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(54) **FERRITIC FREE-CUTTING STAINLESS STEEL MATERIAL**

(57) The present invention relates to a ferritic free-cutting stainless steel material having a component composition contains: in terms of mass%, 10.0%≤Cr≤25.0%, 0.2%≤Mn≤2.0%, 0.30%≤Al≤2.50%, 0.02%≤Si≤0.60%, and 0.10%≤S≤0.45%, and further two or more selected from the group consisting of 0.03%≤Pb≤0.40%, 0.03%≤Bi≤0.40%, and 0.01%≤Te≤0.10%, with a balance being Fe and unavoidable impurities. The component composition satisfies: 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al] < 300, and ([Cr] + [Mo] + 1.5[Si] + 4[Al])/([Ni] + 0.5[Mn] + 30[C] + 30[N]) ≥ 7. The ferritic free-cutting stainless steel material contains sulfides having a circle equivalent diameter of 1.5 μm or more, and the sulfides have an average circle equivalent diameter of 3.0 to 15.0 μm, an average aspect ratio of 2.5 or less, and an area ratio of 0.5 to 2.0%, and the maximum value of Vickers hardness of 170 HV or less.

(52) Cooperative Patent Classification (CPC): (Cont.)
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Description

TECHNICAL FIELD

[0001] The present invention relates to a ferritic free-cutting stainless steel material having excellent machining performance, and in particular, relates to a ferritic free-cutting stainless steel material having excellent homogeneity.

BACKGROUND ART

[0002] Ferritic free-cutting stainless steel represented by SUS430F has low machining resistance during drilling but is inferior in chip breakability. Therefore, free-cutting elements such as S, Se, Pb, Bi, and Te are often added in combination. Here, when drilling such a fine hole having a hole diameter of 2 mm or less, in particular, when processing a small-diameter deep hole having a hole depth that is twice or more a drill diameter, a tool life, processing surface roughness, chip breakability, and the like significantly deteriorate if a processing speed is increased in order to improve manufacturability, as compared with the case of drilling of a large-diameter shallow hole, and therefore, higher machinability is required.

[0003] For example, Patent Literature 1 discloses, as ferritic free-cutting stainless steel having excellent machinability and hot workability, a free-cutting steel having a high content of Al, which is a ferrite-stabilizing element, to improve ferrite phase stability. Specifically, the free-cutting steel has a component composition containing, in terms of mass%, C: 0.015% or less, Si: 0.02% to 0.60%, Mn: 0.2% to 2.0%, P: 0.050% or less, Cu: 1.5% or less, Ni: 1.5% or less, Cr: 10.0% to 25.0%, Mo: 2.0% or less, Al: 0.30% to 2.50%, O: 0.0030% to 0.0400%, N: 0.035% or less, and S: 0.10% to 0.45%, further containing two or more selected from the group consisting of Pb: 0.03% to 0.40%, Bi: 0.03% to 0.40%, and Te: 0.01% to 0.10%, satisfying 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al] ≤ 300, in which [M] is a mass% of an element M, and a remaining part being Fe and unavoidable impurities. The free-cutting steel has a ferrite cross-sectional area ratio of 95% or more when hot-forged in a ferrite single-phase region. The formula of the element M indicates matrix strength provided by solid solution elements, and here, the matrix strength is reduced while maintaining a ferrite single phase to balance machining performance and hot workability.

Patent Literature 1: JP2017-110285A

SUMMARY OF INVENTION

[0004] A ferritic free-cutting stainless steel material can be processed into a steel material such as bar steel or a wire material by partially machining a steel material or cutting and machining the steel material. Such a steel material is required to have homogeneity that ensures stable machinability over the entire steel material. On the other hand, for example, in the case of the stainless steel as disclosed in Patent Literature 1 whose chemical composition (main components and free-cutting elements) is adjusted to improve machinability, a variation in the chemical composition, in particular, a variation in a microstructure may occur, which may cause a variation in the machinability.

[0005] The present invention has been made in view of the above circumstances, and an object thereof is to provide a ferritic free-cutting stainless steel material having excellent machinability, which has excellent machinability with respect to thin drill over the entire steel material and is particularly suitable for a product to be subjected to a cold cutting process.

[0006] The present invention provides a ferritic free-cutting stainless steel material having excellent corrosion resistance, having a component composition contains and preferably consists of: in terms of mass%,

$$10.0\% \leq Cr \leq 25.0\%,$$

$$0.2\% \leq Mn \leq 2.0\%,$$

$$0.30\% \leq Al \leq 2.50\%,$$

$$0.02\% \leq Si \leq 0.60\%,$$

and

$$0.10\% \leq S \leq 0.45\%,$$

and

further
two or more selected from the group consisting of:

$$0.03\% \leq Pb \leq 0.40\%,$$

$$0.03\% \leq Bi \leq 0.40\%,$$

and

$$0.01\% \leq Te \leq 0.10\%,$$

and
optionally

$$C \leq 0.015\%,$$

$$P \leq 0.050\%,$$

$$Cu \leq 1.5\%,$$

$$Ni \leq 1.5\%,$$

$$Mo \leq 2.0\%,$$

$$B \leq 0.0080\%,$$

$$Mg \leq 0.0100\%,$$

and

$$Ca \leq 0.0100\%,$$

with a balance being Fe and unavoidable impurities,

in which, when [M] represents a mass% of an element M, the component composition satisfies the following formulae (1) and (2):

$$\text{formula (1): } 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al] \leq 300,$$

and

$$\text{formula (2): } ([Cr] + [Mo] + 1.5[Si] + 4[Al])/([Ni] + 0.5[Mn] + 30[C] + 30[N]) \geq 7,$$

and

in which the ferritic free-cutting stainless steel material contains sulfides having a circle equivalent diameter of 1.5 μm or more, and the sulfides have an average circle equivalent diameter of 3.0 μm to 15.0 μm, an average aspect ratio of 2.5 or less, and an area ratio of 0.5% to 2.0%, and

the ferritic free-cutting stainless steel material has a maximum value of Vickers hardness of 170 HV or less.

[0007] According to this aspect, the ferritic free-cutting stainless steel material is suitable for a product that has excellent machinability, in particular, excellent machinability with respect to thin drill over the entire steel material and which is to be subjected to cold cutting.

[0008] In the above-described aspect, the component composition may further satisfy one or two or more selected from the group consisting of 0.0001≤B≤0.0080%, 0.0005≤Mg≤0.0100%, and 0.0005≤Ca≤0.0100%. The component composition may further satisfy, as the unavoidable impurities, O≤0.0100% and N≤0.035%. Further, the ferritic free-cutting stainless steel material may be free of an unrecrystallized structure. According to this aspect, it is possible to obtain better machinability.

[0009] In the above-described aspect, the ferritic free-cutting stainless steel material may have a form of a bar steel or a wire material. According to this aspect, the ferritic free-cutting stainless steel material is suitable for use in cutting and machining.

[0010] The ferritic free-cutting stainless steel material may have a corrosion resistance such that rust does not occur after being left for 24 hours in a wet atmosphere having a temperature of 50°C and a relative humidity of 98%. According to this aspect, the ferritic free-cutting stainless steel material is suitable for use in a wet environment.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIGs. 1A and 1B are appearance photographs of test pieces in a corrosion resistance test. FIG. 1A shows an example in which rust does not occur, and FIG. 1B shows an example in which rust occurs.

