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54 **Stainless steels.**

57 A stainless steel having improved cold forgeability, corrosion resistance and electromagnetic properties as a raw material for electromagnetic components, which consists essentially of, by weight percentage, C≤0.030%, Si≤1.00%, Mn≤0.50%, P≤0.030%, S≤0.030%, 17%≤Cr≤35%, 0.03%<Al≤7%, N≤0.030%, 0≤0.010%, and optional alloying elements such as Nb, Ti, Ni, Mo, Pb, Bi, and so on for improving the characteristics including machinability.

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STAINLESS STEELS

This invention relates to a stainless steel which is excellent in cold forgeability, corrosion resistance and electromagnetic properties, and suitable for use as materials of, for example, electromagnetic components requiring good corrosion resistance and electromagnetic properties as well as good workability at cold forging.

5 Heretofore, there has been used, for example, pure iron or the like generally as materials for electromagnetic components requiring good electromagnetic properties. ('9.6 Magnetic Materials' on pp. 1025~ 1062 of "KINZOKU BINRAN 4th edition" issued on Dec. 20, 1982 by The Japan Institute of Metals or '13.8 Magnetic Materials' on pp. 1021~ 1037 of "KAGAKU BINRAN, Applied Chemistry Vol. II Materials" issued on Oct.15, 1986 by The Chemical Society of Japan is to be referred, for example.)

10 However, aforementioned materials of pure iron or the like are liable to be corrode because of poor corrosion resistance thereof. Therefore, there is a problem since it is feared that the electromagnetic components may deteriorate in the durability and the reliability.

Therefore, this invention is made in view of the aforementioned problem of the prior art and aims to provide a stainless steel suitable for materials of electromagnetic components requiring good corrosion resistance and electromagnetic properties as well as good workability at the manufacturing by cold forging and possible to maintain high reliability over a long time.

The construction of the stainless steel according to this invention is characterized by consisting essentially of, not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt. of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O, and at least one of not more than 1.5 wt % of Nb, not more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt % of Zr and not more than 1.5 wt.% of V if necessary, and similarly at least one of not more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo if necessary, further at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se if necessary, and the balance being Fe and inevitable impurities.

The present invention will now be described in greater detail and by way of example only.

The reason why the chemical composition (by weight percentage) of the stainless steel according to this invention is limited to the above range will be described below.

30 C : not more than 0.030%

C is an element having a bad influence upon the electromagnetic properties, especially upon the coercive force in case the stainless steel is used for a material of electromagnetic components, and is also an element harmful for the toughness and the cold forgeability. Thus the content of C is not more than 0.030%.

35 Si : not more than 1.00%

Si is an element effective for improving the electromagnetic properties and the corrosion resistance, but harmful for the cold forgeability. Therefore, the upper limit of Si content should be 1.00% or 0.20% preferably in order to maintain the good workability of the components by cold forgeability which makes a contribution to improve the dimensional accuracy.

40 Mn : not more than 0.50%

If Mn is contained in excess, the cold forgeability is degraded, so that the upper limit of Mn content is defined as 0.50%.

P : not more than 0.030%

Containing P in excess causes deterioration of the cold forgeability. The content of P is limited to not more than 0.030% for such a reason.

S : not more than 0.030%

Containing S in excess invites deterioration of the cold forgeability. The content of S is limited to not more than 0.030% for such a reason.

Cr : 17 to 35%

50 Cr is an element effective for improving the corrosion resistance, many types of chromic stainless steels such as 13% Cr steel (type 405 stainless steel), 17% Cr steel (type 430 stainless steel) have been developed for electromagnetic components so far. However, the requirement of the corrosion resistance for the stainless steels of this kind used for electromagnetic components becomes more strictly as compared with before in recent years, therefore it becomes impossible to satisfy the requirement of the corrosion resistance sufficiently by the aforementioned conventional stainless steels. Accordingly, in the stainless

steel according to this invention, the lower limit of Cr content is defined as 17% so as to satisfy the corrosion resistance required more strictly. However, the saturation magnetic flux density decreases if the content of Cr increases in excess, and so the performance characteristics sometimes deteriorates at the case in which the stainless steel according to this invention is used for an electromagnetic valve and so on.

5 Therefore, the content of Cr is limited to not more than 35%.

Al : more than 0.03% and not more than 7.0%

Al is an element effective for increasing the volume resistivity and effective for improving the electromagnetic properties owing to the reduction of the coercive force. Therefore Al is contained more than 0.03% in order to obtain the effects such as the increase of the volume resistivity and the improvement of the electromagnetic properties according to the reduction of the coercive force. However, the content of Al is limited to not more than 7.0% because the cold forgeability is degraded if Al is contained more than 7.0%.

