to 2.0% at highest.

Ni: up to 2.0%

50 **[0020]** Nickel improves the corrosion resistance of the steel, and is necessary for increasing the corrosion resistance given by adding Cr only, which is not sufficient. Addition amount of Ni should not exceed 2.0%, since a larger amount of Ni increases the manufacturing cost. It is desirable that the Ni-content is chosen in the range of 0.3-0.8% for ensuring sufficient corrosion resistance and good straightness.

Cr: 2.0-9.0%

55 **[0021]** Chromium is an element improving corrosion resistance. If the content is less than 2.0%, sufficient corrosion resistance cannot be obtained. On the other hand, at a Cr-content exceeding 9.0% straightness, workability and machinability decrease and the cost increases. Suitable range of Cr-addition in view of the balance of the corrosion resistance and the cost is 6.0-9.0%.

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One or both of Ti and Zr, in term of  $[\text{Ti}\%]+0.52[\text{Zr}\%]$ : 0.03-1.20%

**[0022]** Titanium and zirconium form, by coexisting with C and one of S and Se, or with one of S and Se, the compounds such as  $(\text{Ti,Zr})_4(\text{S,Se})_2\text{C}_2$  and  $(\text{Ti,Zr})(\text{S,Se})$ , which contribute to improvement in the machinability. Particularly, the former compound renders services to the machinability without lowering the corrosion resistance and without damaging the cold forgeability due to fine dispersion thereof in the steel. In order to enjoy such merits it is necessary to have Ti and Zr contained in the amounts, in terms of  $[\text{Ti}\%]+0.52[\text{Zr}\%]$ , 0.03-1.20%. Excess content more than 1.2% causes formation of hard inclusions, TiN and  $\text{TiO}_2$ , which increase hardness of matrix and results in lowered machinability.

One or both of S: 0.01-0.50% and Se: 0.01-0.40%

**[0023]** As described above, sulfur and selenium contribute to improvement in machinability by coexisting with Ti and Zr, together with S, to form the compounds of  $(\text{Ti,Zr})_4(\text{S,Se})_2\text{C}_2$  and  $(\text{Ti,Zr})(\text{S,Se})$ . For the purpose of forming desirable amounts of these compounds it is necessary to have S contained in the amount of 0.01% or Se in the amount of 0.01%. Because excess amounts of S and Se are harmful to the hot workability and the machinability, the upper limits of addition are set to be 0.50% for S and 0.40% for Se.

N: up to 0.050%

**[0024]** Nitrogen is one of the impurities of the steel. Nitrogen combines with Ti and Zr, which are necessary for forming the machinability-improving compounds, and forms nitrides, which are harmful to the machinability, and therefore, it is necessary to reduce the N-content in the steel to the lowest possible level. However, decrease of N-content to the extremity incurs increase in the manufacturing cost, and the allowable upper limit is set to be 0.050%. Preferably, the upper limit of N-content is 0.025%, more preferably, 0.010%.

O: up to 0.030%

**[0025]** Oxygen is also one of the impurities of the steel. Like nitrogen, oxygen combines with Ti and Zr, which are necessary for forming the machinability-improving compounds, and forms oxides, which are harmful to the machinability, and therefore, it is necessary to reduce the O-content as low as possible. Of course, extreme decrease of O-content also increases the manufacturing cost, and the allowable upper limit is set to be 0.030%. Preferably, O-content is limited to 0.010% or lower.

**[0026]** Effect of addition of the optional components of the present steel and the reasons for restricting the composition ranges are explained below.

One or both of Mo: 0.1-4.0% and W: 0.1-3.0%

**[0027]** Both molybdenum and wolfram are the elements further improving the machinability of the present steel, if added. In order to obtain the effect, the steel must contain one or both of Mo and W in an amount of 0.1% or more. Too much addition, however, causes decreased hot workability and increased manufacturing cost. The upper limits of the contents are thus decided to be 4.0% for Mo and 3.0% for W.

