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(54) **Ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance**

(57) A ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance is disclosed which comprises in weight percentage, 0.06% or less of C, 0.05 to 1.0% of Si, 2.0% or less of Mn, 0.050% or less of P, 0.05 to 0.50% of S, 2.0% or less of Cu, 2.0% or less of Ni, 9.0 to 25.0% of Cr, 4.0% or less of Mo, 0.065 to 2.0% of Ti, 0.0150% or less of O, 0.020% or less of N, 0.001 to 0.100% of Al, and Fe and inevitable impurity in the rest portion, wherein the steel satisfies Equations (1) and (2) of the equations,

$$(WTi+WCr) > 2 \times WMn \quad \text{Equation (3)}$$

where the amount of Ti contained in the steel is represented by [Ti], that of S is represented by [S] and that of Mn is represented by [Mn], and wherein the steel satisfies Equation (3) where the amount of Ti contained in sulfide produced in the texture of the steel is represented by WTi, that of Cr is represented by WCr and that of Mn is represented by WMn.

$$[Ti] \geq 1.3 \times [S] \quad \text{Equation (1)}$$

$$[Mn]/[Ti] \leq 3 \quad \text{Equation (2)}$$

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a ferritic free-cutting stainless steel excellent in surface roughness and out-gass resistance.

2. Description of the Related Art

[0002] In recent years, in order to facilitate the trend toward making computers, their peripheral equipment or other electronic products be maintenance-free, ferritic stainless steel with which corrosion resistance can be obtained at a relatively low cost is widely used as the material for parts thereof. Especially, since improvement of machinability is regarded as important for a part to which precise finish machining is required to secure the precision of dimensions and a part having a complicated shape and including large machining removal, the amount of elements giving the free-cutting property to be contained tends to increase. Furthermore, such elements are used in not only adding each of them respectively but also adding them in combinations.

[0003] As the elements giving machinability, S, Pb, Se, Bi, Te and Ca and so on are known. Among these, Pb tends to be hated gradually in recent years during which the interest in environmental protection is globally being raised. Therefore, the apparatuses and parts for which use of Pb is restricted are getting more. Then, a material in which S is used as the main element of the elements improving machinability is considered as a substituting material (see, e.g., Japanese Patent Application Laid-Open Publication Nos. S56-16653, S62-258955, S54-17567 and H10-46292). By producing Mn-based sulfide such as mainly MnS in these materials, they are arranged to improve the stress concentration effect when forming chips against sulfide, and machinability and grindability due to lubricating action between a tool and chips.

[0004] However, when Mn-based sulfide is produced, the sulfide becomes a cause to degrade the corrosion resistance and outgass resistance of an alloy. Degrading outgass resistance means that, when an alloy is exposed to the atmosphere, S component contained in the alloy material produces a gas which contains sulfur and the gas is released and tends to facilitate corrosion of peripheral circuits of parts. Such a sulfur-containing gas especially tends to cause troubles in components such as computer peripheral devices often used in a sealed status, for example, Hard Disk Drive (HDD).

SUMMARY OF THE INVENTION

[0005] The objective of the invention is to provide a ferritic free-cutting stainless steel excellent in surface roughness, corrosion resistance and outgass resistance while having an excellent machinability.

[0006] In order to achieve the above objective, according to an aspect of the present invention there is provided a ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance, comprising:

in weight percentage, 0.06% or less of C, 0.05 to 1.0% of Si, 2.0% or less of Mn, 0.050% or less of P, 0.05 to 0.50% of S, 2.0% or less of Cu, 2.0% or less of Ni, 9.0 to 25.0% of Cr, 4.0% or less of Mo, 0.065 to 2.0% of Ti, 0.0150% or less of O, 0.020% or less of N, 0.001 to 0.100% of Al, and Fe and inevitable impurity in the rest portion, wherein the steel satisfies Equations (1) and (2) of the equations,

$$[\text{Ti}] \geq 1.3 \times [\text{S}] \quad \text{Equation (1)}$$

$$[\text{Mn}]/[\text{Ti}] \leq 3 \quad \text{Equation (2)}$$

$$(\text{WTi} + \text{WCr}) > 2 \times \text{WMn} \quad \text{Equation (3)}$$

where the amount of Ti contained in the steel is represented by [Ti], that of S is represented by [S] and that of Mn is represented by [Mn], and wherein the steel satisfies Equation (3) where the amount of Ti contained in sulfide produced in the texture of the steel is represented by WTi, that of Cr is represented by WCr and that of Mn is represented by WMn.

