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Asada et al.

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[54] **COLD WORKABLE AND AGE-HARDENABLE STEEL**

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[52] **U.S. Cl.** **75/124,** 75/125

[51] **Int. Cl.** **C22c 57/14**

[58] **Field of Search** 75/124, 125

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[57] **ABSTRACT**

A cold workable and age-hardenable steel includes weight percentages of carbon and manganese within an area enclosed by a line connecting a point P indicating zero weight % of carbon and 1.8 weight % of manganese, a point Q indicating 0.08 weight % of carbon and 0.5 weight % of manganese, and a point R indicating 0.08 weight % of carbon and zero % of manganese to a point S indicating zero weight % of carbon and zero weight % of manganese; less than 0.6 weight % of silicon; as age-hardenability improving alloying metals more than 2.5 weight % of nickel and more than 0.6 weight % of aluminium or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of copper or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of titanium or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum, more than 0.5 weight % of copper and more than 0.5 weight % of titanium; the total amount of nickel and aluminum or nickel, aluminum and copper or nickel, aluminum and titanium or nickel, aluminium, copper and titanium being in the range of from 4.5 to 6.5 weight %; and the balance which is substantially iron and impurities.

Added as ductility and temperability improving alloying metals may be at least one element selected from the group consisting of less than 2.5 weight % of chromium, less than 0.5 weight % of molybdenum, less than 0.5 weight % of tungsten, less than 0.5 weight % of cobalt, less than 0.5 weight % of beryllium and less than 0.01 weight % of both. Added as alloying metals for improving the fineness of the crystalline particles of the steel may be at least one element selected from the group consisting of less than 0.5 weight % the total amount of niobium and tantalum, less than 0.5 weight % of vanadium and less than 0.5 weight % of zirconium. Added as machinability improving alloying metals may be at least one element selected from the group consisting of less than 0.3 weight % of sulphur, less than 0.4 weight % of lead, less than 0.5 weight % of selenium, less than 0.3 weight % of tellurium and less than 0.3 weight % of bismuth.