At least one of Pb: 0.01-0.30%, Te: 0.005-0.30% and Bi: 0.01-0.20%

**[0028]** Lead, tellurium and bismuth are the elements further improving the machinability of the steel. To obtain the effect, it is necessary to add 0.01% or more of Pb, 0.005% or more of Te, or 0.01% or more of Bi. Addition of large amount or amounts will damage the hot workability of the steel, and the contents are limited not to exceed the upper limits, 0.30% for Pb, 0.30% for Te and 0.20% for Bi.

At least one of Ca, Mg, B and REM: 0.005-0.010%

**[0029]** Calcium, magnesium, boron and rare earth metals are the elements improving hot workability of the steel. For this purpose one or more of these elements are added in an amount (when two or more are added, in total) of 0.005% or higher. If the addition is made in an excess amount, reverse effect, decreased hot workability, will be observed. Thus, the addition amount should not exceed 0.010%.

At least one of Nb, V, Ta and Hf: 0.01-0.50%

**[0030]** Niobium, vanadium, tantalum and hafnium are the elements which form carbonitrides and, by making the crystal grains of the steel fine, enhance the toughness of the steel. In order to ensure this effect, one or more of these elements are added in an amount (when two or more are added, in total) of 0.01% or higher. Excess addition causes formation of coarse carbonitride particles, which effect contrarily to lower the toughness. The addition amount must be not higher than 0.50%.

$[\text{S}\%] \geq 32[\text{Cr}\%]/12$

**[0031]** This condition means that, when the amounts of S and C are compared by atomic percentages, S is in the same amount as that of C or overwhelming. It is essential that the amount of S does not fall below the amount of C for preventing formation of carbides bringing about undesirable influence to the machinability.

$0 < L \leq 0.5$ , wherein  $L = 4[\text{C}\%]/([\text{Ti}\%]+0.52[\text{Zr}\%])$

**[0032]** In case where this condition is met, substantially no carbon forming the carbides exists in the matrix of the steel, and the resulting steel is a corrosion resistant steel exhibiting good cold workability and machinability. If the value of "L" exceeds 0.5, then excess C forms undesirable carbides.

**[0033]** Having the above-described alloy compositions, the corrosion resistant steel of the invention contains Ti-based, Zr-based or Ti-Zr-based compounds such as  $(\text{Ti,Zr})_4(\text{S,Se})_2\text{C}_2$ , which contain both C and S and/or Se as in-

clusions finely dispersed in the steel. Hardness of the steel is regulated by fixing C and decrease in corrosion resistance is prevented by fixing S, and as the results, the present steel has, in addition to the good machinability, good corrosion resistance, hot workability and cold workability (good straightness after wire drawing and cold forgeability).

$0 < H \leq 0.5$ , wherein  $H = 1.5([S\%] + 0.40[Se\%]) / ([Ti\%] + 0.52[Zr\%])$

5 **[0034]** In case where this condition is met, the corrosion resistant steel of the invention exhibits particularly good cold forgeability. This is because formation of inclusions is so suppressed to be in the necessary limit.

$0.5 < H \leq 1.2$ , wherein H is as defined above

10 **[0035]** On the other hand, in case where this condition is met, the corrosion resistant steel of the invention exhibits particularly high machinability in drilling. This is because the steel contains S and/or Se, which are machinability-improving elements, in the amount excess to form the necessary quantity of the above inclusions, and therefore, relatively large amount of MnS is formed and dispersed finely in the steel to give favorable influence to the machinability in drilling.

15 **[0036]** The corrosion resistant steel of the present invention may be produced by known technologies. This is because the present corrosion resistant steel may be prepared by adding the above-noted specific amounts of one or both of Ti and Zr, C and one or both of S and Se to the conventional steel containing Cr of 2.0-9.0% or the similar steel.

20 **[0037]** As shown in the data of the working examples described below the steel of the present invention enjoys the merits of good machinability, corrosion resistance sufficient to the ordinary indoor use, and lower manufacturing cost due to decreased Cr-content compared with those of the conventional stainless steel, which are the merits given by the above-noted steel already disclosed. No necessity of plating the surfaces of the shaft products gives advantage from the viewpoints of the cost saving and environmental protection. Further to the above-mentioned merits the present steel enjoys the additional merits of improvement in the cold workability, particularly, straightness after wire drawing. Choice of the alloy compositions makes it possible to produce a steel having desired properties, such as the steel of excellent cold forgeability, or alternatively, the steel of excellent machinability in drilling.

