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(54) **FREE-CUTTING STEEL**
AUTOMATENSTAHL
ACIER DE DECOLLETAGE

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- DATABASE CA [Online] CHEMICAL ABSTRACTS SERVICE, COLUMBUS, OHIO, US; FILIPPI, P. A. ET AL: "Automation of sulfide testing of improved-machinability steels" XP002305193 retrieved from STN Database accession no. 1979: 526841 -& SYMP. PAP. - INT. SYMP. QUANT. METALLOGR. , 199-208 PUBLISHER: ASSOC. ITAL. METALL., MILAN, ITALY. CODEN: 40BXAS, 1978, XP009039782

Description

[Technical Field]

5 **[0001]** The present invention relates to a free cutting steel, particularly, to a low carbon free cutting steel to which lead is not added or in which the lead addition amount is markedly decreased from the conventional level of 0.15 to 0.35 mass %, which is adapted for use as a substitute steel for the conventional low carbon resulfurized and leaded free cutting steel.

10 [Background Art]

15 **[0002]** A low carbon resulfurized and leaded free cutting steel, in which lead (Pb) and sulfur (S) are added as the free cutting elements to a low carbon steel for imparting a free-cutting capability to the steel, is known as a low carbon free cutting steel. However, there is a requirement for suppressing the use of Pb, which is used as one of the free cutting elements, in view of the earth environmental problem.

20 **[0003]** Such being the situation, Japanese Patent Disclosure (Kokai) No. 9-25539 (hereinafter referred to as "prior art 1") discloses a free cutting microalloyed steel without quenching and tempering to which Pb is not added. In this case, Nd is added to the steel for promoting the finely dispersed precipitation of MnS. Japanese Patent Disclosure No. 2000-160284 (hereinafter referred to as "prior art 2") also discloses a free cutting steel to which Pb is not added. In this case, a large amount of S is added to the steel so as to increase the amount of the sulfide, and the form of the sulfide is controlled by oxygen. Further, Japanese Patent Publication (Kokoku) No. 2-6824 (hereinafter referred to as "prior art 3") discloses a free cutting steel, in which Cr having a reactivity with S to form a compound higher than that of Mn is added to the steel so as to form CrS in place of MnS, thereby improving the free-cutting capability.

25 **[0004]** However, prior art 1 is directed to a microalloyed steel containing 0.2 to 0.6% of C without quenching and tempering. In addition, a special element of Nd is used in prior art. It follows that it is impossible to comply sufficiently with the requirement for the cost reduction. Also, a large amount of S is added to the steel in prior art 2, with the result that the hot ductility of the steel tends to be lowered. Further, prior art 3 necessitates the addition of a large amount reaching 3.5 to 5.9% of costly Cr, resulting in failure to comply sufficiently with the requirement for the cost reduction. In addition, formation of a large amount of CrS as in prior art 3 is disadvantageous because the difficulty accompanying the smelting of the material is increased by the presence of a large amount of CrS.

30 **[0005]** There is a strong requirement for the further improvement in the machinability of the low carbon resulfurized and leaded free cutting steel in view of the reduction in the machining cost.

35 **[0006]** In compliance with the requirement, Japanese Patent Disclosure No. 1-32302 (hereinafter referred to as "prior art 4") discloses a free cutting steel, in which a relatively large amount of S is added to the steel so as to increase the amount of the sulfide, and the form of the sulfide is controlled by Te, and the oxygen amount is suppressed to 0.0030% or less so as to decrease the number of alumina clusters, thereby improving the machinability of the free cutting steel. Also, Japanese Patent Disclosure No. 1-309946 (hereinafter referred to as "prior art 5") discloses a free cutting steel, in which a relatively large amount of S is added to the steel so as to increase the amount of the sulfide, and a free cutting element of Pb is added to the steel so as to improve the machinability of the free cutting steel. Prior art 5 also teaches that the oxygen amount is suppressed to 0.008% or less for preventing the streak flaw caused by the gigantic oxide.

40 **[0007]** In each of prior arts 4 and 5, however, the form of the sulfide which effective for improving the machinability of the free cutting steel cannot be controlled sufficiently because the oxygen content of the steel is low, with the result that an elongated sulfide comes to be present in the steel. It follows that the free cutting steel is incapable of producing a sufficient effect of improving the machinability of the free cutting steel. Also, as described previously, the free cutting steel of prior art 2 is excellent in machinability because the form of a large amount of the sulfide is controlled by oxygen. However, the hot ductility of the free cutting steel tends to be lowered because a large amount of S is added to the steel.