1 Claim, 3 Drawing Figures

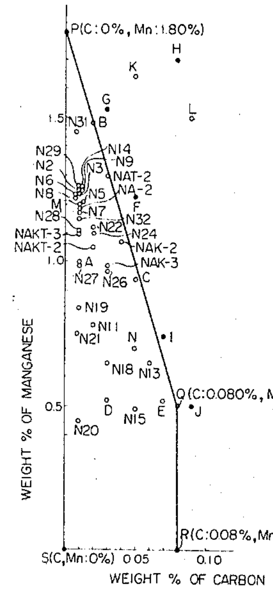

FIG. 1

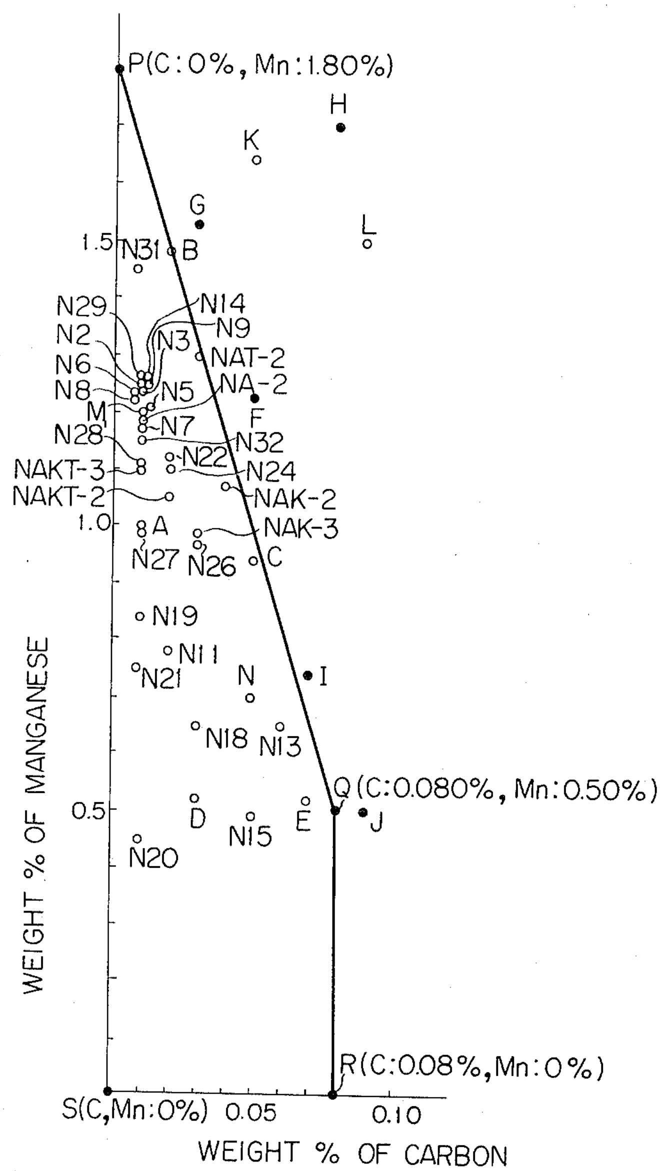

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FIG. 2

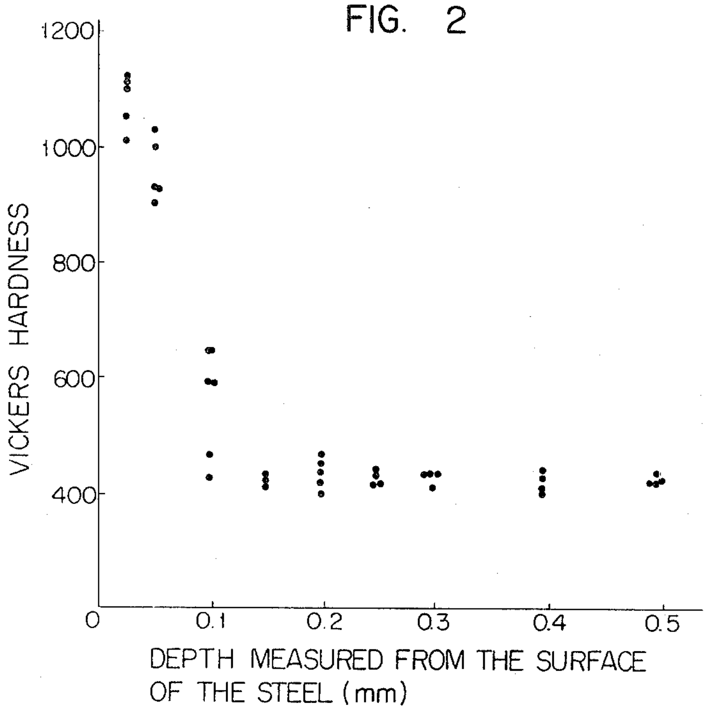
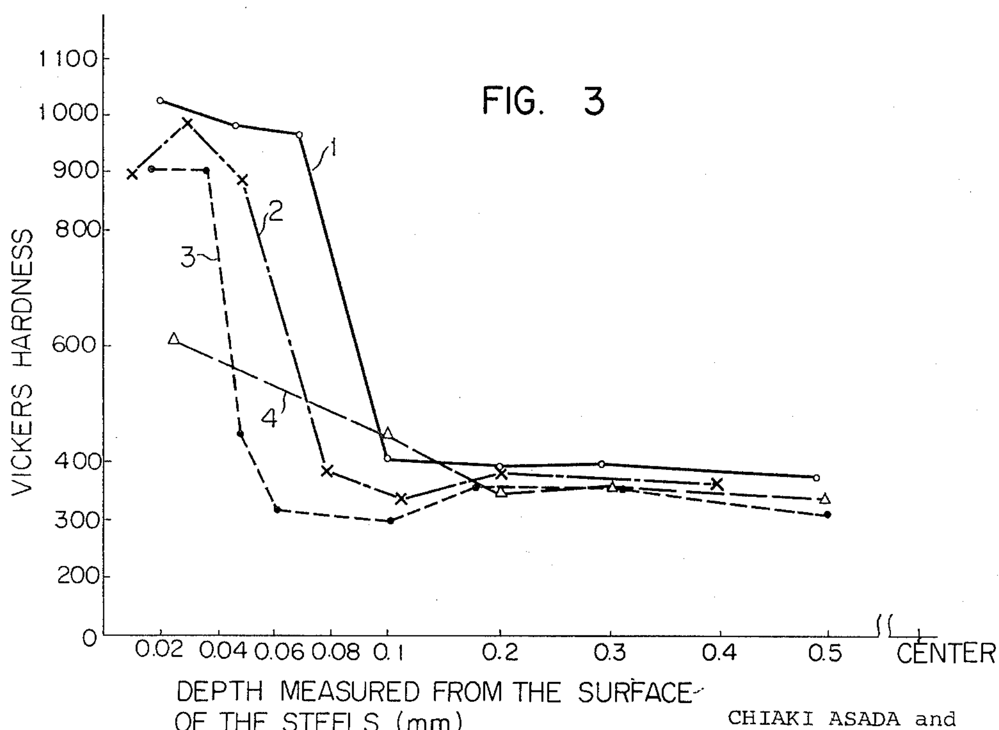