25 EXAMPLES

30 **[0038]** Molten steels of the alloy compositions as shown in TABLE 1 (Working Examples - Alloy Compositions), TABLE 2 (Working Examples-Alloy Compositions - continued) and TABLE 3 (Control Examples - Alloy Compositions) were prepared and cast into ingots. The ingots were bloomed into the billets of 155mm square section, and the billets were wire-rolled into wires of diameter 9.5mm. The wires were annealed and, after removal of surface scale, processed by a combined machine to straight rods. The straight rods were finished by a centerless grinder to be round rods of diameter 8mm, which were used as the samples.

35 **[0039]** Test pieces of diameter 8mm and length 400mm were cut off from the above samples. The test pieces were subjected to the tests of corrosion resistance, machinability and straightness by the methods described below.

[Corrosion Resistance]

40 **[0040]** The test pieces are kept in the warm, humid atmosphere of temperature 60°C and humidity 95%RH, for 240 hours, and occurrence of rust is observed.

[Machinability]

45 **[0041]** Machinability in turning was evaluated by turning the outer surface of 500 samples under the conditions below and by determining abrasion of tool tips.

Tool: Cemented carbide bites Feed: 0.05mm/rev.	Cutting Speed: 150mm/min. Depth of Cut: 1mm
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50 **[0042]** Machinability in drilling was evaluated by drilling 500 samples under the conditions below, and by determining abrasion of tool tips.

Tool: High speed drill Feed: 0.07mm/rev.	Cutting Speed: 15m/min. Depth of Hole: 10mm
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55 [Straightness]

**[0043]** The test pieces are set on a pair of points of support with distance of 400mm, then rotated, and the center

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run-out was measured with a dial gaze. The dimension is " $\mu\text{m}/400\text{mm}$ ".

**[0044]** In order to determine the cold forgeability, columnar test pieces of diameter 12mm and height 18mm were taken from the above billets. They were subjected to monoaxial compression test with a press of capacity 600 tons, and were evaluated by the critical upsetting ratios (the largest compression ratios where no crack is observed).

5 **[0045]** The test results are shown in TABLE 4, TABLE 5 and TABLE 6 together with the ratios between the specific alloy components.

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Table 1

Examples (Alloy Compositions)													
No.	C	Si	Mn	Ni	Cr	Ti	Zr	S	Se	P	O	N	Others
1	0.020	0.19	0.15	0.30	8.1	0.27	-	0.07	-	0.018	0.004	0.021	-
2	0.035	0.28	0.18	0.09	8.4	0.80	-	0.24	-	0.008	0.013	0.016	-
3	0.025	0.15	0.30	0.17	7.5	0.45	-	0.12	-	0.019	0.002	0.019	-
4	0.050	0.31	0.19	0.28	8.8	0.60	-	0.17	-	0.033	0.005	0.022	-
5	0.045	0.31	0.08	0.80	8.9	0.43	-	0.12	-	0.028	0.002	0.017	-
6	0.028	0.33	0.17	0.47	7.8	0.82	-	0.11	0.15	0.042	0.004	0.027	-
7	0.010	0.21	0.15	0.31	8.5	0.19	-	0.04	-	0.007	0.002	0.029	-
8	0.043	0.61	0.22	0.88	8.7	0.51	0.42	0.10	-	0.005	0.002	0.014	-
9	0.039	0.32	0.09	0.56	8.2	0.77	0.24	0.19	-	0.029	0.009	0.023	-
10	0.085	0.29	0.11	0.19	8.4	1.19	-	0.32	0.24	0.015	0.007	0.012	-
11	0.123	0.49	0.21	0.05	7.3	1.18	-	0.41	-	0.025	0.008	0.013	Mo2.3 Mg0.007
12	0.118	0.32	0.46	0.34	6.9	1.08	0.24	0.43	-	0.013	0.005	0.026	Cu0.2 B0.008
13	0.045	0.72	0.47	1.20	8.4	0.68	-	0.20	-	0.018	0.010	0.004	Bi0.08 Nb0.15
14	0.055	0.08	0.14	0.69	8.9	0.70	-	0.19	-	0.008	0.008	0.009	W 1.6 B0.005
15	0.067	0.61	0.13	0.41	6.8	0.91	-	0.23	-	0.019	0.005	0.009	-
16	0.088	0.30	0.17	1.88	7.8	1.02	-	0.46	-	0.033	0.011	0.012	Ca0.006 Ta0.22
17	0.044	0.04	0.23	0.55	8.3	0.63	-	0.31	-	0.028	0.009	0.021	Co1.2 Ca0.0056
18	0.057	0.32	0.31	0.41	8.2	0.73	-	0.48	0.20	0.042	0.010	0.012	Pb0.25
19	0.022	0.49	0.33	1.32	8.1	0.32	-	0.16	-	0.007	0.013	0.018	-