45 **[0008]** On the other hand, the resulfurized and resulfurized and leaded free cutting steels contain in general a large amount of oxygen in order to control the form of the sulfide which is effective for improving the machinability of the free cutting steel. However, since all the oxygen does not dissolve in the sulfide, it is unavoidable for a gigantic oxide to be formed so as to cause the streak flaw, thereby giving rise to a serious defect in the processed article.

50 **[0009]** In prior art 5, the oxygen content of steel is suppressed to 0.008% or less in order to avoid generation of the streak flaw. In prior art 2, the required amount of oxygen is decreased by increasing the addition amount of S. Further, in prior art 1, the required amount of oxygen is decreased by using Nd as a free cutting element.

55 **[0010]** In prior art 5, however, the oxygen amount is simply decreased, though the oxygen amount is limited to 0.008% or less. Therefore, the form of the sulfide cannot be sufficiently controlled, as desired, with the result that an elongated sulfide comes to be present in the steel. It follows that the free cutting steel disclosed in prior art 5 cannot be said to be satisfactory in terms of the machinability. Also, concerning the free cutting steel disclosed in prior art 2, the reduction in the hot ductility caused by S is worried about as pointed out previously. Further, in prior art 1, as described above, there

is a problem that it is difficult to reduce the cost.

[Disclosure of the Invention]

5 **[0011]** An object of the present invention is to provide a low carbon free cutting steel to which lead is not added or in which the lead addition amount is markedly lowered from the level in the conventional low carbon resulfurized and leaded free cutting steel, the low carbon free cutting steel being allowed to exhibit a machinability fully comparable to or higher than that in the conventional low carbon resulfurized and leaded free cutting steel without obstructing the cost reduction and without lowering the hot ductility.

10 **[0012]** According to the present invention, there is provided a low carbon free cutting steel containing 0.02 to 0.15 mass % of C, 0.05 to 1.8 mass % of Mn, 0.20 to 0.49 mass % of S, more than 0.01 mass % and not more than 0.03 mass % of O, 0.3 to 2.3 mass % of Cr, not more than 0.1 mass % of Si, 0.01 to 0.12 mass % of P, and not more than 0.01 mass % of Al and the balance consisting of Fe and inevitable impurities, the Cr/S ratio falling within a range of between 2 and 6, wherein the sulfides having the major axis of at least 10 μ m occupy at least 90% of all the sulfides and the sulfides having an aspect ratio not larger than 5 occupies at least 80% of the sulfides having the major axis of at least 10 μ m.

[Brief Description of the Drawing]

20 **[0013]**

FIG. 1 is a drawing for explaining an aspect ratio ; and
FIG. 2 is a graph showing the relationship in tool life between turning and drilling.

25 [Best Mode for Working the invention]

[0014] The present invention will now be described in detail.

30 **[0015]** A free cutting steel is provided by the low carbon free cutting steel according to the first aspect of the present invention, containing 0.02 to 0.15 mass % of C, 0.05 to 1.8 mass % of Mn, 0.20 to 0.49 mass % of S, more than 0.01 mass % and not more than 0.03 mass % of O, 0.3 to 2.3% of Cr, not more than 0.1 mass % of Si, 0.01 to 0.12 mass % of P, and not more than 0.01 mass % of Al and the balance consisting of Fe and inevitable impurities, the Cr/S ratio falling within a range of between 2 and 6, wherein the sulfides having the major axis of at least 10 μ m. occupy at least 90% of all the sulfides and the sulfides having an aspect ratio not larger than 5 occupies at least 80% of the sulfides having the major axis of at least 10 μ m.

35 **[0016]** It is possible for the free cutting steel of the present invention to further contain at least one element selected from the group consisting of 0-0001 to 0.0005 mass % of Ca, 0.01 to 0.03 mass % of Pb, 0.02 to 0.30 mass % of Se, 0.1 to 0.15 mass % of Te, 0.02 to 0.20 mass % of Bi, 0.003 to 0.020 mass % of Sn, 0.004 to 0.010 mass % of B, 0.005 to 0.015 mass % of N, 0.05 to 0.50 mass % of Cu, 0.003 to 0.090 mass % of Ti, 0.005 to 0.200 mass % of V, 0.005 to 0.090 mass % of Zr, and 0.0005 to 0.0080 mass % of Mg.