N : not more than 0.030%

N is an element having a bad influence upon the electromagnetic properties, especially upon the coercive force similarly to C, in the case where the stainless steel according to this invention is used for the material of the electromagnetic components, and is also an element harmful for the toughness and the cold forgeability. Therefore the content of N is limited to not more than 0.030%.

O : not more than 0.010%

O deteriorates the cold forgeability remarkably by forming inclusion consisting of oxides. The coercive force is reduced by lowering the content of O, and the electromagnetic properties is improved, so that the content of O is limited to not more than 0.010%. Further, it is preferable to control the content of O within a range of not more than 0.006% for such a reason.

Nb : not more than 1.5%, Ta : not more than 1.5%,

Ti : not more than 1.5%, Zr : not more than 1.5%,

25 V : not more than 1.5%.

Since C and N are elements which cause the degradation of the coercive force as described above, it is also preferable to try the grain refining by adding at least one of Nb, Ta, Ti, Zr and V which are carbide and nitride-forming elements according to demand in order to reduce the bad influence caused by said C and N. For example, when Ti is added in the stainless steel according to this invention in order to reduce the bad influence of C and N upon the coercive force, said Ti improves the electromagnetic properties, the cold forgeability and the toughness by forming TiC, TiN. The similar effect can be obtained by Nb, Ta Zr and V. However, the addition of these elements in excess damages the workability by deteriorating the cold forgeability or by degrading the machinability. Therefore, the upper limits of the respective elements are defined as 1.5% in case of addition.

35 Cu : not more than 2.0%, Ni : not more than 3.0%, Mo : not more than 5.0%

Cu, Ni and Mo are elements effective for improving the corrosion resistance, therefore one or more of these elements may be added according to demand. However, since the excessive addition of these elements deteriorates the cold forgeability, it is necessary to limit the contents within a range of not more than 2.0% as to for Cu, of not more than 3.0% as to for Ni, and of not more than 5.0% as to for Mo in case of addition.

Pb : 0.03 to 0.30%, Bi : 0.002 to 0.020%, Ca : 0.002 to 0.020%, Te : 0.01 to 0.20%, Se : 0.03 to 0.30%

Pb, Bi, Ca, Te and Se are elements effective for improving the machinability, for example, the machinability in the case where a very small drill hole is made in the component after forming an external shape of said component by cold forging. Accordingly, one or more of these elements also may be added according to demand in order to obtain such an effect. However, because these elements degrade the cold forgeability and deteriorate the magnetic properties by the excessive addition, these elements should be added within an appropriate range so as not to harm said characteristics, may be added according to demand within a range of 0.03 to 0.30% as to for Pb, a range of 0.002 to 0.020% as to for Bi, a range of 0.002 to 0.020% as to for Ca, a range of 0.01 to 0.20% as to for Te and a range of 0.03 to 0.30% of Se.

50 The stainless steel according to this invention has the aforementioned chemical composition, therefore is excellent in the cold forgeability remarkably by the proper control of C, Si, Mn, P, S, N and O. And the electromagnetic properties of the stainless steel are improved and the grain size is refined by the effect of the addition of Al, Nb, Ta, Ti, Zr, and V in the proper quantity and by the control of C, N and O. Furthermore the corrosion resistance is improved by the effect of the proper addition of Cr, Cu, Ni, and Mo, and the machinability of the stainless steel is also improved by the effect of the addition of Pb, Bi, Ca, Te and Se in the proper quantity.

EXAMPLE

Each of stainless steels having chemical compositions shown in Table 1 was melted. And then, the
5 electric resistance, the magnetic flux density and the coercive force of the respective stainless steel were
measured, and the cold forgeability, the corrosion resistance and the mechinability were investigated by the
method shown in Table 2 and were evaluated respectively according to the evaluating classifications as also
shown in Table 2. The results are shown in Table 3.