[0012] FIG. 2 is a microscope photograph of a cross-sectional structure of Example 16.

DESCRIPTION OF EMBODIMENTS

[0013] A ferritic free-cutting stainless steel material according to one embodiment of the present invention will be described.

[0014] Such a steel material is excellent in machinability with respect to thin drill over the entire steel material.

[0015] A component composition of such a steel material is as follows. The steel material contains, in terms of mass%, 10.0%≤Cr≤25.0%, 0.2%≤Mn≤2.0%, 0.30%≤Al≤2.50%, 0.02%≤Si≤0.60%, and 0.10%≤S≤0.45% and further contains two or more selected from the group consisting of 0.03%≤Pb≤0.40%, 0.03%≤Bi≤0.40%, and 0.01%≤Te≤0.10%.

[0016] Further, when a mass% of an element M is [M], the following formula (1) and formula (2) are satisfied, and the component composition is adjusted to satisfy C≤0.015%, P≤0.050%, Cu≤1.5%, Ni≤1.5%, and Mo≤2.0%.

$$\text{Formula (1): } 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al] \leq 300,$$

$$\text{Formula (2): } ([Cr] + [Mo] + 1.5[Si] + 4[Al])/([Ni] + 0.5[Mn] + 30[C] + 30[N]) \geq 7$$

[0017] Here, it is necessary to satisfy formula (1) in order to inhibit a decrease in matrix strength of the steel material and to obtain a steel material having excellent machining performance with respect to thin drill. Preferably, 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al]≤230 is satisfied. It is also necessary to satisfy formula (2) in order to obtain a ferrite fraction enabling sufficient hot working.

[0018] Such a component composition is determined by particularly focusing on the following three points in order to obtain excellent machinability.

[0019] First, S is contained as an essential additive element, and two or more selected from Pb, Bi, and Te are contained to add a composite of free-cutting elements.

[0020] Second, by inhibiting the matrix strength of the steel material, the machinability is improved. That is, contents of solid-solution-strengthening elements such as Si, Cr, and Mo are reduced, and instead, Al having a small contribution to solid solution strengthening is contained to satisfy the above formula (1). Further, by satisfying formula (2), a ferrite single phase can be maintained, and the matrix strength is reduced.

[0021] Third, C, O, and N that form a carbide, an oxide, and a nitride as hard inclusions are reduced, and generation of hard particles causing abrasive wear during machining is reduced. The content of C is adjusted to 0.015 mass% or less. In addition, it is desirable to minimize O and N, which are gas components, as impurities. However, since impurities are unavoidably mixed, upper limits of allowable contents are determined to be O≤0.0100% and N≤0.035% in terms of mass%.

[0022] In order to achieve excellent machinability with respect to thin drill over the entire steel material, morphology of sulfides is managed, and hardness of the steel material is also managed. As described above, in order to obtain excellent machinability, S is contained in the steel material and a large number of sulfides are contained. Sulfides having a circle equivalent diameter of 1.5 μm or more have an average circle equivalent diameter of 3.0 μm to 15.0 μm, an average aspect ratio of 2.5 or less, and an area ratio of 0.5% to 2.0%. In addition, a maximum value of Vickers hardness (hardness) over the entire steel material is 170 HV or less. The Vickers hardness is measured under a test force of 300 g.

[0023] As for the morphology of the sulfides, in the case where the average circle equivalent diameter is less than 3.0 μm or exceeds 15.0 μm, chip breakability deteriorates, a dimension at which chips are broken is long, and thus the machining performance is decreased. In addition, in the case where the average aspect ratio exceeds 2.5, anisotropy of metal structure increases, and thus the machinability is decreased. In addition, in the case where the area ratio of the sulfide is less than 0.5%, a tool life and the chip breakability are decreased. In the case where the area ratio exceeds 2.0%, hot workability is decreased.

[0024] As described above, it is possible to provide a steel material having excellent machinability with respect to thin drill over the entire steel material, which is particularly suitable for a product to be subjected to cold cutting.

[0025] It is also preferable that the component composition of the steel material further contains, in terms of mass%, one or two or more selected from the group consisting of 0.0001%≤B≤0.0080%, 0.0005%≤Mg≤0.0100%, and 0.0005%≤Ca≤0.0100%. Addition of these elements can improve the hot workability of the steel material.

[0026] It is also preferable that no unrecrystallized structure is contained over the entire steel material. That is, the entire steel material may be a recrystallized structure. This makes it easy to stabilize the maximum value of the Vickers hardness to 170 HV or less. As a result, the machinability can be stably obtained over the entire steel material and the machinability can be further improved.

[0027] Further, it is preferable that the steel material is processed into bar steel or a wire material. Even in the case where the steel material is used in such a form whose ends are likely to have a difference in thermal history and a large difference in metal structures, since excellent machinability is exhibited over the entire steel material, the steel material is suitable for use in such a form in which the steel material is partially cut and machined.

[0028] The steel material may also have high corrosion resistance. For example, the steel material may have corrosion resistance such that no rust occurs after being left for 24 hours in a wet atmosphere having a temperature of 50°C and a relative humidity of 98%. Accordingly, the steel material is also suitable for use in a wet environment.

[0029] Such a steel material can be manufactured by the following manufacturing process. Here, manufacturing of a wire material will be described as an example.

[0030] First, raw materials of steel are melted to have the above chemical composition, followed by casting to obtain an ingot, and optionally, the ingot is further subjected to a segment forging or segment rolling to obtain a billet. Alternatively, raw materials of steel are subjected to a continuous casting to obtain a billet. The obtained ingot or billet is used as a material.

[0031] Next, the ingot or the billet is subjected to homogenization. Here, a heat treatment may be performed to maintain the ingot or the billet at a predetermined temperature in a range of 1250°C to 1300°C for 1 hour or more. Accordingly, the above-described sulfide morphology can be obtained.

[0032] Next, the ingot or the billet is subjected to hot rolling. In the rolling, it is preferable to perform structure control using recrystallization. Accordingly, matrix hardness can be reduced. The recrystallization is preferably performed under manufacturing conditions where a working temperature during rolling is 700°C to 1000°C, and a total reduction ratio is 3 or more (a cross-sectional area after rolling is 1/3 or less than that before rolling). In the case of rolling having multiple stages, such as using a continuous rolling mill including a large number of rolls, rolling after so-called rough rolling may be performed under the above manufacturing conditions. The above-described working temperature during rolling may be maintained at a final stage of the rolling, and a temperature of the steel material at a start of the rolling may be a high temperature such as 1300°C.

[0033] In the hot rolling, a rolling end temperature may be in a range of 800°C to 1000°C. When the entire steel material is treated at the rolling end temperature, followed by cooling, it is possible to obtain a recrystallized structure over the entire steel material whereas no unrecrystallized structure is contained. A cooling method is not particularly limited, and air cooling is preferable. Such control is performed over the entire steel material, and, in the case of the wire material, it is sufficient to confirm that the manufacturing conditions described above are satisfied at a front end, a center, and a rear end thereof since the wire material is inserted into the rolling mill in a longitudinal direction. In the case where an additional rolling is added for the purpose of dimensional adjustment or the like, the rolling end temperature may be also set in the range of 800°C to 1000°C in the additional rolling. For example, the rolling end temperature may be adjusted by adjusting an initial temperature of the billet to be subjected to the rolling, by heating or cooling the steel material in the middle of the rolling, or by adjusting time of the rolling by changing a rolling speed. For example, since the steel material during the rolling may lose heat due to heat emission to outside air or the rolling mill, or may generate heat due to deformation caused by processing, such heat loss or generation may be taken into consideration to adjust the rolling end temperature.