40 **[0017]** In the free cutting steel of the composition described above, it is desirable for the particular free cutting steel to have a ferrite-pearlite micro structure with a prior austenite grain diameter exceeding the grain size number 7.

[0018] As a result of an extensive research conducted in an effort to achieve the object described above, the present inventors have found that:

- 45 (i) It is possible to obtain a suitable amount of a sulfide containing both Cr and Mn by the addition of suitable amounts of Cr, Mn and S and by optimizing the Cr/S ratio. Since the sulfide containing both Cr and Mn suppresses the elongation in the hot working step, it is possible to allow the sulfide to be large and to be formed like a spindle.
- (ii) In view of the idea known to the art that, where the S amount is the same, the machinability of the free cutting steel is improved with increase in the size of the sulfide and with change in the form of the sulfide toward the spindle shape, it is considered reasonable to understand that a large and spindle-shaped sulfide is formed by the addition of suitable amounts of Cr, Mn and S and by the optimization of the Cr/S ratio, thereby improving the machinability of the free cutting steel including the chip disposability and the surface roughness.
- 50 (iii) It is known to the art that the machinability is improved with increase in the S amount. However, there is an upper limit in the S amount because of the problem in terms of the anisotropy in the hot workability or the mechanical properties. On the other hand, if a large and spindle-shaped sulfide is formed by the addition of suitable amounts of Cr, Mn and S and by the optimization of the Cr/S ration as described above, it is possible to elevate the upper limit of the S amount. As a result, the machinability of the free cutting steel including the chip disposability and the surface roughness can be markedly improved, even if Pb is not added or even if the Pb amount is markedly lowered
- 55

from the level in the prior art.

[0019] It is possible for the free cutting steel described above, which has been obtained on the basis of the ideas given above, to exhibit a machinability fully comparable to or higher than that exhibited by the conventional low carbon resulfurized and leaded free cutting steel without obstruction the cost reduction and without lowering the hot ductility, even if lead is not added to the free cutting steel or even if the lead addition amount is markedly lowered from the level in the conventional low carbon resulfurized and leaded free cutting steel.

[0020] The reasons for defining the composition of the free cutting steel as described above will now be described.

(a) C: 0.02 to 0.15 mass %

[0021] Carbon, which seriously affects the strength and the machinability of the steel, is an important element. However, if the C content is lower than 0.02 mass %, it is impossible to obtain a sufficient strength of the steel. On the other hand, if the C content exceeds 0.15 mass %, the strength of the steel is rendered excessively high so as to deteriorate the machinability of the steel. Such being the situation, the C content is defined in the present invention to fall within a range of between 0.02 mass % and 0.15 mass %. Preferably, the C content should fall within a range of between 0.02 mass % and 0.10 mass %.

(b) Mn: 0.05 to 1.8 mass %

[0022] Manganese is a sulfide formation element that is important for improving the machinability of the steel. However, if the Mn content is lower than 0.05 mass %, the amount of the sulfide formed is excessively small, resulting in failure to obtain a sufficient machinability. On the other hand, if the Mn content exceeds 1.8 mass %, the formed sulfide is much elongated, with the result that the machinability of steel is lowered. Such being the situation, the Mn content is defined in the present invention to fall within a range of between 0.05 and 1.8 mass %. Preferably, the Mn content should be not lower than 0.22 mass % and lower than 0.60 mass %.

(c) S: 0.20 to 0.49 mass %

[0023] Sulfur is a sulfide formation element which forms a sulfide effective for improving the machinability of the steel. However, if the S content is lower than 0.20 mass %, the amount of the sulfide formed is excessively small, resulting in failure to obtain a sufficient effect for improving the machinability of the steel. On the other hand, if the S content exceeds 0.49 mass %, the hot workability and the ductility of the steel are markedly lowered. Such being the situation, the S content of steel is defined in the present invention to fall within a range of between 0.20 and 0.49 mass %.

(d) O: higher than 0.01 mass % and not higher than 0.03 mass %

[0024] Oxygen is an element effective for suppressing the elongation of the sulfide in the hot working step such as a rolling step. Therefore, oxygen is an element important for improving the machinability of the steel by suppressing the elongation of the sulfide. However, if the O content is not higher than 0.01 mass %, it is difficult to obtain a sufficient effect of suppressing the elongation of the sulfide. Since the elongated sulfide remains in the steel, it is impossible to obtain a sufficient effect of improving the machinability of the steel. On the other hand, even if the O addition amount exceeds 0.03 mass %, the effect of suppressing the elongation of the sulfide is saturated. It follows that the addition of an excessively large amount of O is disadvantageous in economy. In addition, a casting defect such a blow-hole is generated. Under the circumstances, the O content is defined in the present invention to exceed 0.01 mass % and to be not higher than 0.03 mass %.