FIG. 3



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COLD WORKABLE AND AGE-HARDENABLE STEEL

DETAILED EXPLANATION OF INVENTION

This invention relates to cold workable and age-hardenable Ni-Al type, Ni-Al-Cu type, Ni-Al-Ti type and Ni-Al-Cu-Ti type steels which are machinable with easiness and have high ductility under the solution treatments.

Business machines such as data-processing machines and complicated articles such as racks, gears, arms, stoppers and carriages used in making a computer are made by using a case hardening steel and then they are heat-treated for hardening the case hardening steel. Also such business machines and such complicated articles are made of a heat-treated band steel. In such a case, the case hardening steel has a defect so that it has strain after it was heat-treated, and also the heat-treated band steel has a defect so that it is difficult to work it into such a complicated article.

It is preferable to use an age-hardenable steel, which has less strain after it was heat-treated, for making such a business machine and such a complicated article but the prior known age-hardenable steels do not always give the satisfactory results in making the business machines and the complicated articles.

The inventors have investigated for removing the above mentioned defects form the prior known steels and have discovered cold workable and age-hardenable steels which are improved in their cold-workability by reducing their hardness under the solution treatments and can be hardened by age-treatment and have little strain after they were heat-treated.

It is an object of this invention to provide a cold workable and age-hardenable steel consisting essentially of weight percentages of carbon and manganese within an area enclosed by a line connecting points P, Q and R to a point S as shown in the accompanying FIG. 1; less than 0.6 weight % of silicon; as age-hardenability improving alloying metals more than 2.5 weight % of nickel and more than 0.6 weight % of aluminum or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of copper or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of titanium or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum, more than 0.5 weight % of copper and more than 0.5 weight % of titanium; the total amount of nickel and aluminum or nickel, aluminum and copper or nickel, aluminum and titanium or nickel, aluminum, copper and titanium being in the range of from 4.5 to 6.5 weght %; and the balance which is substantially iron and impurities, said point P indicating zero weight % of carbon and 1.8 weight % of manganese, said point Q indicating 0.08 wieght % of carbon and 0.5 weight % of manganese, said point R indicating 0.08 weight % of carbon and zero weight % of manganese and said point S indicating zero weight % of carbon and zero weight % of manganese.

Also, it is another object of this invention to provide a cold workable and age-hardenable steel consisting essentially of weight percentages of carbon and manganese within an area enclosed by a line connecting points P. Q and R to a point S as shown in the accompanying FIG. 1; less than 0.6 weight % of silicon; as age-hardenability improving alloying metals more than 2.5 weight % of nickel and more than 0.6 weight % of aluminum or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of copper or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum and more than 0.5 weight % of titanium or more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum, more than 0.5 weight % of copper and more than 0.5 weight % of titanium; the total amount of nickel and aluminum or nickel, aluminum and copper or nickel, aluminum and titanium or nickel, aluminum, copper and titanium being in the range of from 4.5 to 6.5 weight %; and the balance which is substantially iron and impurities in combination with at least one of ductility and temperability improving alloying metals alone or at least one of alloying metals alone for improving the fineness of the crystalline particles of said steel and at least one of machinability improving alloying metals alone or in combination with at least two metals selected from said ductility and temperability improving alloying metal, said alloying metal for improving the fineness of the crystalline particles of said steel and said machinability improving alloying metal, said point P indicating zero weight % of carbon and 1.8 weight % of manganese, said point Q indicating 0.08 weight % of carbon and 0.5 weight % of manganese, said point R indicating 0.08 weight % of carbon and zero weight % of manganese and said point S indicating zero weight % of carbon and zero weight % of manganese.

The reasons why carbon, maganese, silicon, age-hardenability improving alloying metals, ductility and temperability improving alloying metals, alloying metals for improving the fineness of the crystalline particles of the steel and machinability improving alloying metals are defined as the components and also in their amounts in accordance with this invention are explained hereinafter.