[0034] In the cooling after the rolling, in the case where a cooling rate is slow due to, for example, furnace cooling performed instead of air cooling, or in the case where the cooling rate is high due to oil cooling or water cooling, corrosion resistance of the ferritic stainless steel may decrease. In such a case, annealing may be performed as an additional heat treatment to ensure the corrosion resistance. In such annealing, a holding temperature may be determined in a range of 730°C to 870°C.

[0035] Rough rolling may be performed prior to the hot rolling as necessary, such as for adjusting a dimension of the steel material used in the hot rolling. In the case where such rough rolling is performed, rolling conditions are not particularly limited, and, for example, a working temperature during the rolling may be 1200°C to 1300°C. In such rough rolling, it is possible to wind the steel material in a coil shape by a winding machine as it is in a high temperature after the rolling is ended, and then cooling may be performed.

[0036] After the annealing after the rolling, a descaling treatment may be performed. In the descaling treatment, for example, acid pickling or shot blasting is performed. Cold drawing may further be performed for the purpose of dimensional adjustment or the like.

[Manufacturing Test]

[0037] Next, results of a manufacturing test of the above-described ferritic free-cutting stainless steel material will be described.

[0038] First, steel having a component composition shown in Tables 1 and 2 was melted and cast into a 5t steel ingot. The ingot was formed into billets of 150 mm square × 3000 mm by segment rolling. In Tables 1 and 2, "MS" refers to a value on the left side in formula (1), and "FS" refers to a value on the left side in formula (2).

[Table 1]

Alloy No.	Chemical component (mass%)									
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Al
1	0.005	0.12	0.45	0.015	0.25	0.1	0.1	18.9	0.1	0.33
2	0.011	0.15	1.50	0.011	0.33	0.2	0.2	11.9	0.2	0.51
3	0.008	0.20	0.45	0.019	0.19	0.1	0.2	15.1	0.1	0.45
4	0.007	0.16	1.42	0.008	0.27	0.1	0.1	14.6	0.2	0.59
5	0.009	0.12	1.35	0.022	0.28	0.1	0.1	13.5	0.1	0.49
6	0.008	0.15	1.29	0.033	0.33	0.2	0.1	12.5	0.1	0.71
7	0.006	0.16	0.91	0.015	0.18	0.1	0.1	13.8	0.2	0.53
8	0.005	0.10	1.49	0.016	0.25	0.2	0.2	12.7	0.2	0.45
9	0.007	0.28	1.37	0.018	0.27	0.1	0.1	11.1	0.3	0.83
10	0.008	0.08	1.45	0.026	0.28	0.2	0.2	18.8	0.1	0.35
11	0.008	0.09	1.29	0.017	0.29	0.1	0.1	13.3	0.1	0.46
12	0.009	0.16	1.17	0.026	0.19	0.1	0.1	12.8	0.2	0.44
13	0.006	0.10	1.26	0.019	0.35	0.2	0.2	15.3	0.2	0.31
14	0.007	0.16	0.87	0.012	0.33	0.1	0.1	13.8	0.1	0.50
15	0.009	0.22	1.26	0.006	0.40	0.2	0.2	13.5	0.1	0.70
16	0.009	0.10	1.33	0.019	0.28	0.1	0.1	13.2	0.1	0.44
17	0.011	0.29	1.12	0.012	0.31	0.1	0.2	12.1	0.2	0.73
18	0.009	0.11	1.54	0.019	0.33	0.1	0.1	14.3	0.1	0.61

(continued)

Alloy No.	Chemical component (mass%)									
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Al
19	0.010	0.19	0.93	0.017	0.27	0.2	0.2	13.1	0.2	1.02
20	0.008	0.16	1.33	0.013	0.29	0.2	0.1	12.5	0.3	0.43
21	0.009	0.15	1.56	0.009	0.34	0.2	0.2	12.8	0.2	0.55
22	0.006	0.08	1.35	0.029	0.25	0.1	0.1	13.6	0.1	0.48
23	0.005	0.07	1.04	0.024	0.28	0.1	0.2	14.1	0.1	0.71
24	0.006	0.17	0.92	0.014	0.21	0.2	0.1	11.9	0.3	0.54
25	0.005	0.19	0.56	0.016	0.19	0.1	0.1	18.0	0.2	0.33
1	0.0017	0.012	-	0.22	0.044	-	-	-	268.6	24.8
2	0.0027	0.008	0.21	-	0.035	-	-	-	196.5	9.5
3	0.0007	0.011	-	0.28	0.046	-	-	-	239.8	17.4
4	0.0017	0.013	0.27	-	0.039	-	-	-	232.3	12.3
5	0.0023	0.009	0.18	-	0.034	-	-	-	206.5	12.0
6	0.0023	0.010	-	0.25	0.036	-	-	-	201.8	12.2
7	0.0010	0.012	-	0.21	0.048	-	-	-	220.3	14.9
8	0.0007	0.009	-	0.22	0.035	-	-	-	192.5	10.9
9	0.0011	0.006	-	0.14	0.032	-	-	-	209.8	12.9
10	0.0022	0.013	-	0.18	0.029	-	-	-	264.6	13.1
11	0.0025	0.009	-	0.22	0.030	-	-	-	197.8	12.3
12	0.0009	0.012	0.11	0.13	0.039	-	-	-	210.1	11.4
13	0.0036	0.008	0.14	0.08	0.037	-	-	-	222.3	13.5
14	0.0029	0.006	-	0.29	0.040	-	-	-	212.5	17.4
15	0.0008	0.011	-	0.12	0.026	-	-	-	227.4	11.7
16	0.0026	0.010	-	0.18	0.035	-	-	-	199.9	11.4
17	0.0017	0.010	0.19	-	0.042	0.0031	-	-	226.7	11.3
18	0.0022	0.009	0.26	-	0.047	-	0.0038	-	215.6	12.1
19	0.0016	0.013	0.18	-	0.027	-	-	0.0048	226.4	13.0
20	0.0007	0.015	-	0.19	0.041	0.0049	-	-	211.2	10.1
21	0.0013	0.008	0.05	0.20	0.035	-	0.0019	0.0022	205.9	10.4
22	0.0022	0.011	-	0.13	0.033	0.0039	-	-	199.9	12.2
23	0.0028	0.007	-	0.15	0.036	-	0.0037	-	202.0	15.9
24	0.0013	0.008	-	0.14	0.040	-	-	0.0042	198.7	14.9
25	0.0020	0.010	-	0.21	0.038	0.0023	-	0.0031	271.1	23.9

[Table 2]