(e) Cr: 0.3 to 2.3 mass %

[0025] Chromium is an element effective for suppressing the elongation of the sulfide in the hot working step such as a rolling step. Therefore, Cr is an element important for improving the machinability of the steel by suppressing the elongation of the sulfide. However, if the Cr content is lower than 0.3 mass %, it is difficult to obtain a sufficient effect of suppressing the elongation of the sulfide. Since the elongated sulfide remains in the steel, it is impossible to obtain a sufficient effect of improving the machinability of the steel. On the other hand, even if the Cr addition amount exceeds 2.3 mass %, the effect of suppressing the elongation of the sulfide is saturated. It follows that the addition of an excessively large amount of Cr is disadvantageous in economy. Under the circumstances, the Cr content is defined in the present invention to fall within a range of between 0.3 mass % and 2.3 mass %. Preferably, the Cr content should fall within a range of between 0.3 mass % and 1.5 mass %.

(f) Cr/S ratio: 2 to 6

[0026] The Cr/S ratio is an important index seriously affecting the degree of elongation of the sulfide in the hot working step such as a rolling step. It is possible to obtain a sulfide having a desired degree of elongation, which permits improving the machinability of the steel, by defining the Cr/S ratio appropriately. If the Cr/S ratio is smaller than 2, the sulfide elongated by the formation of MnS is rendered prominent so as to deteriorate the machinability of the steel. On the other hand, if the Cr/S ratio exceeds 6, the effect of suppressing the elongation of the sulfide is saturated. Such being the situation, the Cr/S ratio is defined in the present invention to fall within a range of between 2 and 6. Preferably, the Cr/S ratio should fall within a range of between 2 and 4.

[0027] The conditions given above are absolutely necessary for the free cutting steel of the present invention. The other conditions of the first free cutting steel are as follows:

(g) Si: 0.1 mass % or less

[0028] Silicon is a deoxidizing element. Since the oxide of Si acts as a nucleus of the sulfide formation, Si promotes the sulfide formation so as to pulverize finely the sulfide, with the result that the tool life is shortened. Such being the situation, where it is desired to further prolong the tool life, it is desirable to define the Si content not to exceed 0.1 mass %. More desirably, the Si content of the steel should not exceed 0.03 mass %.

(h) P: 0.01 to 0.12 mass %

[0029] Phosphorus is an element effective for suppressing the formation of the built-up edge in the cutting process step so as to lower the finish surface roughness. However, if the P content is lower than 0.01 mass %, it is difficult to obtain a sufficient effect. On the other hand, if the P content exceeds 0.12 mass %, the effect noted above is saturated. Also, the hot workability and the ductility of the steel are markedly lowered. Such being the situation, the P content is defined in the present invention to fall within a range of between 0.01 mass % and 0.12 mass %. Preferably, the P content should fall within a range of between 0.01 mass % and 0.09 mass %.

(i) Al: 0.01 mass % or less

[0030] Aluminum is a deoxidizing element like Si. Since the oxide of Al acts as a nucleus of the sulfide formation, Al promotes the sulfide formation so as to pulverize finely the sulfide, with the result that the tool life is shortened. Such being the situation, where it is desired to further prolong the tool life, it is desirable to define the Al content not to exceed 0.01 mass %. More desirably, the Al content of the steel should not exceed 0.003 mass %.

(j) At least one of:

[0031]

Ca: 0.0001 to 0.0005 mass %;
 Pb: 0.01 to 0.03 mass % ;
 Se: 0.02 to 0.30 mass % ;
 Te: 0.1 to 0.15 mass %;
 Bi: 0.02 to 0.20 mass % ;
 Sn: 0.003 to 0.020 mass %;
 B: 0.004 to 0.010 mass %;
 N: 0.005 to 0.015 mass %;
 Cu: 0.05 to 0.50 mass %;
 Ti: 0.003 to 0.090 mass % ;
 V: 0.005 to 0.200 mass %;
 Zr: 0.005 to 0.090 mass %;
 Mg: 0.0005 to 0.0080 mass %.