1. Carbon and Manganese:

The cold workability which is determined on the basis of the 180°tight-bending of the steel is varied depending upon not only the solution treated hardness but the contents of carbon and maganese, and therefore it is preferable to use carbon and manganese in the amounts as defined within the area enclosed by the line connecting the points P, Q and R to the point S as shown in the accompanying FIG. 1 showing carbon versus manganese. This is fully explained as the description goes on.

2. Silicon:

A small amount of silicon is essential for conducting the smelting technique but a larger amount of silicon impairs the ductility and the cold workability of steels and therefore the content of silicon is defined to less than 0.6 weight percentage.

3. Nickel:

Nickel is an alloying element for producing a Ni-Al alloy or a Ni-Ti alloy, and also it is an essential alloying element for improving the age-hardenability of steels by the synergistic actions and effects between Ni and Cu but the actions and effects of Ni are not remarkable when it is added into steels in an amount of below 2.5 weight percentages.

4. Aluminum:

Aluminum is an alloying element for producing an Al-Ni alloy and an Al-Ti alloy, and also it is an essential alloying element for improving the age-hardenability of steels by the synergistic actions and effects between Al and Cu, and therefore it is required to use aluminum in an amount of above 0.6 weight percentage.

5. Copper:

Copper is deposited as an ε-phase in steels for improving the age-hardenability of the steels and it is used as an essential element for strengthening the steels by the synergistic actions and effects between Cu and depositions resulted by the presence of nickel, aluminum and titanium. It is preferable to use copper in an amount of above 0.5 weight percentage.

6. Titanium:

Titanium is an alloying element for producing a metal compound between Ti and Ni or Ti and Al and it is used as an essential element for improving the age-hardenability of steels by the synergistic actions and effects between Ti and Cu. It is preferable to use titanium in an amount of above 0.5 weight percentage.

It is obvious from the data as shown in Table 2 that the total amount of the age-hardenability improving alloying metals which are added in the cold workable and age-hardenable steel of this invention in combination of Ni and Al or Ni, Al and Cu or Ni, Al and Ti or Ni, Al, Cu and Ti is required to limit to the lower content of 4.5 weight percentages for obtaining the intended Vickers' age-hardness of above 300. However, if the age-hardenability improving alloying metals are used in a larger amount of above 6.5 weight percentages, they become expensive and also in some cases aluminum, copper and titanium impede the output of the steels and therefore the total amount of the age-hardenability improving alloying metals are defined within the range of from 4.5 to 6.5 weight percentages.

7. Chromium, molybdenum, tungsten, cobalt, beryllium and boron:

These metals can be used alone or in combination for improving the ductility and the resistance against the softening of the cold workable and age-hardenable steel of this invention when less than 2.5 weight % of chromium, less than 0.5 weight % of molybdenum, less than 0.5 weight % of tungsten, less than 0.5 weight % of cobalt and less than 0.5 weight % of beryllium are incorporated with said steel but they impeded the cold workability of the steel and become expensive when they are used in a larger amount. Also, the cold workable and age-hardenable steel of this invention is improved markedly in its temperability when a small amount of boron is incorporated with said steel but the ductility and the output of the steel are impeded when boron is incorporated with the steel in an excess amount. Therefore, it is preferable to use boron in an amount of below 0.01 weight percentage.

8. Niobium, tantalum, vanadium and zirconium:

These metals can be used for improving the cold workability under the conditions of solution treatment and the fineness of the crystalline particles of the cold workable and age-hardenable steel of this invention but they become expensive and the output of the steel is impeded when they are used in a larger amount. Therefore, the total amount of niobium and tantalum is defined to less than 0.5 weight percentage and vanadium and zirconium are defined to less than 0.5 weight percentage respectively.

9. Sulphur, lead, selenium, tellurium and bismuth:

These metals can be used for improving the machinability and retaining the age-hardenability of the cold workable and age-hardenable steel of this invention but the steel is impeded in its ductility and workability and it tneds to become brittle when such metals are incorporated with the steel in a larger amount. Therefore it is preferable to use sulphur, lead, selenium, tellurium and bismuth in an amount of below 0.3 weight %, below 0.4 weight %, below 0.5 weight % below 0.3 weight % and below 0.3 weight % respectively.

This invention is illustrated by the following Examples.

Referring to Table 1, it shows various kinds of steels designated by the signs M(or Na–1), NA–2, D, E, NAK–2, NAK–3, N(or NAT–1), NAT–2, A (or NAKT–1), B, C, NAKT–2, N28′, NAKT–3, F, G(or NAK–1), H, I, J, K and L.