Alloy No.	Chemical component (mass%)									
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Al
26	0.017	0.21	1.01	0.028	0.25	0.1	0.2	13.5	0.2	0.48
27	0.006	0.10	1.26	0.019	0.30	0.2	0.2	15.3	0.2	0.31
28	0.009	0.14	0.90	0.012	0.28	0.1	0.1	13.8	0.1	0.50
29	0.008	0.18	1.26	0.030	0.31	0.1	0.2	13.5	0.1	0.58
30	0.008	0.18	1.26	0.030	0.31	0.1	0.2	13.5	0.1	0.58
31	0.007	0.20	0.99	0.025	0.28	0.1	0.1	13.2	0.1	0.44
32	0.007	0.20	0.99	0.025	0.28	0.1	0.1	13.2	0.1	0.44
33	0.011	0.21	1.23	0.021	0.31	0.1	0.2	12.1	0.2	0.73
34	0.011	0.21	1.23	0.021	0.31	0.1	0.2	12.1	0.2	0.73
35	0.010	0.18	1.45	0.019	0.30	0.2	0.1	14.3	0.1	0.61
36	0.010	0.18	1.45	0.019	0.30	0.2	0.1	14.3	0.1	0.61
37	0.009	0.18	1.22	0.017	0.35	0.2	0.2	13.1	0.2	0.59
38	0.009	0.18	1.22	0.017	0.35	0.2	0.2	13.1	0.2	0.59
39	0.010	0.17	1.33	0.033	0.25	0.1	0.1	12.5	0.3	0.48
40	0.012	0.21	1.50	0.035	0.34	0.2	0.2	12.8	0.2	0.45
26	0.0017	0.011	-	0.17	0.033	-	-	-	233.7	10.3
27	0.0030	0.009	0.16	-	0.033	-	-	-	223.2	13.2
28	0.0022	0.010	0.17	-	0.038	-	-	-	214.5	14.4
29	0.0008	0.011	-	0.17	0.035	-	-	-	218.5	11.6
30	0.0008	0.011	-	0.17	0.035	-	-	-	218.5	11.6
31	0.0011	0.009	-	0.18	0.041	-	-	-	214.2	14.3
32	0.0011	0.009	-	0.18	0.041	-	-	-	214.2	14.3
33	0.0015	0.007	-	0.14	0.036	-	-	-	210.4	11.5
34	0.0015	0.007	-	0.14	0.036	-	-	-	210.4	11.5
35	0.0022	0.013	-	0.19	0.036	-	-	-	232.0	11.3
36	0.0022	0.013	-	0.19	0.036	-	-	-	232.0	11.3
37	0.0012	0.009	-	0.12	0.040	-	-	-	215.9	11.8
38	0.0012	0.009	-	0.12	0.040	-	-	-	215.9	11.8
39	0.0009	0.019	-	0.20	0.031	-	-	-	218.8	9.2
40	0.0012	0.009	-	0.13	0.029	-	-	-	218.7	9.6

[0039] Under manufacturing conditions shown in Table 3, each billet was subjected to homogenization, rough rolling, intermediate rolling, and finish rolling, and then cooled to form a wire material having a diameter of 20 mm. As shown in Table 3, a part of the billets were annealed. As the reduction ratio, a dimension in the rough rolling was individually adjusted, and thereafter, a cross-sectional area ratio until a diameter was finished to 20 mm was calculated.

[Table 3]

	Alloy No.	Homogenization temperature	Intermediate rolling		Finish rolling	Cooling method	Annealing
			Reduction ratio	Working temperature	End temperature		
Ex. 1	1	1300°C	13	Appropriate	Appropriate	Air	Yes
Ex. 2	2	1300°C	14	Appropriate	Appropriate	Air	Yes
Ex. 3	3	1300°C	14	Appropriate	Appropriate	Air	Yes
Ex. 4	4	1300°C	8	Appropriate	Appropriate	Air	Yes
Ex. 5	5	1250°C	10	Appropriate	Appropriate	Air	Yes
Ex. 6	6	1250°C	10	Appropriate	Appropriate	Furnace	Yes
Ex. 7	7	1250°C	16	Appropriate	Appropriate	Furnace	Yes
Ex. 8	8	1250°C	16	Appropriate	Appropriate	Oil	Yes
Ex. 9	9	1280°C	15	Appropriate	Appropriate	Oil	Yes
Ex. 10	10	1280°C	17	Appropriate	Appropriate	Air	Yes
Ex. 11	11	1280°C	9	Appropriate	Appropriate	Air	Yes
Ex. 12	12	1280°C	5	Appropriate	Appropriate	Air	Yes
Ex. 13	13	1300°C	7	Appropriate	Appropriate	Air	No
Ex. 14	14	1300°C	8	Appropriate	Appropriate	Air	No
Ex. 15	15	1300°C	14	Appropriate	Appropriate	Air	No
Ex. 16	16	1300°C	16	Appropriate	Appropriate	Air	No
Ex. 17	17	1300°C	19	Appropriate	Appropriate	Air	No
Ex. 18	18	1300°C	19	Appropriate	Appropriate	Air	No
Ex. 19	19	1300°C	16	Appropriate	Appropriate	Air	No
Ex. 20	20	1300°C	16	Appropriate	Appropriate	Air	No
Ex. 21	21	1300°C	18	Appropriate	Appropriate	Air	No
Ex. 22	22	1300°C	12	Appropriate	Appropriate	Air	No
Ex. 23	23	1300°C	12	Appropriate	Appropriate	Air	No
Ex. 24	24	1300°C	20	Appropriate	Appropriate	Air	No
Ex. 25	25	1300°C	16	Appropriate	Appropriate	Air	No
Comp. Ex. 1	26	1280°C	16	Appropriate	Appropriate	Air	No
Comp. Ex. 2	27	1200°C	14	Appropriate	Appropriate	Air	No
Comp. Ex. 3	28	1320°C	12	Appropriate	Appropriate	Air	No
Comp. Ex. 4	29	1280°C	2	Appropriate	Appropriate	Air	No
Comp. Ex. 5	30	1280°C	2	Appropriate	Appropriate	Air	Yes
Comp. Ex. 6	31	1280°C	10	Low	Appropriate	Air	No

(continued)

	Alloy No.	Homogenization temperature	Intermediate rolling		Finish rolling	Cooling method	Annealing
			Reduction ratio	Working temperature	End temperature		
Comp. Ex. 7	32	1280°C	16	Low	Appropriate	Air	Yes
Comp. Ex. 8	33	1280°C	5	High	Appropriate	Air	No
Comp. Ex. 9	34	1280°C	5	High	Appropriate	Air	Yes
Comp. Ex. 10	35	1280°C	12	Appropriate	Low	Air	No
Comp. Ex. 11	36	1280°C	15	Appropriate	Low	Air	Yes
Comp. Ex. 12	37	1280°C	15	Appropriate	High	Air	No
Comp. Ex. 13	38	1280°C	18	Appropriate	High	Air	Yes
Comp. Ex. 14	39	1280°C	12	Appropriate	Appropriate	Furnace	No
Comp. Ex. 15	40	1280°C	14	Appropriate	Appropriate	Oil	No

[0040] In Table 3, a working temperature in the intermediate rolling was evaluated as follows based on a temperature of a wire material on an inlet side and an outlet side in the intermediate rolling.