[0032] Any of Ca, Pb, Se, Te, Bi, Sn, B, N, Cu, Ti, V, Zr and Mg is used in the case where it is important to improve the machinability of the steel. However, if the addition amount of each of these elements is smaller than the lower limit noted above, the effect of improving the machinability of the steel cannot be obtained. On the other hand, where the addition amount of each of these elements exceeds the upper limit noted above, the effect of improving the machinability of the steel is saturated. Also, the addition of an excessively large amount of each of these elements is disadvantageous

in economy. Under the circumstances, in the case of adding these elements, these elements should be added such that Ca falls within a range of between 0.0001 and 0.0005 mass %, Pb falls within a range of between 0.01 and 0.03 mass %, Se falls within a range of between 0.02 and 0.30 mass %, Te falls within a range of between 0.1 and 0.15 mass %, Bi falls within a range of between 0.02 and 0.20 mass %, Sn falls within a range of between 0.003 and 0.020 mass %, B falls within a range of between 0.004 and 0.010 mass %, N falls within a range of between 0.005 and 0.015 mass %, Cu falls within a range of between 0.05 and 0.50 mass %, Ti falls within a range of between 0.003 and 0.090 mass %, V falls within a range of between 0.005 and 0.200 mass %, Zr falls within a range of between 0.005 and 0.090 mass %, and Mg falls within a range of between 0.0005 and 0.0080 mass %.

(k) Micro structure

[0033] It is desirable for the micro structure of the first free cutting steel to be a ferrite • pearlite-based structure. Concerning the machinability of the steel, it is advantageous for the prior austenite grain size to be large. However, a satisfactory machinability can be maintained even in the case of fine grains. In view of the mechanical properties of the article, it is desirable for the grains to be fine such that the grain size exceeds the grain size number 7 (grain size measured by the method of measuring austenite grain size specified in JIS (Japanese Industrial Standards) G 0551).

(1) Size of Sulfide

[0034] Concerning the machinability of the steel, it is advantageous for the sulfide to grow into a large body. To be more specific, it is desirable for the major axis of the sulfide to be at least 10 μm . It is also desirable for the sulfide having the major axis of at least 10 μm to occupy at least 90% of all the sulfides.

(m) Aspect Ratio of Sulfide

[0035] The aspect ratio of the sulfide is represented by L/d , where "L" denotes the major axis and "d" denotes the minor axis of the sulfide, as shown in FIG. 1. Concerning the machinability of the steel, it is advantageous for the sulfide to be formed like a spindle. Therefore, it is desirable for the sulfide to have an aspect ratio not larger than 5. It is also desirable for the sulfide having an aspect ratio not larger than 5 to occupy at least 80% of the sulfide having the major axis of at least 10 μm .

(Example)

[0036] An Example of the present invention will now be described.

[0037] Prepared were steel sample No. 1 having a chemical composition falling within the range of the free cutting steel of the present invention (hereinafter referred to as Example of the present invention), as shown in Table 1, steel samples Nos. 2 to 6 each having a chemical composition failing to fall within the range of the first free cutting steel of the present invention (hereinafter referred to as Comparative Examples), and a steel sample No. 7 used as a reference Example and directed to a low carbon resulfurized and leaded free cutting steel. Each of these steel samples was smelted and then casted into an ingot having a cross sectional area of 400 mm x 300 mm, followed by subjecting the ingot to a hot rolling so as to obtain an 80 mm diameter steel rod. Further, the steel rod thus obtained was subjected to a normalizing treatment such that the steel rod was heated at 925°C for one hour, followed by cooling the heated steel rod to room temperature by means of the air cooling.

[0038] The form of the sulfide of each steel rod thus manufactured was measured. Also, a test for the machinability was applied to the steel rod thus manufactured.

[0039] For measuring the form of the sulfide, the major axis L (length in the rolling direction) and the minor axis d (thickness or length in a direction perpendicular to the rolling direction) were measured by an image analyzing apparatus in respect of all the sulfides present in a region of 5.5 mm x 11 mm in the central portion of steel rod. Also, obtained was a ratio of the sulfides having the major axis not smaller than 10 μm and a ratio of the sulfides having an aspect ratio L/d not larger than 5 to all the sulfides having the major axis not smaller than 10 μm . Further, a machinability test was conducted under the conditions shown in Table 2.