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Table 1

	Steel No .	Chemical composition (wt. %)																	
		C	Si	Mn	P	S	Cr	Al	N	O	Nb,Ti,Zr,V	Cu	Ni	Mo	Pb	Bi	Ca	Te	Se
Invention steel	1	0.010	0.85	0.20	0.025	0.029	20.00	0.10	0.0220	0.0080	-	-	-	0.2	-	-	-	-	-
	2	0.008	0.01	0.23	0.018	0.018	20.50	0.11	0.0180	0.0095	-	-	-	-	-	-	-	-	-
	3	0.013	0.05	0.21	0.029	0.022	21.50	1.89	0.0118	0.0041	Nb:0.20	-	-	-	-	-	-	-	-
	4	0.019	0.99	0.31	0.006	0.005	17.01	0.08	0.0290	0.0056	V:0.15	-	-	2.9	-	-	-	-	-
	5	0.006	0.05	0.25	0.023	0.025	35.00	3.51	0.0095	0.0066	-	0.50	-	-	0.07	-	-	-	-
	6	0.014	0.45	0.26	0.019	0.006	19.05	1.83	0.0250	0.0098	-	-	-	-	-	-	0.01	-	-
	7	0.016	0.09	0.19	0.008	0.021	32.01	0.99	0.0209	0.0065	Ti:0.11	-	0.35	-	-	-	-	-	-
	8	0.028	0.15	0.45	0.021	0.019	25.00	2.30	0.0109	0.0051	Zr:0.15	0.15	-	0.58	-	0.003	-	0.10	-
	9	0.018	0.65	0.15	0.011	0.004	23.05	1.59	0.0115	0.0098	Nb:0.11,Ti:0.05	-	-	-	-	0.005	-	-	0.05
	10	0.011	0.09	0.11	0.023	0.019	22.35	0.85	0.0211	0.0040	-	-	-	-	-	-	-	-	-
Comparative steel	11	0.015	1.10	0.41	0.028	0.026	40.05	1.05	0.0251	0.0045	-	-	-	-	-	-	-	-	-
	12	0.022	0.51	0.35	0.019	0.065	13.01	0.01	0.0159	0.0055	-	-	-	-	-	-	-	-	-
	13	0.017	1.01	0.29	0.015	0.021	15.00	1.01	0.0085	0.0095	-	-	-	-	-	-	-	-	-
	14	0.045	0.85	0.15	0.028	0.015	18.01	0.50	0.0450	0.0098	-	-	-	6.0	-	-	-	-	-
	15	0.015	0.95	0.18	0.005	0.018	30.00	0.15	0.0210	0.0290	Ti:0.05	-	-	-	0.05	-	-	-	-

Table

5	Characteristics	Evaluating method	Evaluating classification			
			◎	○	△	×
10	Cold forgeability	Restrained cold forging test (Test piece : 14mmφ×21mmℓ)	Not Cracked	Slightly cracked	Partially cracked	Cracked
	Corrosion resistance	Atmospheric exposure test	Not rusted	Slightly rusted	Rusted	Rusted in red
15	Machinability	Drilling test (2mmφ)	81 holes ~110 holes	51 holes ~80 holes	21 holes ~50 holes	20 holes and under

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Table 3

	Steel No .	Electric resistance ρ ($\mu\Omega\text{cm}$)	Coercive force $H_c(\text{Oe})$	Magnetic flux density B_{30} (KG)	Corrosion resistance	cold forgeability	Machinability
Invention steel	1	75	1.5	11.6	○	⊙	○
	2	50	1.8	11.4	○	⊙	○
	3	103	0.9	10.8	○	⊙	○
	4	74	1.2	12.5	○	⊙	○
	5	126	1.9	10.9	⊙	○	⊙
	6	95	2.5	10.3	○	⊙	○
	7	99	1.6	11.2	⊙	○	⊙
	8	124	1.0	10.0	⊙	○	⊙
	9	109	1.3	10.5	○	○	⊙
	10	82	0.8	11.9	○	⊙	○
Comparative steel	11	100	3.2	10.4	⊙	△	△
	12	59	2.5	13.1	×	⊙	⊙
	13	91	2.2	12.0	△	○	○
	14	85	7.3	11.5	⊙	×	○
	15	93	6.8	10.5	⊙	△	⊙

As shown in Table 1 to Table 3, the comparative steel No.11 containing excessive Si and Cr has the large coercive force and the poor cold forgeability, and the machinability of the steel is not so good. And the comparative steels Nos.12 and 13 containing insufficient Cr are poor in the corrosion resistance. Further, the comparative steel No. 14 containing C and N in excess is inferior in the magnetic properties because of the large coercive force thereof. Furthermore, the comparative steel No. 15 containing excessive O is poor in the cold forgeability, and it is seen that the coercive force of the steel No.15 takes a high value and so the magnetic properties are also inferior considerably.