[0007] Usually, S tends to form sulfide with Mn, a component of a steel material. However, as described above, Mn-based sulfide becomes a cause to degrade the corrosion resistance and outgass resistance of an alloy. Then, according to the invention, by producing Ti-based sulfide such as TiS but not Mn-based sulfide by adding Ti in the texture of the steel, the corrosion resistance and the outgass resistance are improved. Furthermore, since the Ti-based sulfide takes a form of a sphere and disperses finely, the ferritic free-cutting stainless steel of the invention has excellent machinability and is excellent in the inclusion falling property, especially surface roughness in precision machining. Moreover, the same effect can be obtained when the sulfide contains Cr. "A"-based sulfide used herein refers to sulfide for which the component (element) contained in the sulfide at the highest ratio in weight is "A" among the components bonding with S. That is, in Ti-based sulfide, more Ti bonds with S compared to other elements (such as Mn).

[0008] Next, reasons for restriction of the claims of the invention will be described.

C (carbon): 0.06% or less

[0009] When the amount of C contained is excessive, C prevents improvement of machinability by producing much carbide in the form of simple substance. Therefore, the upper limit is 0.06% and the preferable range is 0.03% or less. More preferably, the range is 0.015% or less.

Si(silicon): 0.05 to 1.0%

[0010] Si is added as a deoxidizer for steel. In order to obtain the effect of the deoxidizer, 0.05% or more of Si is necessary. However, when the amount of Si contained is excessive, the hot workability of the steel is degraded. Therefore, the upper limit is 1.0%. A preferable range emphasizing the hot workability is 0.05 to 0.5%.

Mn (manganese): 2.0% or less

[0011] Mn is added as a deoxidizer for steel and, in addition, has an effect of improving machinability since it produces Mn-based sulfide (MnS). However, since the Mn-based sulfide (MnS) degrades the corrosion resistance, the upper limit of the amount is 2.0%. When the corrosion resistance is especially emphasized, the range of the amount is 1.0% or less. More preferably, it is 0.5% or less.

P (phosphorus): 0.050% or less

[0012] As lower amount as possible of P contained is desirable since P causes decrease of the toughness in addition to increasing intergranular corrosion sensitivity by segregating in the grain boundary. The range of the amount of P contained is desirably 0.050 % or less. Preferably, it is 0.030% or less.

S (sulfur): 0.05 to 0.50%

[0013] S is a constituent element of sulfide, that improves the machinability and 0.05% of S is necessary to obtain this effect. However, since hot workability is degraded when the amount of S contained is excessive, the upper limit is 0.50%. The range of the amount of S contained is desirably 0.15 to 0.40% taking into consideration the balance between the improvement of machinability and the degradation of hot workability.

Cu (copper): 2.0% or less

[0014] Cu may be added when necessary since Cu is effective for improving the corrosion resistance, especially the corrosion resistance in a reducing acid environment. However, since excessive addition of Cu degrades the hot workability, the upper limit is 2.0%. It is desirably 1.0% or less.

Ni (nickel): 2.0% or less

[0015] Ni is an element necessary for supplementing the corrosion resistance that is insufficient when only Cr is contained. However, since excessive addition of Ni causes increase of cost, the upper limit is 2.0%. Furthermore, the amount of Ni contained is desirably 1.0% or less taking into consideration the balance between the efficient corrosion resistance and the blending cost.

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Cr (chromium): 9.0 to 25.0%

[0016] Cr is an element which improves the corrosion resistance, and 9.0% or more of Cr should be contained in order to obtain the effect. On the other hand, since the hot workability is degraded in addition to increasing of cost when the amount contained is excessive, the upper limit is 25.0%. Furthermore, the range of the amount of Cr contained may desirably be 13.0 to 21.0% taking into consideration the balance between the efficient corrosion resistance and the blending cost.

Mo (molybdenum): 4.0% or less

[0017] Mo can further improve the corrosion resistance and strength. However, since excessive addition of Mo degrades the hot workability and, in addition, causes increase of cost, the upper limit is 4.0%. The range of the Mo contained is desirably 1.5% or less taking into account the increase of cost.