Table 1

No.	Classification	Chemical Composition (mass %)											Cr/S
		C	Si	Mn	P	S	Cr	Al	N	O	Bi	Pb	
1	Present Invention	0.07	0.08	1.32	0.078	0.455	2.09	tr	0.02	0.02	tr	tr	4.59
2	Comparative Example	0.06	0.01	2.52	0.077	0.403	1.12	tr	0.008	0.006	tr	tr	2.78
3	Comparative Example	0.08	tr	0.53	0.074	0.177	0.88	tr	0.007	0.005	tr	tr	4.97
4	Comparative Example	0.07	tr	0.54	0.078	0.431	0.23	tr	0.006	0.05	tr	tr	0.53
5	Comparative Example	0.06	tr	1.19	0.077	0.399	1.51	0.001	0.01	0.001	tr	tr	3.78
6	Comparative Example	0.06	tr	0.52	0.079	0.402	0.52	0.001	0.012	0.005	tr	tr	1.29
7	Reference Example	0.07	tr	1.22	0.071 0,319		0.05	tr	0.01	0.015	tr	0.21	0.16

Table 2

Item	Tool Material	Cutting Conditions					Evaluation Method
		Feeding Rate (mm/rev)	Cutitng Depth (mm)	Cutting Rate (m/min)	Cutting Time (min)	Lubricant	
Turning	P20	0.20	2.0	150		None	Life: Cutting Time until Front Flank Wear Amount VB is increased to reach 0.2mm
		0.10		30,50,			Evaluation in the Shape of Chips (sum of 15 cutting donditions)
		0.20	2.0	100, 150	1	None	Single Chip had a Length shorter than 30 mm: 1 point
		0.30		200			Single Chip had a Length not shorter than 30 mm: 3 point
		0.20	2.0	150	1	None	Maximum Surface Roughness Rmax
	SKH4	0.20	2.0	100		None	Life: Until Incapability of Cutting
Drilling	SKH51 (φ10)	0.35		20~80		Use of Water-Soluble Cutting Oil	Life: Cutting Rate that makes cutting impossible at 1000 mm in total length of drilling

[0040] Table 3 shows the results. Also, FIG. 2 is a graph showing the relationship between the life of the turning tool (SKH4), Which is taken up as a typical characteristic value, and the life of the drilling tool.

[0041] As apparent from Table 3, it was confirmed that sample No. 1. " of the present invention had been satisfactory

in various characteristics, compared with the low carbon resulfurized and leaded free cutting steel for sample No. 7 (Reference Example).

[0042] On the other hand, the Mn content exceeded the upper limit specified in the present invention in sample No. 2 for the Comparative Example. The Cr content was lower than the lower limit specified in the present invention in sample No. 4 for the Comparative Example. The O content was insufficient in sample No. 5 for the Comparative Example. Further, the Cr/S ratio was lower than the lower limit specified in the present invention in sample No 6 for the Comparative Example. As a result, the aspect ratio of the sulfide was rendered large in each of these steel samples of the Comparative Example and, thus, these steel samples were rendered inferior to the steel samples of the present invention in the machinability. On the other hand, the S content of the steel sample No.3 for the Comparative Example was lower than the lower limit specified in the present invention. Therefore, the steel sample No.3 noted above was insufficient in the total amount of the sulfide effective for improving the machinability of the steel, with the result that the steel sample No. 3 was inferior in the machinability of the steel to the steel samples of the present invention.

Table 3

No.	Classification	Form of Sulfide		Tool Life			Chip Disposability	Surface Roughness	Micro structure	Prior γ Grain Size
		Ratio of Sulfides having Major Axis not smaller than 10 μm (%)	Ratio of Sulfides having aspect Ratio ≤ 5 (%)	Life of Turning P20 (min)	Life of Turning SKH4 (min)	Life of Drill (m/min)	Evaluation of Chip (point)	Rmax (μm)		
1	Present Invention	98	84	47	46	62	15	16	Ferrite-pearlite	8
2	Comparative Example	74	41	23	33	36	33	35	"	7
3	Comparative Example	65	38	24	35	37	37	37	"	7
4	Comparative Example	63	46	24	31	33	36	36	"	8
5	Comparative Example	55	41	22	30	32	32	35	"	8
6	Comparative Example	61	39	21	29	31	31	36	"	8
7	Reference Example	73	42	41	40	44	21	17	"	8