Table 1

Signs of Steels	Compositions of Steels (%)								
	C	Si	Mn	P	S	Ni	Al	Cu	Ti	Others
M or NA–1	0.01	0.09	1.20	0.007	0.012	3.65	1.10	0.15	—	—
N2	0.009	0.10	1.25	0.010	0.010	3.56	1.04	0.13	—	Cr : 0.50
N3	0.01	0.008	1.19	0.009	0.008	3.52	1.08	0.16	—	Nb + Ta : 0.08
NA–2	0.01	0.06	1.18	0.010	0.005	3.67	1.09	0.10	—	se : 0.05
N5	0.011	0.09	1.21	0.011	0.007	3.40	0.98	0.09	—	Cr : 0.50,V :0.15
N6	0.008	0.11	1.24	0.013	0.009	3.35	1.01	0.13	—	Cr : 0.45,Pb:0.15
N7	0.01	0.12	1.17	0.020	0.011	3.60	1.05	0.08	—	Nb : 0.02,Pb:0.15
N8	0.007	0.15	1.23	0.018	0.103	3.55	1.03	0.07	—	Mo : 0.2, V :0.1
N9	0.01	0.10	1.24	0.011	0.021	3.25	0.98	1.05	—	
D	0.03	0.06	0.52	0.003	0.019	3.14	0.98	0.90	—	Be : 0.01
E	0.07	0.15	0.52	0.003	0.008	3.34	0.96	1.04	—	Mo : 0.20
N11	0.02	0.13	0.78	0.009	0.012	3.45	1.05	1.01	—	Nb : 0.06
NAK–2	0.04	0.10	1.07	0.004	0.090	3.35	1.08	0.98	—	
N13	0.06	0.13	0.65	0.010	0.010	3.10	1.02	0.95	—	Mo : 0.20,V:0.10
N14	0.01	0.07	1.25	0.005	0.094	3.25	0.97	0.98	—	Mo : 0.15
N15	0.05	0.08	0.49	0.009	0.084	3.40	0.94	0.91	—	V : 0.15
NAK–3	0.03	0.25	0.99	0.008	0.108	3.28	1.12	1.10	—	Mo : 0.15,V:0.10
N or NAT–1	0.05	0.03	0.70	0.010	0.007	3.85	0.90	0.01	1.05	—
N18	0.03	0.02	0.65	0.010	0.010	3.64	0.98	0.05	1.15	Mo : 0.21
N19	0.01	0.14	0.84	0.008	0.011	3.45	0.97	0.10	1.01	Nb : 0.02
N20	0.01	0.12	0.45	0.013	0.016	3.50	1.05	0.05	0.98	Pb : 0.14
N21	0.009	0.09	0.75	0.017	0.018	3.71	1.10	0.13	1.13	Cr : 0.45,V:0.10
N22	0.02	0.14	1.12	0.013	0.012	3.49	1.08	0.10	1.15	Mo : 0.12,Pb:0.10
NAT–2	0.03	0.04	1.30	0.015	0.009	3.51	1.02	0.05	1.10	Nb + Ta : 0.20 Pb : 0.15
N24	0.02	0.07	1.10	0.013	0.075	3.21	0.95	0.11	0.95	B : 0.001,V:0.10
A or NAKT–1	0.01	0.08	1.00	0.003	0.008	3.14	0.99	0.90	1.10	—
B	0.02	0.21	1.49	0.013	0.009	3.05	0.93	0.93	1.06	—
C	0.05	0.11	0.94	0.004	0.009	3.05	1.00	0.87	1.03	—