Ti (titanium): 0.065 to 2.0%

[0018] Ti is an element necessary for producing Ti-based sulfide that improves the machinability, and 0.065% or more of Ti is necessary in order to obtain this effect. On the other hand, since cost is increased when the amount of Ti contained is excessive, the upper limit of the amount of Ti contained is 2.0%. Furthermore, the range of the amount of Ti contained may desirably be 0.075 to 2.0% in order to obtain further sufficient machinability.

O (oxygen): 0.0150% or less

[0019] The upper limit of the amount of O contained is 0.0150% since O bonds with Ti which is a constituent element of a compound effective for improving machinability and forms oxide which does not contribute to improvement of the machinability. The range of the amount of O contained may be desirably 0.0080% or less, and is further desirably 0.0050% taking into consideration of manufacturing cost and in order to secure the effective amount of Ti necessary for forming Ti-based sulfide.

N (nitrogen): 0.020% or less

[0020] The upper limit of the amount of N contained is 0.020% since N bonds with Ti which is a constituent element of a compound effective for improving machinability and forms nitride which does not contribute to improvement of the machinability. The range of the amount of N contained may be desirably 0.010% or less and is further desirably 0.006% or less taking into consideration of manufacturing cost and in order to secure the effective amount of Ti necessary for forming Ti-based sulfide.

Al (aluminum): 0.001 to 0.100%

[0021] Al is added as a deoxidizer for the steel. However, the upper limit of the amount of Al contained is 0.100% since oxide harmful to machinability is formed when the amount of Al contained is excessive. The range of the amount of Al contained is desirably 0.050% or less.

$$[\text{Ti}] \geq 1.3 \times [\text{S}] \quad \text{Equation (1)}$$

[0022] The amount of Ti contained is 1.3 times as much the amount of S contained or more in order to suppress the production of Mn-based sulfide (MnS) that degrades the corrosion resistance and the outgass resistance and to fix all S in the texture of the steel onto Ti. More desirably, $[\text{Ti}] \geq 1.5 \times [\text{S}]$, that is, the amount of Ti contained may be 1.5 times as much the amount of S contained or more. [] indicates the amount of a component contained in the steel.

$$[\text{Mn}]/[\text{Ti}] \leq 3 \quad \text{Equation (2)}$$

[0023] The amount of Mn contained is three times as much the amount of Ti contained or less in order to suppress the production of Mn-based sulfide (MnS) that degrades the corrosion resistance and the outgass resistance, and (in order to decrease the amount of Mn contained and to increase the amount of Ti contained in the sulfide) to cause Ti-based sulfide to be produced.

$$(W_{Ti} + W_{Cr}) > 2 \times W_{Mn}$$

Equation (3)

[0024] In order to make the corrosion resistance and the outgass resistance of the steel excellent, it is preferable that, in the sulfide, the sum of the amount of Ti contained and the amount of Cr contained exceeds the double of the amount of Mn contained. Here, "W" indicates the amount of a component following it contained in the sulfide.

[0025] In a ferritic free-cutting stainless steel of the invention, the steel may further contain in addition to the components described above, in weight percentage any one or more selected from the group consisting of 0.01 to 0.30% of Pb, 0.01 to 0.30% of Se, 0.10% or less of Te and 0.01 to 0.30% of Bi.

[0026] Since Pb (lead), Se (selenium), Te (tellurium) and Bi (bismuth) can improve the machinability furthermore, they can be added as necessary. However, since excessive addition of them degrades the hot workability, the upper limit of the amount to be added for each of them is respectively 0.3% for Pb, 0.30% for Se, 0.10% for Te and 0.30% for Bi. In order to obtain sufficiently the effect of improving the machinability, it is desirable to add 0.01% or more of each of the above components respectively.

[0027] In a ferritic free-cutting stainless steel of the invention, the steel may further contain in addition to the components described above, in weight percentage any one or more selected from the group consisting of 0.05% or less of Ca, 0.02% or less of Mg, 0.02% or less of B, 0.02% or less of REM, 0.50% or less of V, 0.50% or less of Nb, 2.0% or less of W and 0.50% or less of Ta.