Claims

1. A low carbon free cutting steel containing 0.02 to 0.15 mass % of C, 0.05 to 1.8 mass % of Mn, 0.20 to 0.49 mass % of S, more than 0.01 mass % and not more than 0.03 mass % of O, 0.3 to 2.3 mass % of Cr, not more than 0.1 mass % of Si, 0.01 to 0.12 mass % of P, and not more than 0.01 mass % of Al, and the balance consisting of Fe and inevitable impurities, the Cr/S ratio falling within a range of between 2 and 6, wherein the sulfides having the major axis of at least 10 μ m occupy at least 90% of all the sulfides and the sulfides having an aspect ratio not larger than 5 occupies at least 80% of the sulfides having the major axis of at least 10 μ m.
2. The low carbon free cutting steel according to claim 1, further containing at least one element selected from the group consisting of 0.0001 to 0.0005 mass % of Ca, 0.01 to 0.03 mass % of Pb, 0.02 to 0.30 mass % of Se, 0.1 to 0.15 mass % of Te, 0.02 to 0.20 mass % of Bi, 0.003 to 0.020 mass % of Sn, 0.004 to 0.010 mass % of B, 0.005 to 0.015 mass % of N, 0.05 to 0.50 mass % of Cu, 0.003 to 0.090 mass % of Ti, 0.005 to 0.200 mass % of V, 0.005 to 0.090 mass % of Zr, and 0.0005 to 0.0080 mass % of Mg.
3. The low carbon free cutting steel according to any one of claims 1 and 2, wherein the free cutting steel has a ferrite-pearlite structure, and the prior austenite grain size exceeds the grain size number 7 measured by the austenite grain size measuring method specified in JIS G 0551.

Patentansprüche

1. Ein kohlenstoffarmer Automatenstahl, der 0,02 bis 0,15 Massenprozent an C, 0,05 bis 1,8 Massenprozent an Mn, 0,20 bis 0,49 Massenprozent an S, mehr als 0,01 Massenprozent und nicht mehr als 0,03 Massenprozent an O, 0,3 bis 2,3 Massenprozent an Cr, nicht mehr als 0,1 Massenprozent Si, 0,01 bis 0,12 Massenprozent an P und nicht mehr als 0,01 Massenprozent an Al enthält, und worin der Rest aus Fe und unvermeidlichen Verunreinigungen besteht, wobei das Cr/S-Verhältnis in einen Bereich von zwischen 2 und 6 fällt, worin die Sulfide, die die Hauptachse von mindestens 10 μ m haben, mindestens 90% aller Sulfide besetzen, und die Sulfide, die ein Aspektverhältnis haben, das nicht größer als 5 ist, mindestens 80% der Sulfide besetzen, die die Hauptachse von mindestens 10 μ m haben.
2. Der kohlenstoffarme Automatenstahl nach Anspruch 1, der weiterhin mindestens ein Element enthält, das aus der Gruppe ausgewählt wird, die aus 0,0001 bis 0,0005 Massenprozent an Ca, 0,01 bis 0,03 Massenprozent an Pb, 0,02 bis 0,30 Massenprozent an Se, 0,1 bis 0,15 Massenprozent an Te, 0,02 bis 0,20 Massenprozent an Bi, 0,003 bis 0,020 Massenprozent an Sn, 0,004 bis 0,010 Massenprozent an B, 0,005 bis 0,015 Massenprozent an N, 0,05 bis 0,50 Massenprozent an Cu, 0,003 bis 0,090 Massenprozent an Ti, 0,005 bis 0,200 Massenprozent an V, 0,005 bis 0,090 Massenprozent an Zr und 0,0005 bis 0,0080 Massenprozent an Mg besteht.
3. Der kohlenstoffarme Automatenstahl gemäß irgendeinem der Ansprüche 1 und 2, worin der Automatenstahl eine Ferrit-Perlit-Struktur hat und die vorherige Austenit-Korngröße die Korngrößenzahl 7 übersteigt, die durch das im JIS G 0551 bestimmten Korngrößenmeßverfahren gemessen wird.