Table 1 – Continued

Signs of Steels	Compositions of Steels (%)								
	C	Si	Mn	P	S	Ni	Al	Cu	Ti	Others
N26	0.03	0.14	0.97	0.015	0.010	3.35	1.07	0.95	1.15	B : 0.003
N27	0.01	0.16	0.99	0.016	0.015	3.25	0.96	1.05	0.98	V : 0.13
NAKT–2	0.02	0.09	1.05	0.003	0.008	3.20	0.95	1.01	1.02	Pb : 0.15
N28'	0.01	0.11	1.10	0.005	0.102	3.10	0.98	0.97	1.02	
N29	0.01	0.13	1.25	0.016	0.010	3.25	0.95	1.10	1.12	Mo : 0.25,V:0.1
NAKT–3	0.01	0.11	1.10	0.005	0.102	3.10	0.98	0.97	1.02	Cr : 0.87
N31	0.008	0.16	1.45	0.010	0.095	3.35	1.11	0.98	1.13	V : 0.10
N32	0.01	0.13	1.15	0.017	0.084	3.10	1.05	0.97	1.03	V : 0.10,Cr:0.56
F	0.05	0.07	1.22	0.003	0.009	3.08	1.02	0.87	1.10	
G or NAK–1	0.03	0.41	1.53	0.004	0.010	3.27	1.20	1.05	—	
H	0.08	0.06	1.70	0.003	0.024	3.14	1.02	0.003	1.06	
I	0.07	0.14	0.74	0.003	0.009	3.22	1.01	1.00	—	
J	0.09	0.14	0.50	0.003	0.010	3.22	0.91	1.01	—	
K	0.05	0.06	1.64	0.005	0.008	3.13	1.16	0.05	—	
L	0.09	0.08	1.50	0.003	0.007	0.06	0.002	0.98	—	

It should be noted from Table 1 that the steels M, N, A and G are the same as the steels NA–1, NAT–1, NAKT–1 and NAK–1 respectively. Also it should be noted from Table 1 that the steels M (or NA–1), NA–2, D, E, NAK–2, NAK–3, N(or NAT–1), NAT–2, A (or NAKT-**1**), B, C, NAKT–2, N28' and NAKT–3 are the cold workable and age-hardenable steels of this invention and the steels F, G, (or NAK-**1**), H, I, J, K and L are the comparative steels. Still further, it should be noted that the steels M and NA–2 are the cold workable and age-hardenable Ni-Al type steels; the steels D, E, NAK–2 and NAK–3 are the cold workable and age-hardenable Ni-Al-Cu type steels; and steels N(or NAT–1) and NAT–2 are the cold workable and age-hardenable Ni-Al-Ti type steels; and the steels A(or NATK–1), B, c, NAKT–2, N28'and NAKT-**3** are the cold workable and age-hardenable Ni-Al-Cu-Ti type steels of this invention.

Test samples of the steels as shown in Table **1** were subjected to the solution treatment at 900°C for 10 minutes, followed by cooling them in oil and then the treated test samples were tested for 180°tight-bending and machinability. Further, the treated test samples were age-treated at 525°C for 5 hours. The cold workability of the steels which were subjected to the solution treatment was determined by observing the presence or the absence of cracks on the bent part of each of the test samples after they were tested for 180°tight-bending in the direction along the rolling of the steels. The test results are give in Table 2.

Table 2

Signs of Steels	Total sum of Ni, Al, Cu, Ti (%)	Solution treated hardness (Vickers)	180° tight-bending	Life of cutting tool(in minutes)	Age-hardness (Vickers)	Tensile strength after age-treated(kg/mm²)
M or NA–1	4.90	188	good	207	355	118.0
N2	4.73	189	good		356	119.5
N3	4.76	190	good	203	359	120.0
NA–2	4.86	179	good	283	360	125.0
N5	4.47	193	good	185	371	121.0
N6	4.49	188	good		357	119.0
N7	4.73	191	good	265	356	115.3
N8	4.65	192	good	253	361	120.1
N9	5.28	190	good		363	121.0
D	5.02	195	good		366	122.0
E	5.34	230	good		350	118.3
N11	5.51	197	good		351	117.0
NAK–2	5.41	195	good	275	380	127.3
N13	5.07	209	good		395	131.7
N14	5.20	206	good		394	131.3
N15	5.25	201	good		385	128.0
NAK–3	5.50	225	good	258	445	148.7
N or NAT–1	5.81	205	good	141	420	140.0
N18	5.82	210	good		415	138.5
N19	5.53	220	good		425	140.1
N20	5.58	207	good		410	136.8
N21	6.07	225	good		441	147.0
N22	5.82	218	good		430	143.0
NAT–2	5.68	215	good	237	451	154.1
N24	5.22	235	good		455	151.8
A or NAKT–1	6.13	180	good	180	450	155.3
B	5.97	185	good		490	160.2
C	5.95	175	good		460	153.0
N26	6.52	190	good		467	155.5
N27	6.24	179	good		441	147.0
NAKT–2	6.18	178	good	270	451	155.7
N28'	6.07	175	good	260	455	150.1
N29	6.42	182	good		445	148.5
NAKT–3	6.07	175	good	260	455	151.0
N31	6.57	184	good		460	153.0
N32	6.15	195	good		475	155.0
F	6.07	180	bad		480	