Table 2

Examples (Alloy Compositions - continued)													
No.	C	Si	Mn	Ni	Cr	Ti	Zr	S	Se	P	O	N	Others
20	0.039	0.29	0.11	1.68	8.9	0.70	-	0.22	0.32	0.005	0.003	0.014	W3.1 B0.007
21	0.051	0.30	0.12	0.08	9.0	0.56	-	0.14	-	0.029	0.005	0.008	-
22	0.062	0.31	0.14	0.08	8.5	0.89	-	0.20	-	0.015	0.007	0.007	Mo2.4 REM0.0031
23	0.067	0.81	0.15	0.69	7.5	0.90	-	0.26	-	0.002	0.008	0.010	-
24	0.087	0.41	0.16	0.28	8.3	0.84	-	0.23	-	0.019	0.003	0.012	Pb0.21
25	0.111	0.39	0.19	0.59	8.2	1.05	-	0.31	0.13	0.011	0.003	0.014	-
26	0.049	0.79	0.35	0.93	8.6	0.77	-	0.22	-	0.028	0.004	0.009	Mo1.2
27	0.066	0.46	0.25	0.33	8.5	0.88	-	0.18	-	0.011	0.004	0.014	Cu0.3 Mo0.5
28	0.132	0.29	0.13	0.22	7.4	1.20	-	0.35	-	0.019	0.001	0.021	Cu0.8
29	0.077	0.51	0.05	0.02	8.1	0.95	-	0.26	0.07	0.025	0.002	0.017	-
30	0.038	0.33	0.29	1.41	7.7	0.59	-	0.16	-	0.013	0.005	0.008	V0.4

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TABLE 3

Control Examples (Alloy Compositions)													
No.	C	Si	Mn	Ni	Cr	Ti	Zr	S	Se	P	O	N	Others
1	0.002	0.42	2.62	0.71	5.2	-	-	0.01	-	0.028	0.008	0.025	-
2	0.016	1.52	0.30	0.40	1.7	-	-	0.33	-	0.018	0.012	0.033	-
3	0.009	0.68	0.77	0.16	10.5	-	-	0.20	-	0.025	0.006	0.180	-
4	0.008	0.45	2.43	0.38	7.2	-	-	0.61	-	0.018	0.007	0.018	-

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TABLE 4

Examples (Test Results)									
No.	Ti+0.52 Zr	S+0.40 Se	4C/(Ti+0.52Zr)	1.5(S+0.4Se)/ (Ti+0.52Zr)	Rust	Machinability in turning	Machinability in drilling	Straightness	Critical upsetting ratio
1	0.27	0.07	0.30	0.39	No	51	70	8	≧84
2	0.80	0.24	0.18	0.45	No	33	65	9	≧84
3	0.45	0.12	0.22	0.40	No	55	66	6	≧84
4	0.60	0.17	0.33	0.43	No	57	72	9	≧84
5	0.43	0.12	0.42	0.42	No	46	68	5	≧84
6	0.82	0.17	0.14	0.31	No	60	73	7	≧84
7	0.19	0.04	0.21	0.32	No	61	76	3	≧84
8	0.73	0.10	0.24	0.21	No	56	69	4	≧84
9	0.89	0.19	0.17	0.32	No	43	59	9	≧84
10	1.19	0.42	0.29	0.52	No	37	48	7	82
11	1.18	0.41	0.42	0.52	No	40	51	6	80
12	1.20	0.43	0.39	0.54	No	42	50	5	81
13	0.68	0.20	0.26	0.44	No	57	74	9	≧84
14	0.70	0.19	0.31	0.41	No	54	73	7	≧84
15	0.91	0.23	0.29	0.38	No	59	69	4	≧84
16	1.02	0.46	0.35	0.68	No	49	47	6	≧84
17	0.63	0.31	0.28	0.74	No	60	49	5	≧84
18	0.73	0.56	0.31	1.15	No	58	52	9	≧84
19	0.32	0.16	0.28	0.75	No	65	41	10	≧84