[0028] Since Ca (calcium), Mg (magnesium), B (boron) and REM (one or more of rare-earth elements) can improve the hot workability of the steel, they can be added as necessary. However, since excessive addition of them makes the effect saturate and, on the contrary, degrades the hot workability, the upper limit of the amount to be added is 0.05% for Ca, 0.02% for Mg, 0.02% for B and 0.02% for REM.

[0029] Since W (tungsten) can improve the corrosion resistance and the strength of the steel, it can be added as necessary. However, since excessive addition of it degrades the hot workability and causes increase of cost, the upper limit of the amount to be added is 2.0%.

[0030] Since Nb (niobium), V (vanadium) and Ta (tantalum) have the effect of improving toughness by forming carbon nitride and making the crystal grain in the steel very fine, each of them can be added respectively in the range of 0.50% or less.

Example

[0031] In order to verify the effect of the invention, the following experiment was performed.

[0032] First, after producing by melting in a high-frequency induction furnace a 50kg-ingot of each type of steel having the component composition shown in Table 1, ingots were produced by cooling the melted steel. Then, each ingot was heated to 1,050 to 1,100°C and shaped into a round bar having a length of 20mm by hot-forging. After further heating those round bars at 800°C for one hour, they were air-cooled (annealing) and supplied to each test. The result of each test is shown in Table 1.