Contrary to above, the steels Nos. 1 to 10 according to this invention which contain C, Si, Mn, P, S, N and O limited to the proper contents and contain Cr and Al controlled within appropriate ranges are satisfactory in the machinability, the corrosion resistance and the cold forgeability as well as the electric resistance, the magnetic flux density and the magnetic properties in all cases. And it is confirmed that it is possible to prevent the deterioration of the magnetic properties caused by the addition of the other alloying elements or to further improve the magnetic properties by adding at least one of Nb, Ta, Ti, Zr and V, and it is possible to prevent the degradation of the corrosion resistance caused by the addition of the other alloying elements or to further improve the corrosion resistance by adding one or more of Cu, Ni and Mo, further it is possible to improve the machinability more than ever by adding at least one of Pb, Bi, Ca, Te and Se.

As described above, the stainless steel according to this invention consists essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O, and at least one of not more than 1.5 wt.% of Nb, not more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt.% of Zr and not more than 1.5 wt.% of V if necessary, and similarly at least one of not more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo if necessary, further at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se if necessary, and the balance is Fe and inevitable impurities. Therefore, the stainless steel according to this invention is favorable in the workability remarkably in the case of manufacturing components by cold forging which is excellent in dimensional accuracy and productivity, and also satisfactory in the corrosion resistance and the electromagnetic properties, and so is especially suitable for the raw material of the electromagnetic components. A very excellent effect can be obtained since it is possible to maintain the highly reliability of the electromagnetic components over a long period.

Claims

1. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O and the balance being Fe and inevitable impurities.

2. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O and at least one of not more than 1.5 wt.% of Nb, not more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt.% of Zr and not more than 1.5 wt.% of V, and the balance being Fe and inevitable impurities.

3. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O, and at least one of not more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo, and the balance being Fe and inevitable impurities.

4. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O, and at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se, and the balance being Fe and inevitable impurities.

5. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si,

not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not more than 0.010 wt.% of O, and at least one of not more than 1.5 wt.% of Nb, no more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt.% of Zr and not more than 1.5 wt.% of V, and at least one of not
 5 more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo, and the balance being Fe and inevitable impurities.

6. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not
 10 more than 0.010 wt.% of O, and at least one of not more than 1.5 wt.% of Nb, not more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt.% of Zr and not more than 1.5 wt.% of V, and at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se, and the balance being Fe and inevitable impurities.

7. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not
 15 more than 0.010 wt.% of O, and at least one of not more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo, and at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se, the balance being Fe and
 20 inevitable impurities.

8. A stainless steel consisting essentially of not more than 0.030 wt.% of C, not more than 1.00 wt.% of Si, not more than 0.50 wt.% of Mn, not more than 0.030 wt.% of P, not more than 0.030 wt.% of S, 17 to 35 wt.% of Cr, more than 0.03 wt.% and not more than 7.0 wt.% of Al, not more than 0.030 wt.% of N, not
 25 more than 0.010 wt.% of O, and at least one of not more than 1.5 wt.% of Nb, not more than 1.5 wt.% of Ta, not more than 1.5 wt.% of Ti, not more than 1.5 wt.% of Zr and not more than 1.5 wt.% of V, and at least one of not more than 2.0 wt.% of Cu, not more than 3.0 wt.% of Ni and not more than 5.0 wt.% of Mo, and at least one of 0.03 to 0.30 wt.% of Pb, 0.002 to 0.020 wt.% of Bi, 0.002 to 0.020 wt.% of Ca, 0.01 to
 0.20 wt.% of Te and 0.03 to 0.30 wt.% of Se, and the balance being Fe and inevitable impurities.

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European
Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 7465

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-1 002 909 (UNIVERSAL-CYCLOPS STEEL CORP.) * Claims 1-3 * & DE-B-1 171 624 -- --	1-3	C 22 C 38/18
X	DE-A-2 334 462 (NIPPON STEEL CORP.* Claims 1-4 * & FR-A-2 192 185) -- --	1,2	
X	GB-A-1 162 562 (STAHLWERKE SUDWESTFALEN AG) * Claims 1-3,7,8; page 2, examples 1,2, lines 85-110 * & DE-B-1 483 305 -- --	1,3	
X	GB-A-1 269 916 (TOYO KOGYO CY, AND TOKYO SHIBAURA ELECTRIC CY, LTD) * Claims 1-3; page 8, examples 1,2,4,5,9-16 * -- --	1,2	
X	GB-A-2 058 133 (ARMCO INC.) * Claims 1,2,5,6,8 * -- --	1-3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 22 C 38/18
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of search 23 October 90	Examiner LIPPENS M.H.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			