High: Temperature of the front end portion of the wire material on the inlet side in the intermediate rolling was higher than 1000°C

Low: Temperature of the rear end portion of the wire material on the outlet side in the intermediate rolling was lower than 700°C

Appropriate: Temperatures of all portions of the front end, center, and rear end of the wire material were in a range of 700°C to 1000°C on both the inlet side and the outlet side

[0041] An end temperature of the finish rolling was evaluated as follows based on the temperature of the wire material on the inlet side and the outlet side in the finish rolling.

High: Temperature of the front end portion of the wire material on the inlet side in the finish rolling was higher than 1000°C
Low: Temperature of the rear end portion of the wire material on the outlet side in the finish rolling was lower than 800°C
Appropriate: Temperatures of all portions of the front end, center, and rear end of the wire material were in a range of 800°C to 1000°C on both the inlet side and the outlet side

[0042] Items shown in Table 4 were tested for each obtained wire material to obtain the results.
[0043] As for the ferrite amount, a sample was collected from each of the front end, the center, and the rear end of the wire material, a cross-section was mirror-polished, etched, and then subjected to microstructure observation to perform evaluation. The case where an area ratio of a ferrite phase in the structure was 99% or more was evaluated as "A", and the case where the area ratio was less than 99% was evaluated as "C". On this basis, the sample was acceptable when evaluated as "A".
[0044] As the maximum value of the Vickers hardness, a sample was collected from each of the front end, the center, and the rear end of the wire material, and the Vickers hardness was measured 10 points each at a position of R/2 from

an outer surface (the term "R" refers to the radius of the wire material) and a center position, respectively, and a maximum value among 60 points was obtained. On this basis, the case where the maximum value of the Vickers hardness is 170 HV or less was evaluated as acceptable.

[0045] The sulfide morphology was evaluated by image analysis of a cross-sectional structure photograph of the billet after the homogenization (before the rolling). Specifically, a sample was collected from each of one end, the center, and the other end in a longitudinal direction of the billet, a position T/2 from an outer surface (the term "T" refers to half of the diagonal) and a center position in a cross-section perpendicular to the longitudinal direction were mirror-polished, and ten microstructure photographs were captured at each position. Sulfides in each microstructure photograph were identified by image analysis, and the circle equivalent diameter, the aspect ratio, and the area ratio were obtained for sulfides having a circle equivalent diameter of 1.5 μm or more. For each item, the case where the average circle equivalent diameter was in a range of 3 μm to 15 μm, the case where the average aspect ratio was 2.5 or less, and the case where the area ratio was in a range of 0.5% to 2.0% were evaluated as "A", and the other case was evaluated as "C". On this basis, for each item, the sample was acceptable when evaluated as "A".

[0046] As for unrecrystallized grains, a sample was collected from each of the front end, the center, and the rear end of the wire material, a cross-section was mirror-polished, etched, and then subjected to microstructure observation to perform evaluation. The case where no unrecrystallized grain was found over an entire observation field of view was marked "none" and evaluated as acceptable. The case where unrecrystallized grains were found was marked "present" and evaluated as unacceptable.

[0047] As for the machinability, a plurality of cylindrical samples each having a diameter of 15 mm and a length of 30 mm were prepared from each of the front end, the center, and the rear end of the wire material. A machining test was performed in the following manner that the cylindrical sample was drilled repeatedly in a longitudinal direction by a φ1 high-speed drill, and a drilling distance until a tool life of the drill was reached was measured. Drilling conditions were a feed of 0.05 mm/rev, a machining speed of 120 mm/min, and no lubrication. The tool life was evaluated as "A" in the case where a minimum value of the drilling distance was more than 4000 mm when the tool life was reached at each of the front end, the center, and the rear end of the wire material, as "B" in the case where the minimum value was from 2000 mm to 4000 mm, and as "C" in the case where the minimum value was less than 2000 mm. On this basis, the tool life was acceptable when evaluated as "A" or "B". In addition, the chip breakability was evaluated as "A" in the case where 80% or more of chips were broken into one or two curls, as "B" in the case of being broken into 3 to 5 curls, and as "C" in the case of being broken into 6 or more curls. On this basis, the chip breakability was acceptable when evaluated as "A" or "B".

[0048] For the corrosion resistance, a test was performed to confirm whether the corrosion resistance as ferritic stainless steel was maintained. First, a cylindrical sample having a diameter of 10 mm and a length of 50 mm was collected from each of the front end, the center, and the rear end of the wire material. The sample was subjected to dry surface finishing by polishing a surface with #400 paper. The sample was held in a constant-temperature constant-humidity chamber in a wet environment having a temperature of 50°C and a relative humidity of 98%, and presence or absence of rust on the surface of the sample was visually observed after 24 hours.

[0049] The sample was evaluated as "A" in the case where no rust was recognized in all parts of the front end, the center, and the rear end as shown in FIG. 1A. The sample was evaluated as "C" in the case where rust was recognized in any part of the front end, the center, and the rear end as shown in FIG. 1B. On this basis, the sample was acceptable when evaluated as "A".

[0050] As a result, in Examples 1 to 25 using alloys No. 1 to 25, all the above items were acceptable. That is, the ferrite single phase could be maintained, the maximum value of the Vickers hardness was 170 HV or less, the sulfide morphology was within the above range, there was no unrecrystallized grain, and favorable machinability and corrosion resistance were exhibited.

[0051] As shown in FIG. 2, for example, in Example 16, it is observed from a structure photograph that it is a ferrite single phase and there is no unrecrystallized grain.

[0052] On the other hand, Comparative Example 1 is unacceptable in terms of the tool life among the machinability. It is considered that use of alloy No. 26 containing a large amount of C resulted in an increase in the matrix strength.

[0053] Comparative Examples 2 and 3 were unacceptable in terms of both the tool life and the chip breakability, which are evaluation items relative to the machinability. In Comparative Example 2, a temperature in the homogenization was low, and in Comparative Example 3, a temperature in the homogenization was high. In both cases, the circle equivalent diameter of the sulfide morphology was unacceptable, and the predetermined sulfide morphology could not be obtained. It is considered that because of this, the machinability was unacceptable. The average circle equivalent diameter of sulfides in Comparative Example 2 was less than 3 μm. The average circle equivalent diameter of sulfides in Comparative Example 3 was more than 15 μm.

[0054] Comparative Examples 4 and 5 were unacceptable in terms of both the tool life and the chip breakability among the machinability. In both cases, the reduction ratio was as small as 2, which was considered to result in a lack of a driving force causing recrystallization, and thus unrecrystallized grains remained. As a result, the maximum value of the

Vickers hardness exceeded 170 HV. In addition, the circle equivalent diameter among the sulfide morphology was unacceptable, and it is considered that coarse sulfides were not sufficiently broken in the rolling since the reduction ratio was small. Accordingly, it is considered that the machinability is adversely affected.

[0055] Comparative Examples 6 and 7 were unacceptable in terms of the tool life among the machinability. In both cases, a working temperature in the intermediate rolling was low, and therefore, unrecrystallized grains remained. As a result, the maximum value of the Vickers hardness exceeded 170 HV. Accordingly, it is considered that the machinability is adversely affected.

[0056] Comparative Examples 8 and 9 were unacceptable in terms of the tool life among the machinability. In both cases, a working temperature in the intermediate rolling was high, and therefore, unrecrystallized grains remained. As a result, the maximum value of the Vickers hardness exceeded 170 HV. Accordingly, it is considered that the machinability is adversely affected.