Table 1

wt%

	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Ti	Al	O	N	Pb Se Te Bi	Ca Mg B REM	V Nb W Ta	[Ti] /[S] ≥ 1.3	[Mn] /[Ti] ≤ 3	VERIFICATION Outer Diameter (μm)	Machinability Surface Roughness (μm)	Shape of Chips	Corrosion Resistance	Outgassing Resistance
Steel of the Invention	1	0.003	0.21	0.04	0.019	0.206	0.30	0.05	16.5	0.05	0.56	0.020	0.0040	0.0057			2.72	0.07	Small	0.07	Good	Good	A
	2	0.021	0.40	0.16	0.007	0.263	0.14	0.23	19.0	0.30	0.75	0.017	0.0023	0.0043			2.96	0.21	Small	0.14	Good	Good	A
	3	0.005	0.35	0.50	0.019	0.196	0.02	0.97	18.3	0.32	0.47	0.007	0.0009	0.0053			2.40	1.06	Small	0.11	Good	Good	B
	4	0.014	0.33	0.43	0.032	0.151	0.28	0.28	13.4	0.95	0.28	0.043	0.0037	0.0038			1.85	1.54	Small	0.08	Good	Good	B
	5	0.006	0.05	0.03	0.050	0.394	0.80	0.80	20.9	1.32	0.86	0.032	0.0049	0.0029			2.18	0.03	Small	0.09	Good	Good	A
	6	0.016	0.50	0.01	0.029	0.298	0.47	0.47	19.4	0.27	0.94	0.022	0.0031	0.0049	Mg:0.0012		3.15	0.01	Small	0.05	Good	Good	A
	7	0.011	0.27	0.22	0.035	0.179	0.31	0.31	17.8	0.63	0.54	0.038	0.0018	0.0021			3.02	0.41	Small	0.09	Good	Good	A
	8	0.024	0.46	0.32	0.009	0.161	0.88	0.88	20.5	0.83	0.43	0.001	0.0035	0.0047	Pb:0.29		2.67	0.74	Small	0.12	Good	Good	A
	9	0.018	0.13	0.28	0.011	0.368	0.56	0.56	13.1	0.02	0.78	0.012	0.0043	0.0034	Se:0.19		2.12	0.36	Small	0.11	Good	Good	A
	10	0.023	0.19	0.11	0.001	0.188	0.41	0.01	15.2	0.22	0.35	0.028	0.0029	0.0060	Te:0.05		1.86	0.31	Small	0.10	Good	Good	A
	11	0.032	0.41	0.02	0.031	0.163	0.54	0.68	18.4	0.33	0.56	0.038	0.0048	0.0059	Pb:0.17		3.44	0.04	Small	0.10	Good	Good	A
	12	0.031	0.89	0.38	0.008	0.289	0.33	0.19	19.5	0.05	0.88	0.021	0.0029	0.0059			3.04	0.43	Small	0.15	Good	Good	A
	13	0.048	0.33	0.43	0.032	0.432	0.03	0.29	16.7	0.58	0.89	0.028	0.0039	0.0041	Ca:0.0132 Mg:0.0021		2.06	0.48	Small	0.11	Good	Good	A
	14	0.037	0.05	0.53	0.019	0.263	0.21	0.09	19.2	0.50	0.86	0.029	0.0034	0.0078			3.27	0.62	Small	0.08	Good	Good	A
	15	0.028	0.33	0.16	0.045	0.147	0.12	0.19	18.2	0.34	0.23	0.061	0.0029	0.0051			1.56	0.70	Small	0.09	Good	Good	A
	16	0.013	0.07	0.22	0.035	0.051	0.31	0.31	17.8	0.63	0.32	0.038	0.0089	0.0043	B:0.01		6.27	0.69	Small	0.10	Good	Good	A
	17	0.009	0.37	0.43	0.022	0.264	0.88	1.09	9.3	0.85	0.43	0.032	0.0034	0.0045			1.63	1.00	Small	0.14	Good	Good	B
	18	0.002	0.13	0.25	0.019	0.206	1.59	1.97	16.8	0.50	0.49	0.014	0.0048	0.0058			1.66	0.51	Small	0.13	Good	Good	A
	19	0.007	0.19	1.97	0.041	0.290	0.41	0.32	15.2	0.22	0.91	0.041	0.0021	0.0089	B:0.005		3.14	2.16	Small	0.11	Good	Good	A
	20	0.021	0.98	0.43	0.032	0.182	0.28	0.28	13.4	0.95	1.96	0.030	0.0069	0.0041	Pb:0.11		10.77	0.22	Small	0.12	Good	Good	A
Steel for Comparison	21	0.019	0.39	0.63	0.060	0.485	0.32	0.48	23.8	0.49	1.43	0.029	0.0042	0.0059			2.95	0.44	Small	0.13	Good	Good	A
	22	0.010	0.50	1.06	0.029	0.278	0.59	0.19	24.9	0.27	0.70	0.022	0.0031	0.0049			2.52	1.51	Small	0.15	Good	Good	B
	23	0.059	0.27	0.49	0.035	0.354	0.31	0.21	12.3	0.33	0.87	0.023	0.0030	0.0060			2.46	0.56	Small	0.13	Good	Good	A
	24	0.005	0.43	0.31	0.028	0.234	0.88	0.35	21.0	0.15	0.58	0.081	0.0035	0.0055			2.48	0.53	Small	0.12	Good	Good	A
	25	0.007	0.14	0.22	0.011	0.334	0.44	0.27	19.7	0.87	0.64	0.028	0.0043	0.0034			1.92	0.34	Small	0.09	Good	Good	A
	26	0.036	0.19	0.11	0.041	0.188	0.41	0.32	15.2	0.22	0.35	0.028	0.0043	0.0139	Ca:0.0085		1.86	0.31	Small	0.06	Good	Good	A
	27	0.001	0.39	0.10	0.011	0.051	0.33	0.33	18.9	0.07	0.07	0.039	0.0023	0.0054	Mg:0.0013		1.37	1.43	Small	0.14	Good	Good	B
	28	0.013	0.80	1.04	0.019	0.278	0.09	0.11	14.9	0.01	0.41	0.011	0.0010	0.0210			1.47	2.54	Small	0.13	Good	Good	B
	29	0.001	0.41	0.19	0.025	0.348	0.02	0.31	22.3	1.48	0.47	0.038	0.0020	0.0170	Se:0.25		1.35	0.40	Small	0.09	Good	Good	A
	30	0.009	0.08	0.13	0.013	0.158	1.41	0.38	20.8	0.08	0.21	0.019	0.0050	0.0080			1.33	0.62	Small	0.10	Good	Good	A
	1	0.060	0.29	0.34	0.008	0.043	0.95	0.12	19.3	0.20	-	0.052	0.0048	0.0168					Large	0.44	Bad	Good	B
	2	0.045	1.32	0.60	0.019	0.031	0.37	0.09	18.4	0.54	-	0.011	0.0086	0.0253					Large	0.54	Bad	Good	B
	3	0.094	0.58	0.19	0.041	0.002	0.18	0.43	19.1	1.04	-	0.121	0.0091	0.0178					Large	0.42	Bad	Good	C
	4	0.032	0.39	1.67	0.032	0.189	0.65	0.32	15.7	0.21	0.17	0.068	0.0072	0.0089			0.90	9.82	Intermediate	0.69	Good	Good	C
	5	0.019	1.98	0.14	0.050	0.034	0.51	0.55	17.9	0.62	-	0.082	0.0089	0.0048					Large	0.29	Bad	Good	A
	6	0.081	0.67	0.38	0.029	0.009	1.88	0.41	18.5	0.87	-	0.290	0.0029	0.0073					Large	0.58	Bad	Good	A
	7	0.105	0.78	0.67	0.028	0.038	0.12	0.11	16.2	0.03	-	0.019	0.0233	0.0067					Large	0.45	Bad	Bad	B
	8	0.089	0.11	1.32	0.011	0.233	0.09	0.32	21.4	0.15	-	0.088	0.0083	0.0149					Intermediate	0.34	Good	Bad	C
	9	0.021	0.25	0.11	0.041	0.008	0.59	0.07	8.5	0.54	-	0.059	0.0091	0.0111					Large	0.32	Bad	Bad	A
	10	0.093	0.60	0.55	0.032	0.652	0.44	1.34	19.4	0.21	-	0.078	0.0022	0.0121	Nb:0.86				Large	0.89	Good	Bad	C
	11	0.056	0.18	2.60	0.050	0.285	0.89	0.63	16.8	0.08	-	0.092	0.0148	0.0198					Small	0.83	Good	Bad	C
	12	0.009	0.43	0.50	0.029	0.032	0.48	0.45	17.3	0.09	-	0.034	0.0105	0.0184					Large	0.41	Bad	Good	B
	13	0.023	0.58	1.95	0.044	0.285	0.34	0.24	16.4	0.15	0.40	0.049	0.0111	0.0135			1.40	4.88	Intermediate	0.65	Good	Bad	C