TABLE 5

Examples (Test Results - continued)									
No.	Ti+0.52Zr	S+0.40Se	4C/(Ti+0.52Zr)	1.5(S+0.4Se)/ (Ti+0.52Zr)	Rust	Machinability in turning	Machinability in drilling	Straightness	Critical upsetting ratio
20	0.70	0.35	0.22	0.75	No	52	43	2	≧84
21	0.56	0.14	0.36	0.38	No	57	62	8	≧84
22	0.89	0.20	0.28	0.34	No	50	77	6	≧84
23	0.90	0.26	0.30	0.43	No	48	72	4	≧84
24	0.84	0.23	0.41	0.41	No	47	65	8	≧84
25	1.05	0.36	0.42	0.52	No	41	71	9	83
26	0.77	0.22	0.25	0.43	No	49	73	2	≧84
27	0.88	0.18	0.30	0.31	No	51	68	5	80
28	1.20	0.35	0.44	0.44	No	39	77	8	≧84
29	0.95	0.29	0.32	0.45	No	43	68	6	≧84
30	0.59	0.16	0.26	0.41	No	54	72	9	≧84

55                      50                      45                      40                      35                      30                      25                      20                      15                      10                      5

TABLE 6

Control Examples (Test Results)									
No.	Ti+0.52 Zr	S+0.40 Se	4C/(Ti+0.52Zr)	1.5(S+0.4Se)/ (Ti+0.52Zr)	Rust	Machinability in turning	Machinability in drilling	Straightness	Critical upsetting ratio
1	-	-	-	-	Yes	123	104	48	70
2	-	-	-	-	Yes	102	121	39	55
3	-	-	-	-	No	156	95	43	60
4	-	-	-	-	Yes	89	113	33	50

Claims

1. A corrosion resistant steel having good cold workability and machinability; **characterized in that** the steel consists essentially of the alloy components of, by weight percent, C: 0.005-0.200%, Si: up to 1.0%, Mn: up to 2.0%, P: up to 0.05%, Cu: up to 2.0%, Ni: up to 2.0%, Cr: 2.0-9.0%, one or both of Ti and Zr:  $[\text{Ti}\%]+0.52[\text{Zr}\%]=0.03-1.20\%$ , one or both of S: 0.01-0.50% and Se:0.01-0.40%, N: up to 0.050% and O: up to 0.030%, and the balance of Fe and inevitable impurities, and that the steel contains, as the inclusions therein, Ti-based, Zr-based, or Ti-Zr-based compound or compounds containing C and one or both of S and Se in the conditions of  $[\text{S}\%]\geq 32[\text{C}\%]/12$ , and  $0 < L \leq 0.5$ , wherein  $L=4[\text{C}\%]/([\text{Ti}\%]+0.52[\text{Zr}\%])$ .
2. The corrosion resistant steel according to claim 1, **characterized in that** the steel has particularly good cold forgeability with the alloy composition satisfying the condition of  $0 < H \leq 0.5$ , wherein  $H=1.5([\text{S}\%]+0.40[\text{Se}\%])/([\text{Ti}\%]+0.52[\text{Zr}\%])$ .
3. The corrosion resistant steel according to claim 1, **characterized in that** the steel has particularly good machinability in drilling with the alloy composition satisfying the condition of  $0.5 < H \leq 1.2$ , wherein  $H=1.5([\text{S}\%]+0.40[\text{Se}\%])/([\text{Ti}\%]+0.52[\text{Zr}\%])$ .
4. The corrosion resistant steel according to one of claims 1 to 3, **characterized in that** the steel further contains, in addition to the above-defined alloy components, by weight percent, one or both of Mo: 0.1-4.0% and W: 0.1-3.0%.
5. The corrosion resistant steel according to one of claims 1 to 4, **characterized in that** the steel further contains, in addition to the above-defined alloy components, by weight percent, at least one of Pb: 0.01-0.30%, Te: 0.005-0.30% and Bi: 0.01-0.20%.
6. The corrosion resistant steel according to one of claims 1 to 5, **characterized in that** the steel further contains, in addition to the above-defined alloy components, by weight percent, at least one of Ca, Mg B and REM of 0.005-0.010%.
7. The corrosion resistant steel according to one of claims 1 to 6, **characterized in that** the steel further contains, in addition to the above-defined alloy components, by weight percent, at least one of Nb, V, Ta and Hf of 0.01-0.50%.
8. Shafts for printers and electric motors made of the corrosion resistant steel according to one of claims 1 to 7.