Table 2 – Continued

Signs of Steels	Total sum of Ni, Al, Cu, Ti (%)	Solution treated hardness (Vickers)	180° tight-bending	Life of cutting tool(in minutes)	Age-hardness (Vickers)	Tensile strength after age-treated(kg/mm²)
G or NAK-1	5.52	200	bad		360	
H	5.22	175	bad		325	
I	5.23	230	bad		360	
J	5.14	335	bad		365	
K	4.34	175	good		230	
L	1.04	150	good		180	

It is noted that the life of the cutting tool was determined when the tool lost its cutting ability. Also it is noted that the cutting test was carried out by using a SKH-9 slitting saw as the cutting tool and the test samples were fed by using a feeding gear having a 0.0174 mm/tooth and they were cut into a 0.8 mm depth at the cutting speed of 70 meters per minute.

It is obvious for the data as shown in Table 2 that the 180° tight-bending of the steels is improved as the solution treated hardness of the steels decreases but the steels are required to have a very low solution treated hardness for securing the reliable 180° tight-bending.

In accordance with this invention, the total sum of the age-hardenability improving alloying metals (Ni, Al Cu and Ti) must be kept at the 4.7 weight percentages or more for securing the age-hardness equivalent to or of above 300 vickers hardness of the cold workable and age-hardenable steel and therefore the solution treated hardness of such a cold workable and age-hardenable steel can not unlimitedly be reduced by decreasing the total amount of the age-hardenability improving alloying metals. Also the solution treated hardness of the cold workable and age-hardenable steel of this invention is required to be kept at 175 Vickers hardness or more for securing the age-hardness of about 300 Vickers hardness. Within the range of such a Vickers hardness, the solution treated hardness is not co-related to the 180° tight-bending as shown in Table 2.

Referring to FIG. **1**, it shows the relationshiip between the 180° tight-bending of the test samples and the amounts of carbon and manganese contained in the test samples.

Referring to FIG. **2**, it shows the hardness distribution depending on the depth measured from the surface of the test sample.

Referring to FIG. **3**, it shows four curves **1**, **2**, **3** and **4** indicating the relationship between the hardness and the depth measured from the surface of the test samples.

In the FIG. **1**, the white marked points indicate that the 180°tight-bending of the test samples is good and also the black marked points indicate that the 180°tight-bending of the test samples is bad. It is obvious from the FIG. **1** that the 180° tight-bending of the cold workable and age-hardenable steels of this invention is strongly co-related to the amounts of carbon and manganese contained in such steels and also that it is possible to secure the 180°tight-bending of such steels when they are fallen within the area enclosed by the line connecting the points P, Q and R to the point S, and they contain less than 0.08 weight % of carbon and less than 1.8 weight % of manganese.

It was also recognized that the use of a suitable amount of the machinability improving alloying metals can improve remarkedly the life of the cutting tools without affecting the 180°tight-bending and the age-hardness of the cold workable and age-hardenable steels of this invention. Still further, it was recognized that the use of a suitable amount of the ductility and temperability improving alloying metals and the alloying metals for improving the fineness of the crystalline particles can improve the strength of the cold workable and age-hardenable steels of this invention without affecting the 180°tight-bending, the age-hardness and the machinability of such steels.

In the FIG. **2**, the test results are shown after the steel A(or NAKT-1) was treated with a liquid nitriding agent, which is sold under the trade name of NH-360 by Nisshin Kagaku Kaisha, at 520°C for 2 hours.

In the FIG. **3**, the curve **1** shows the test results after the steel A(or NAKT-1) was treated at 570°C for 90 minutes by using a tufftriding method. The Curves **2** and **3** show the test results after the steel A(or NAKT-1) was treated at 570°C for 60 minutes and 30 minutes respectively by using the tufftriding method. Also the curve **4** shows the test results after the steel G(or NAK-1) was treated at 570°C for 180 minutes by using the tufftriding method.

As you can see from the foregoing, it is the critical essential features of the cold workable and gehardenable steel of this invention to contain less than 0.08 weight % of carbon and less than 1.8 weight % of maganese and to fall within the area as indicated in the FIG. **1**. Also, it is the critical essential features of the cold workable and age-hardenable steel of this invention to contain the age-hardenability improving alloying metals in combination of Ni and Al or Ni, Al and Cu or Ni, Al and Ti or Ni, Al, Cu and Ti in which Ni is more than 2.5 weight %, Al is more than 0.6 weight %, Cu is more than 0.5 weight % and Ti is more than 0.5 weight %, and the total amount of the age-hardenability improving alloying metals is in the range of from 4.5 to 6.5 weight percentages.