(1) Evaluation of Machinability

[0033] Machinability was evaluated by evaluating the variation of the outer diameter of the works after machining, the surface roughness and the shape of chips.

[0034] Machining was performed under the following conditions using Carbide tool in insoluble oil: 100mm/min. of cutting speed; 0.10mm of depth of cut, and; 0.01 mm/rev of feed amount for one rotation. Machining was performed to 50 samples and the outer diameter of the test pieces and the wear of the tool after machining were measured.

[0035] The variation of the outer diameter is the variation from that of an initial work. The criterion for judging the variation was determined as "small" for the case where the wear of the lateral relief is less than 50μm and "intermediate" for the case where it is 50 μm or more and 100 μ m or less, and "large" for the case where it exceeds 100 μ m.

[0036] The surface roughness is the arithmetic mean (Ra: μm) of the work surface after machining, measured in a method designated in JIS-B0601.

[0037] Furthermore, the shape of the chips was visual-inspected and the chip of the size of approximately 10mm or less, having a good fragmenting property were evaluated and represented as "good" and other chips that were not separated from each other were evaluated and represented as "bad".

(2) Corrosion Resistance

[0038] The corrosion resistance evaluation test was performed in the form of wet-type test. As the test pieces, those having a cylindrical shape, the diameter of 10mm and the height of 50mm were used and their surface was polished to the count number 400 with emery paper and was washed to degrease. Thereafter, these pieces were stored in a high-temperature and high-humidity atmosphere at 50°C of temperature and 98%RH of humidity for 98 hours. Then, whether or not there is rust on the pieces was evaluated by visual inspection of their appearance.

(3) Outgass resistance

[0039] The evaluation of the outgass resistance was performed by determining the amount of S generated. More specifically, test pieces having a shape of rectangular parallelepiped and dimensions of 15mm in height, 3mm in width and 25mm in depth, of which the entire surface has been polished with emery paper of count number 400 were used. Then, the test pieces, a sheet of silver foil (dimensions: 0.1mm in height, 5mm in width and 10mm in depth; and purity: 99.9% or higher) and 0.5cc of pure water were put in a sealed container having the volume of 250cc. Then, the temperature inside the container was maintained at 85°C for 20 hours. The sheet of silver foil acts as the getter when gas containing S is generated and the surface of the sheet of the silver foil turns black due to production of silver sulfide when S component adsorbed by the sheet of the silver foil becomes excessive. Then, the change of the color of the silver foil surface was checked by visual inspection and the outgass resistance was evaluated in three (3) ranks in which those without any change of the color were evaluated as "A", those with a little change of the color were evaluated as "B" and those with apparent change of the color were evaluated as "C". Those that obtained the evaluation result of A or B were judged as excellent in outgass resistance.