[0057] Comparative Examples 10 and 11 were unacceptable in terms of the tool life among the machinability. In both cases, a rolling end temperature in the finish rolling was low, and therefore, unrecrystallized grains remained. As a result, the maximum value of the Vickers hardness exceeded 170 HV. Accordingly, it is considered that the machinability is adversely affected.

[0058] Comparative Examples 12 and 13 were unacceptable in terms of the tool life among the machinability. In both cases, a rolling end temperature in the finish rolling was high, and therefore, unrecrystallized grains remained. As a result, the maximum value of the Vickers hardness exceeded 170 HV. Accordingly, it is considered that the machinability is adversely affected.

[0059] Although it is required to maintain the corrosion resistance as the ferritic stainless steel, Comparative Examples 14 and 15 were unacceptable only in terms of corrosion resistance whereas the same degree of machinability as in Examples was obtained. As described above, in Comparative Example 14, the cooling method after the rolling was furnace cooling which had a low cooling rate, instead of air cooling, and, in Comparative Example 15, oil cooling having a high cooling rate was performed, so that the corrosion resistance was decreased in Comparative Examples 14 and 15. Although the cooling method was furnace cooling or oil cooling in Examples 6 to 9, annealing was performed thereafter, and thus favorable corrosion resistance was obtained. In contrast, in Comparative Examples 14 and 15, since the annealing was not performed, the decrease in the corrosion resistance was observed.

[Table 4]

	Ferrite amount	Maximum value of Vickers hardness	Sulfide morphology			Unrecrystallized grain	Machinability		Corrosion resistance
			Circle equivalent diameter	Aspect ratio	Area ratio		Tool life	Chip breakability	
Ex. 1	A	156	A	A	A	None	B	A	A
Ex. 2	A	144	A	A	A	None	A	A	A
Ex. 3	A	157	A	A	A	None	B	B	A
Ex. 4	A	147	A	A	A	None	A	A	A
Ex. 5	A	141	A	A	A	None	A	A	A
Ex. 6	A	146	A	A	A	None	A	A	A
Ex. 7	A	147	A	A	A	None	B	B	A
Ex. 8	A	138	A	A	A	None	A	A	A
Ex. 9	A	145	A	A	A	None	A	A	A
Ex. 10	A	160	A	A	A	None	B	A	A
Ex. 11	A	143	A	A	A	None	A	A	A
Ex. 12	A	142	A	A	A	None	A	B	A
Ex. 13	A	141	A	A	A	None	A	A	A
Ex. 14	A	146	A	A	A	None	A	A	A
Ex. 15	A	148	A	A	A	None	A	A	A
Ex. 16	A	148	A	A	A	None	A	A	A
Ex. 17	A	145	A	A	A	None	A	A	A
Ex. 18	A	147	A	A	A	None	A	A	A
Ex. 19	A	140	A	A	A	None	A	A	A
Ex. 20	A	145	A	A	A	None	B	A	A
Ex. 21	A	143	A	A	A	None	A	A	A
Ex. 22	A	140	A	A	A	None	A	A	A
Ex. 23	A	136	A	A	A	None	A	A	A
Ex. 24	A	143	A	A	A	None	A	B	A

(continued)

	Ferrite amount	Maximum value of Vickers hardness	Sulfide morphology			Unrecrystallized grain	Machinability		Corrosion resistance
			Circle equivalent diameter	Aspect ratio	Area ratio		Tool life	Chip breakability	
Ex. 25	A	155	A	A	A	None	B	B	A
Comp. Ex. 1	A	159	A	A	A	None	C	A	A
Comp. Ex. 2	A	151	C	A	A	None	C	C	A
Comp. Ex. 3	A	145	C	A	A	None	C	C	A
Comp. Ex. 4	A	172	C	A	A	Present	C	C	A
Comp. Ex. 5	A	173	C	A	A	Present	C	C	A
Comp. Ex. 6	A	177	A	A	A	Present	C	A	A
Comp. Ex. 7	A	181	A	A	A	Present	C	A	A
Comp. Ex. 8	A	179	A	A	A	Present	C	B	A
Comp. Ex. 9	A	177	A	A	A	Present	C	B	A
Comp. Ex. 10	A	174	A	A	A	Present	C	A	A
Comp. Ex. 11	A	175	A	A	A	Present	C	A	A
Comp. Ex. 12	A	173	A	A	A	Present	C	A	A
Comp. Ex. 13	A	173	A	A	A	Present	C	A	A

(continued)

	Ferrite amount	Maximum value of Vickers hardness	Sulfide morphology			Unrecrystallized grain	Machinability		Corrosion resistance
			Circle equivalent diameter	Aspect ratio	Area ratio		Tool life	Chip breakability	
Comp. Ex. 14	A	149	A	A	A	None	A	A	C
Comp. Ex. 15	A	145	A	A	A	None	A	A	C

[0060] As described above, it was demonstrated that the appropriate manufacturing method using the steel having the above component composition can manufacture a ferritic free-cutting stainless steel material having excellent machinability with respect to thin drill over the entire steel material.

[0061] A composition range of a steel material that can exhibit substantially the same machinability as in the above-described manufacturing test is determined as follows.

[0062] Cr is an element that contributes to improvement in the corrosion resistance. On the other hand, in the case where Cr is excessively contained, the matrix strength of the steel material is increased as shown in formula (1), and the machinability is decreased. In this regard, Cr is in a range of 10.0% to 25.0%, and preferably in a range of 10.0% to 17.0% in terms of mass%.

[0063] Mn is an element that forms a compound with S and contributes to improvement in the machinability. In addition, Mn can inhibit grain boundary segregation of S to improve the hot workability. On the other hand, in the case where Mn is excessively contained, a ferrite phase becomes unstable since Mn is an austenite stabilizing element. In this regard, Mn is in a range of 0.2% to 2.0% in terms of mass%.

[0064] Al is a fairly important element that promotes matrix embrittlement by increasing a ductile-brittle transition temperature and that contributes to improvement in the chip breakability. Al is also a strong ferrite stabilizing element and is required to be contained to ensure the hot workability. On the other hand, in the case where Al is excessively contained, cooling cracking of a steel ingot may be induced and manufacturability may be decreased. In this regard, Al is in a range of 0.30% to 2.50%, and preferably in a range of 0.35% to 2.50% in terms of mass%.

[0065] Si is an element effective as a deoxidizer. On the other hand, in the case where Si is excessively contained, the matrix strength is increased and the machinability is decreased since Si is a representative solid-solution-strengthening element. In this regard, Si is in a range of 0.02% to 0.60%, and preferably in a range of 0.02% to 0.40% in terms of mass%.

[0066] S is an element that forms a sulfide and contributes to improvement in the machinability. On the other hand, in the case where S is excessively contained, the hot workability is significantly decreased. In this regard, S is in a range of 0.10% to 0.45%, and preferably in a range of 0.10% to 0.40% in terms of mass%.

[0067] It is necessary to selectively contain two or more of Pb, Bi, and Te below.

[0068] Pb is an element that contributes to improvement in the machinability due to a molten lubrication effect during machining. On the other hand, in the case where Pb is excessively contained, the hot workability is significantly decreased. In this regard, Pb is in a range of 0.03% to 0.40%, and preferably in a range of 0.03% to 0.30% in terms of mass%.