Revendications

1. Acier de décolletage à faible teneur en carbone contenant 0,02 à 0,15 % en masse de C, 0,05 à 1,8 % en masse de Mn, 0,20 à 0,49 % en masse de S, plus de 0,01 % en masse et pas plus de 0,03 % en masse de O, 0,3 à 2,3 % en masse de Cr, pas plus de 0,1 % en masse de Si, 0,01 à 0,12 % en masse de P, et pas plus de 0,01 % en masse de Al, le reste étant composé de Fe et d'impuretés inévitables, le rapport Cr/S variant entre 2 et 6, dans lequel les sulfures dont l'axe principal fait au moins 10 μ m occupent au moins 90 % de tous les sulfures et les sulfures dont le rapport de longueur n'est pas plus grand que 5 occupent au moins 80 % des sulfures dont l'axe principal fait au moins 10 μ m.
2. Acier de décolletage à faible teneur en carbone selon la revendication 1, contenant en outre au moins un élément choisi dans le groupe constitué par 0,0001 à 0,0005 % en masse de Ca, 0,01 à 0,03 % en masse de Pb, 0,02 à 0,30 % en masse de Se, 0,1 à 0,15 % en masse de Te, 0,02 à 0,20 % en masse de Bi, 0,003 à 0,020 % en masse de Sn, 0,004 à 0,010 % en masse de B, 0,005 à 0,015 % en masse de N, 0,05 à 0,50 % en masse de Cu, 0,003 à 0,090 % en masse de Ti, 0,005 à 0,200 % en masse de V, 0,005 à 0,090 % en masse de Zr, et 0,0005 à 0,0080 %

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en masse de Mg.

3. Acier de décolletage à faible teneur en carbone selon l'une quelconque des revendications 1 et 2, dans lequel l'acier de décolletage a une structure ferrite-perlite, et dans lequel la grosseur du grain d'austénite antérieur dépasse la grosseur de grain numéro 7 mesurée par la méthode de mesure de la grosseur de grain d'austénite spécifiée dans la norme JIS G 0551.

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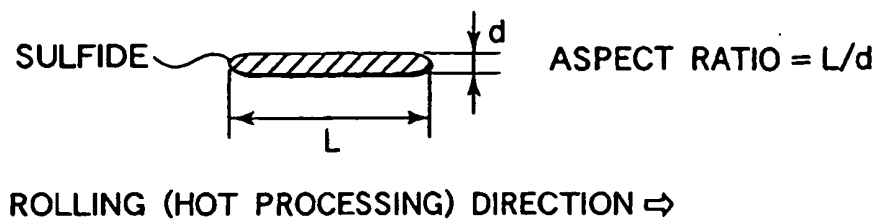


FIG.1

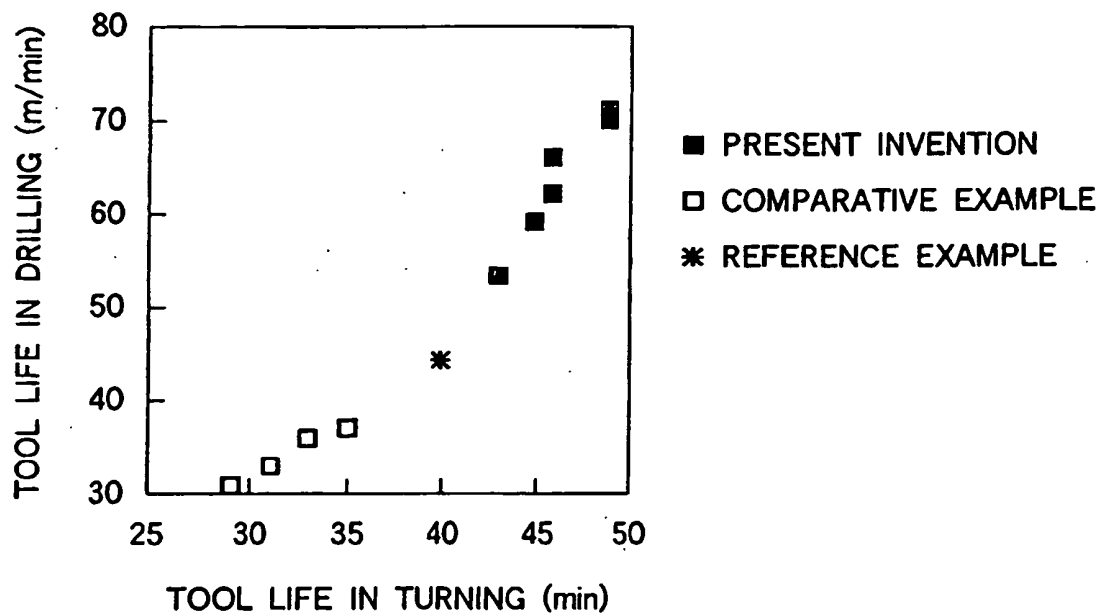


FIG.2

REFERENCES CITED IN THE DESCRIPTION

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