[0040] According to the test results listed in Table 1, it can be seen that any type of the steel according to the invention has excellent machinability and surface roughness as well as is excellent in the corrosion resistance and the outgass resistance.

[0041] Next, for some of the steel types of the invention and steel types for comparison, a composition analysis of sulfide produced in the texture of the steel was performed in electron beam probe micro-analysis (EPMA) method. The results of this analysis are shown in Table 2. According to Table 2, it can be seen that, the composition of sulfide satisfies Equation (3) for the steel of the invention and the sulfide has a high ratio of Ti contained. In contrast, for the steel for comparison No. 4 for which the composition of the steel does not satisfy Equations (1) and (2) and steel for comparison No. 7 for which the composition of the steel does not satisfy Equation (1), almost same amount of Ti and Mn are contained in sulfide and the composition of the sulfide does not satisfy Equation (3). The steel for comparison Nos. 4 and 7 having such sulfide are poor in the corrosion resistance and the outgass resistance as also apparent from Table 1.

$$[\text{Ti}] \geq 1.3 \times [\text{S}] \quad \text{Equation (1)}$$

$$(\text{Mn})/[\text{Ti}] \leq 3 \quad \text{Equation (2)}$$

$$(\text{WTi}+\text{WCr}) > 2 \times \text{WMn} \quad \text{Equation (3)}$$

Table 2

Steel of the Invention	Composition of Sulfide (wt%)			(Ti+Cr)/Mn
	Ti	Cr	Mn	
No.1	58.9	0.7	0.4	149.0
No.4	48.5	1.5	10.5	4.8
No.8	56.5	0.8	2.8	20.5
No.17	48.3	1.2	8.1	6.1
No.19	51.9	0.3	8.1	6.4
No.27	42.8	8.2	9.6	5.3
No.28	42.6	1.1	17.0	2.6
Steel for Comparison	Composition of Sulfide (wt%)			(Ti+Cr)/Mn
	Ti	Cr	Mn	
No.4	33.3	1.2	26.8	1.3
No.14	38.4	0.8	22.3	1.8

Claims

1. A ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance, comprising:

in weight percentage, 0.06% or less of C, 0.05 to 1.0% of Si, 2.0% or less of Mn, 0.050% or less of P, 0.05 to 0.50% of S, 2.0% or less of Cu, 2.0% or less of Ni, 9.0 to 25.0% of Cr, 4.0% or less of Mo, 0.065 to 2.0% of Ti, 0.0150% or less of O, 0.020% or less of N, 0.001 to 0.100% of Al, and Fe and inevitable impurity in the rest portion, wherein the steel satisfies Equations (1) and (2) of the equations,

$$[\text{Ti}] \geq 1.3 \times [\text{S}] \quad \text{Equation (1)}$$

$$[\text{Mn}]/[\text{Ti}] \leq 3 \quad \text{Equation (2)}$$

$$(\text{WTi} + \text{WCr}) > 2 \times \text{WMn} \quad \text{Equation (3)}$$

where the amount of Ti contained in the steel is represented by [Ti], that of S is represented by [S] and that of Mn is represented by [Mn], and wherein the steel satisfies Equation (3) where the amount of Ti contained in sulfide produced in the texture of the steel is represented by WTi, that of Cr is represented by WCr and that of Mn is represented by WMn.

2. A ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance, wherein in addition to the components as claimed in Claim 1, the steel contains in weight percentage any one or more selected from the group consisting of 0.01 to 0.30% of Pb, 0.01 to 0.30% of Se, 0.10% or less of Te and 0.01 to 0.30% or less of Bi.
3. A ferritic free-cutting stainless steel excellent in surface roughness and outgass resistance, wherein in addition to the components as claimed in Claim 1 or 2, the steel contains in weight percentage any one or more selected from the group consisting of 0.05% or less of Ca, 0.02% or less of Mg, 0.02% or less of B, 0.02% or less of REM, 0.50% or less of V, 0.50% or less of Nb, 2.0% or less of W and 0.50% or less of Ta.