[0069] Bi is an element that contributes to improvement in the machinability due to a molten lubrication effect during machining. On the other hand, in the case where Bi is excessively contained, the hot workability is significantly decreased. In this regard, Bi is in a range of 0.03% to 0.40%, and preferably in a range of 0.03% to 0.30% in terms of mass%.

[0070] Te is an element that contributes to improvement in the machinability due to a molten lubrication effect during machining and a decrease in the aspect ratio of the sulfide. On the other hand, in the case where Te is excessively contained, the hot workability is significantly decreased. In this regard, Te is in a range of 0.01% to 0.10%, and preferably in a range of 0.01% to 0.08% in terms of mass%.

[0071] C is a representative solid-solution-strengthening element, which increases the matrix strength and decreases the machinability. Therefore, the content of C is to be reduced and thus is adjusted to 0.015% or less, and preferably 0.012% or less in terms of mass%.

[0072] P is a solid-solution-strengthening element that increases the matrix strength and decreases the machinability. Therefore, the content of P is to be reduced and thus is adjusted to 0.050% or less, and preferably 0.040% or less in terms of mass%.

[0073] Cu is an austenite stabilizing element that destabilizes a ferrite phase. Therefore, the content of Cu is to be reduced and thus is adjusted to 1.5% or less in terms of mass%.

[0074] Ni is an austenite stabilizing element that destabilizes a ferrite phase. Therefore, the content of Ni is to be reduced and thus is adjusted to 1.5% or less in terms of mass%.

[0075] Although Mo is allowed to be contained since Mo contributes to improvement in the corrosion resistance, Mo is a representative solid-solution-strengthening element that increases the matrix strength and decreases the machinability. Therefore, Mo is adjusted to 2.0% or less in terms of mass%.

[0076] B is an element effective for ensuring the hot workability. On the other hand, in the case where B is excessively contained, the hot workability is rather lowered. In this regard, B may be optionally added in a range of 0.0001% to 0.0080%, and preferably in a range of 0.0003% to 0.0060% in terms of mass%.

[0077] Mg is an element effective for ensuring the hot workability. On the other hand, even in the case where Mg is excessively contained, the effect of ensuring the hot workability is saturated. In this regard, Mg may be optionally added in a range of 0.0005% to 0.0100% in terms of mass%.

[0078] Ca is an element effective for ensuring the hot workability. On the other hand, even in the case where Ca is excessively contained, the effect of ensuring the hot workability is saturated. In this regard, Ca may be optionally added in a range of 0.0005% to 0.0100% in terms of mass%.

[0079] O promotes formation of an oxide, which is a hard inclusion, and decreases the machinability. Therefore, the content of O as an impurity element is to be reduced. O is unavoidably mixed and thus is allowed to be contained at a content of 0.0100% or less, and preferably less than 0.0030% in terms of mass%.

[0080] N is a representative solid-solution-strengthening element, which increases the matrix strength, promotes formation of a nitride that is a hard inclusion, and decreases the machinability. Therefore, the content of N as an impurity element is to be reduced. N is unavoidably mixed and thus is allowed to be contained at a content of 0.035% or less in terms of mass%.

[0081] Although representative embodiments of the present invention have been described above, the present invention is not necessarily limited thereto, and various alternative embodiments and modifications may occur to those skilled in the art without departing from the spirit of the present invention or the scope of the appended claims.

[0082] The present application is based on a Japanese patent application No. 2022-177092 filed on November 4, 2022, and the contents thereof are incorporated herein by reference.

Claims

1. A ferritic free-cutting stainless steel material,

having a component composition consisting of: in terms of mass%,

$$10.0\% \leq Cr \leq 25.0\%,$$

$$0.2\% \leq Mn \leq 2.0\%,$$

$$0.30\% \leq Al \leq 2.50\%,$$

$$0.02\% \leq Si \leq 0.60\%,$$

and

$$0.10\% \leq S \leq 0.45\%,$$

and

further
two or more selected from the group consisting of:

$$0.03\% \leq Pb \leq 0.40\%,$$

$$0.03\% \leq Bi \leq 0.40\%,$$

and

$$0.01\% \leq Te \leq 0.10\%,$$

and
optionally

$$C \leq 0.015\%,$$

$$P \leq 0.050\%,$$

$$Cu \leq 1.5\%,$$

$$Ni \leq 1.5\%,$$

$$Mo \leq 2.0\%,$$

$$B \leq 0.0080\%,$$

$$Mg \leq 0.0100\%,$$

and

$$Ca \leq 0.0100\%,$$

with a balance being Fe and unavoidable impurities,

wherein, when [M] represents a mass% of an element M, the component composition satisfies the following formulae (1) and (2):

$$\text{formula (1): } 900([C] + [N]) + 170[Si] + 12[Cr] + 30[Mo] + 10[Al] \leq 300,$$

and

$$\text{formula (2): } ([Cr] + [Mo] + 1.5[Si] + 4[Al])/([Ni] + 0.5[Mn] + 30[C] + 30[N]) \geq 7,$$

and
wherein the ferritic free-cutting stainless steel material contains sulfides having a circle equivalent diameter of 1.5 μm or more, and the sulfides have an average circle equivalent diameter of 3.0 μm to 15.0 μm, an average aspect ratio of 2.5 or less, and an area ratio of 0.5% to 2.0%, and
the ferritic free-cutting stainless steel material has a maximum value of Vickers hardness of 170 HV or less.

2. The ferritic free-cutting stainless steel material according to Claim 1, wherein the component composition further satisfies one or two or more selected from the group consisting of:

$$0.0001 \leq B \leq 0.0080\%,$$

$$0.0005 \leq Mg \leq 0.0100\%,$$

and

$$0.0005 \leq Ca \leq 0.0100\%.$$

3. The ferritic free-cutting stainless steel material according to Claim 1 or 2, wherein the component composition further satisfies, as the unavoidable impurities:

O≤0.0100% and
N≤0.035%.

4. The ferritic free-cutting stainless steel material according to any one of Claims 1 to 3, being free of an unrecrystallized structure.

5. The ferritic free-cutting stainless steel material according to any one of Claims 1 to 4, having a form of a bar steel or a wire material.

6. The ferritic free-cutting stainless steel material according to any one of Claims 1 to 5, having a corrosion resistance such that rust does not occur after being left for 24 hours in a wet atmosphere having a temperature of 50°C and a relative humidity of 98%.