European Patent  
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EUROPEAN SEARCH REPORT

Application Number  
EP 03 02 2733

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X,P	EP 1 260 601 A (DAIDO STEEL COMPANY LTD ;ISHIDA KIYOHITO (JP); DOKURITSU GYOUSEI H) 27 November 2002 (2002-11-27) * table 1 *	1-8	C22C38/50 C22C38/60
A,P	EP 1 262 573 A (DAIDO STEEL COMPANY LTD) 4 December 2002 (2002-12-04) * claim 1; tables 1A,3A,5A,7A *	1-8	
A,P	EP 1 262 572 A (DAIDO STEEL COMPANY LTD) 4 December 2002 (2002-12-04) * table 1 *	1-8	
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 251 (C-1199), 13 May 1994 (1994-05-13) -& JP 06 033186 A (DAIDO STEEL CO LTD), 8 February 1994 (1994-02-08) * abstract *	1-8	
A	EP 1 186 678 A (DAIDO STEEL CO LTD) 13 March 2002 (2002-03-13)		TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	EP 0 903 418 A (SUMITOMO METAL IND) 24 March 1999 (1999-03-24)		C22C
The present search report has been drawn up for all claims			
Place of search <b>MUNICH</b>		Date of completion of the search <b>15 January 2004</b>	Examiner <b>Catana, C</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 03 02 2733

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-01-2004

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1260601	A	27-11-2002	JP 2002339047 A	27-11-2002
			CN 1390973 A	15-01-2003
			EP 1260601 A1	27-11-2002
			US 2003063995 A1	03-04-2003
-----				
EP 1262573	A	04-12-2002	JP 2003049241 A	21-02-2003
			EP 1262573 A1	04-12-2002
			US 2003072672 A1	17-04-2003
-----				
EP 1262572	A	04-12-2002	JP 2003049240 A	21-02-2003
			EP 1262572 A1	04-12-2002
			US 2003072673 A1	17-04-2003
-----				
JP 06033186	A	08-02-1994	JP 3254738 B2	12-02-2002
-----				
EP 1186678	A	13-03-2002	JP 2002146487 A	22-05-2002
			EP 1186678 A1	13-03-2002
			US 2002068006 A1	06-06-2002
-----				
EP 0903418	A	24-03-1999	JP 10195599 A	28-07-1998
			JP 10212559 A	11-08-1998
			JP 10237582 A	08-09-1998
			CA 2243123 A1	04-06-1998
			DE 69718784 D1	06-03-2003
			DE 69718784 T2	18-12-2003
			EP 0903418 A1	24-03-1999
			KR 268536 B1	16-10-2000
			US 5922145 A	13-07-1999
			CN 1205036 A ,B	13-01-1999
			JP 10204578 A	04-08-1998
			WO 9823784 A1	04-06-1998
			JP 10298704 A	10-11-1998
			JP 10324952 A	08-12-1998
			JP 11001743 A	06-01-1999
-----				