Also the steel A(or NAKT-1) was tested for the 180° tight-bending by using various kinds of the solution treatments and the inventors have found that the solution treatments have no effect on the 180° tight bending of the steel A. The test results are given in Table 3.

Table 3

Temp. (°C) used for the solution treatments	Time(minutes) used for the solution treatment. Water cooling is used	Solution treated hardness (Vickers)	180° tight-bending	age-hardness after treated at 525°C for 5 hours (Vickers)
950	1	184	good	450
	5	195	good	460
900	1	180	good	450
	5	182	good	451
800	1	177	good	445
	5	180	good	452
700	1	175	good	440
	5	180	good	447
650	1	177	good	440
	5	180	good	435

Further the steel A (or NAKT-1) was cut into test samples having the size of 1 mm thickness × 30 mm width × 105 mm length and the test samples were bent by the angle of 90° and then the variation of angle was observed after they were age-treated. It was found that the test samples had a little strain resulted by the thermal treatments. The test results are given in Table 4. The test results are compared with much strain of the commercial tempered and annealed steels without showing the data after they were thermally treated.

Table 4

Age-treated at	Bending radiuses(millimeters) 0		0.5		1.0		1.5	
	L	T	L	T	L	T	L	T
500°C for 5 hours	−0.02°	−0.15°	−0.08°	−0.11°	−0.06°	—	−0.04°	—
540°C for 5 hours	−0.04°	−0.02°	−0.04°	−0.04°	−0.04°	—	<0.01°	—
580°C for 5 hours	−0.04°	−0.08°	−0.04°	−0.04°	−0.02°	—	−0.02°	—

Note:
The sign L indicates that the test samples were bent in the direction along the rolling of the steel A.
The sign T indicates that the test samples were bent in the direction perpendicular to the rolling of the steel A.

It is obvious from the foregoing that the cold workable and age-hardenble steels of this invention have been developed for obtaining the materials, which are easily workable by pressing, extruding, deep drawing, heading or cutting by applying the cold workability to the steels under the conditions of the solution treatment, having the age-hardness of above 300 Vickers hardness and the improved machinability after the materials were age-treated. In order to achieve the intended purpose, the specified amount of Ni and Al or Ni, Al and Cu or Ni, Al and Ti or Ni, Al, Cu and Ti is added to the steels as the age-hardenability improving alloying metals and also the contents of carbon and manganese are defined as mentioned above for securing the cold workability of the materials. Still further, the ductility and temperability of the materials, the fineness of the crystalline particles of the materials and the machinability of the materials are improved by incorporating the specified amount of chromium, molybdenum, tungsten, cobalt, beryllium and boron as the ductility and temperability improving alloying metals; the specified amount of niobium, tantalum, vanadium and zirconium as the fineness improving alloying metals; and the specified amount of sulphur, lead, selenium, tellurium and bismuth as the machinability improving alloying metals with the materials. Thus, it is easily understood that the cold workable and age-hardenable steels of this invention can widely be used as the structural steels having high machinability and less thermal strain and they are practically useful steels.

What we claim is that:

1. A cold workable and age-hardenable steel, characterized in that it consists essentially of the weight percentages of carbon and manganese within the area enclosed by the line connecting points P, Q and R to the point S as shown in the accompanying FIG. 1; an effective amount up to 0.6 weight % of silicon, and, as age-hardenability improving alloying metals, more than 2.5 weight % of nickel, more than 0.6 weight % of aluminum, more than 0.5 weight % of copper and more than 0.5 weight % of titanium, the total amount of nickel, aluminum, copper and titanium being in the range of from 4.6 to 6.5 weight %, said point P indicating zero weight % of carbon and 1.8 weight % of manganese, said point Q indicating 0.08 weight % of carbon and 0.5 weight % of manganese, said point R indicating 0.08 weight % of carbon and zero weight % of manganese and said point S indicating zero weight % of carbon and zero weight % of manganese, and further consisting of, as alloying metals for improving the fineness of the crystalline particles of said steel, at least one element selected from the group consisting of an effective amount up to 0.3 weight % of the total amount of niobium and tantalum, an effective amount up to 0.5 weight % of vanadium and an effective amount up to 0.5 weight % of zirconium.

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