FIG. 1A

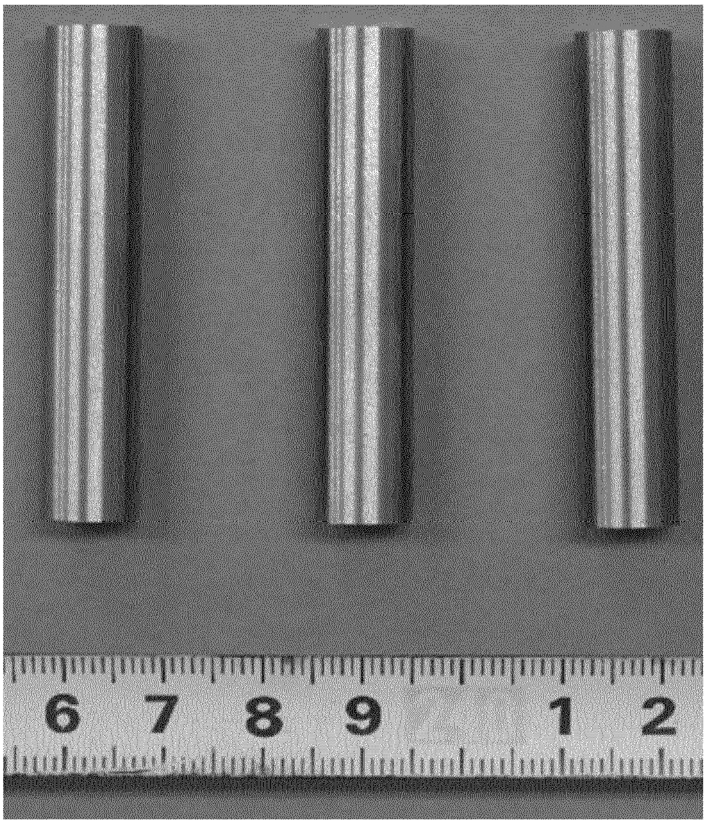


FIG. 1B

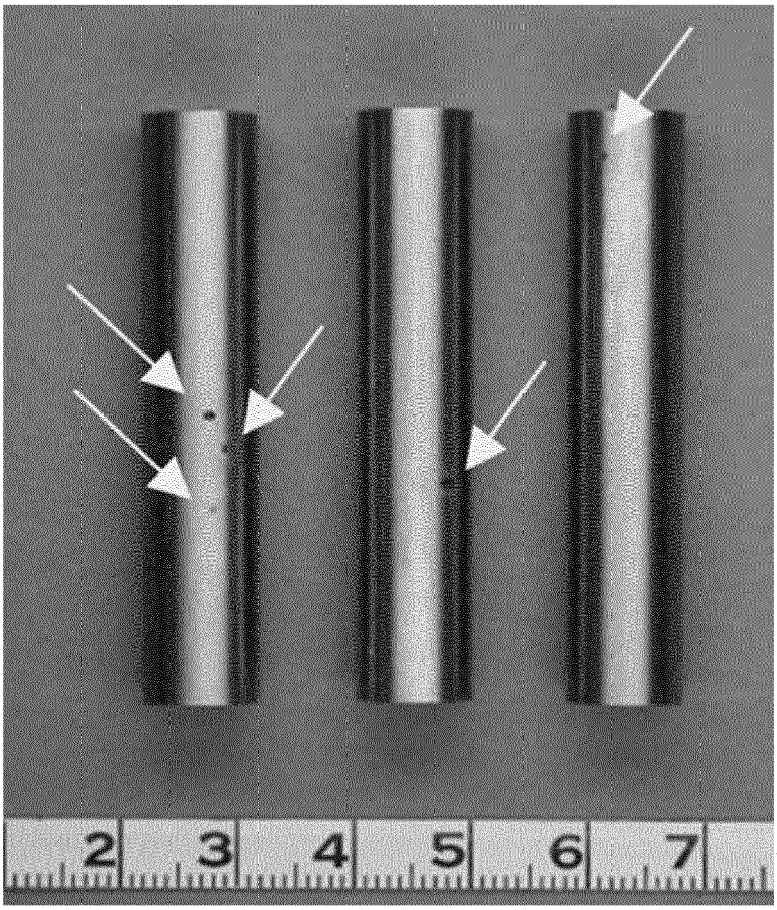
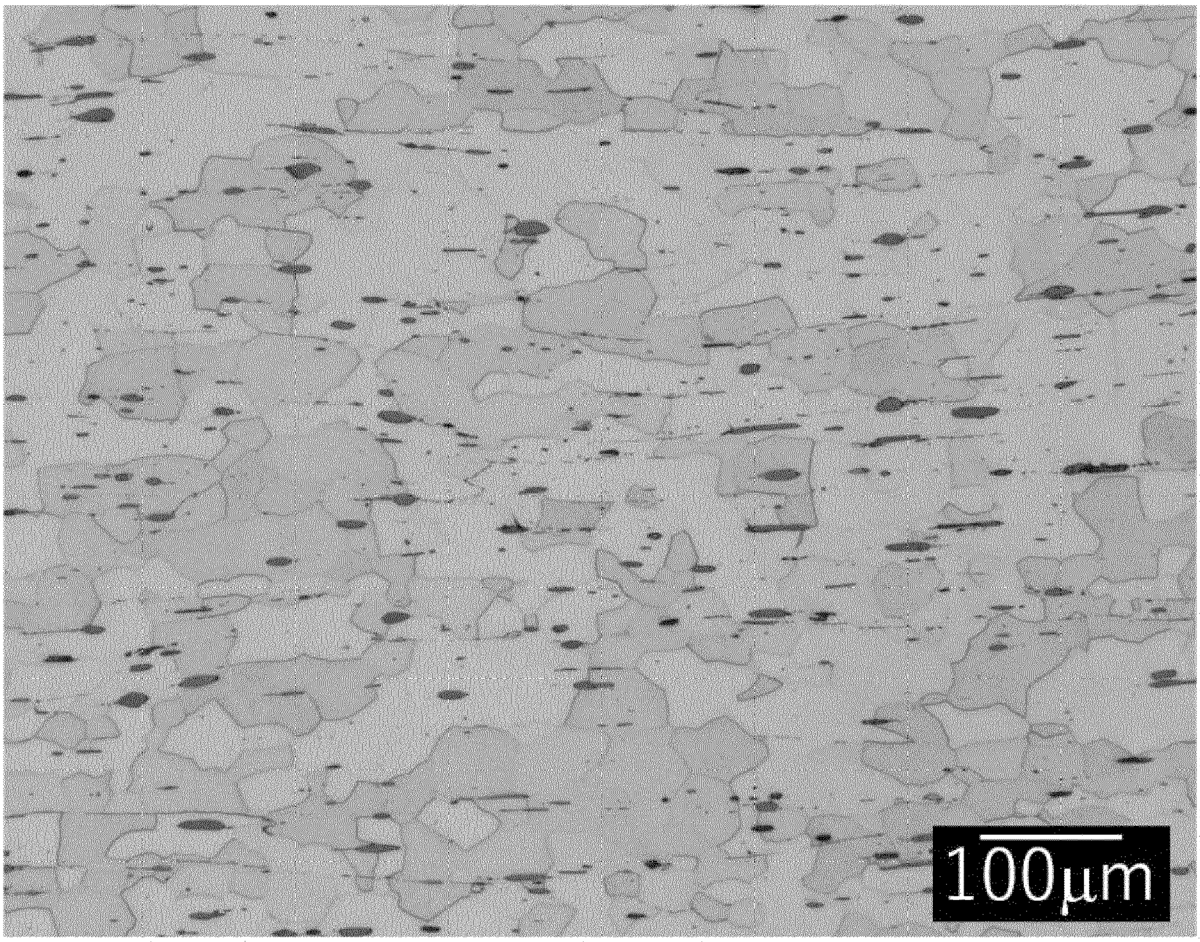


FIG. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 7410

DOCUMENTS CONSIDERED TO BE RELEVANT

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Place of search	Date of completion of the search	Examiner
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EP 23 20 7410

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