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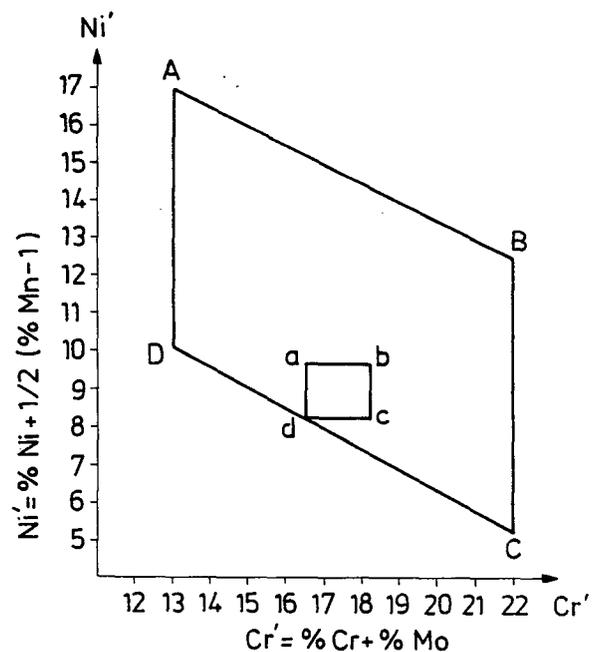
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⑤④ **Austenitic, precipitation hardenable stainless steel.**

⑤⑦ Austenitic, precipitation hardenable, stainless chromium-nickel-aluminium steel with good cold workability. The steel contains Cr 13—22 % and Ni 5—17 % within the area ABCD on the enclosed diagram, Figure 2, and C up to 0.15 %, Si up to 3.0 %, Mn up to 8.0 %, P up to 0.045 %, S up to 0.040 %, Mo up to 2.0 %, N up to 0.15 %, Al 0.5—2.5 %. In addition the steel can contain one more of the metals Ti, Zr and U up to 2 % with the balance iron and impurities normally occurring in stainless steels.



EP 0 031 800 A1

5 AUSTENITIC, PRECIPITATION HARDENABLE STAINLESS STEEL

This invention deals with an austenitic stainless, precipitation hardenable chromium-nickel-aluminium steel with good cold workability. By tempering the martensite
10 obtained by cold working, quenching or in some cases cooling to subzero temperatures, precipitation hardening is obtained. The new alloy can be produced as hot rolled products such as wire rod, bar, strip and plate.

Precipitation hardening of stainless steel using
15 aluminium is a well-known technique. These steels can either be given an annealing treatment designed to raise the M_s temperature so much that martensite is formed on quenching, or they can be annealed at a higher temperature giving an austenitic structure when quenched. In the
20 latter case the steel can be subsequently cold worked, thus transforming the austenite into martensite. After one of these treatments the material can be precipitation hardened.

The disadvantage with these steels is that the rate
25 of martensite formation when cold working is extremely high, thus rendering the material difficult to work. The risk of stress cracks, for example, during the wire drawing process is extremely high.

The main purpose of the present invention is thus to improve the workability in the cold condition of Cr-Ni-Al steels by lowering the M_s and the M_{d30} temperatures sufficiently to ensure that good workability is obtained without at the same time lowering them so far that the austenite is not transformed to martensite when cold worked. Martensite is desirable in the final product since it raises the mechanical strength considerably.

Two production heats with the following analyses have been made under production conditions.

Table 1

Heat No	C	Si	Mn	P	S	Cr	Ni	Mo	N	Al	Ti
3423-71	.064	.60	1.30	.021	.014	17.1	8.9	.16	.034	.82	.09
4029-71	.069	.65	1.19	.018	.010	17.2	9.0	.13	.034	1.06	.10

Both heats were melted in a 10-ton high-frequency induction furnace, ingot teemed and rolled to billets. These were conditioned and rolled to wire rod, \emptyset 6.0 mm for heat 3423-71 and \emptyset 5.6 mm for heat 4029-71. The wire rod was subjected to a normal anneal at 1050°C, pickled and inspected before being drawn to wire.

As reference material a heat (3226-71) in steel of type 17-7 PH (AISI 631) has been produced by the same method. This is a precipitation hardenable Cr-Ni-Al-steel with the following heat analysis (Table 2).

Table 2

<u>Charge</u>	C	Si	Mn	P	S	Cr	Ni	Mo	N	Al	Ti
3226-71	.073	.74	.74	.013	.006	16.4	7.1	.15	.041	.94	.09

Heats 3423-71 (Table 1) and 3226-71 have been drawn from wire rod, Ø 6.0 mm, using single drafts. The tensile strength (R_m), yield strength (R_e), and reduction of area (Z) as measured by tensile testing are compared in Figure 1. It is apparent that the yield and tensile strengths increase more slowly for the alloy in the invention (continuous curve) thus causing the drawability, measured as maximum achievable area reduction, to increase from 75% to 92%. Moreover, the ductility measured as reduction of area is higher for the alloy in the invention over the whole range and particularly at large area reductions. It should be noted that stress cracks are completely absent in the material for area reductions as large as 92% compared with 17-7 PH where a definite risk of stress crack formation exists at area reductions as low as 45%.

The precipitation hardening effect of the alloy in the invention has been tested for two different area reductions and the results are shown below in Table 3.

Table 3

Heat No	Wire diameter mm	Area reduction %	R_m N/mm ²		R_e N/mm ²	
			Un-tempered	Tempered	Un-tempered	Tempered
3423-71	2.68	80.0	1810	1995	1630	1855
4029-71	1.83	89.4	2116	2525	1976	2357

Tempering treatment: 30 minutes at 450°C.

Thus, the tempering treatment gives an increase of yield and tensile strengths of about 200 N/mm² for heat

3423-71 and about 400 N/mm^2 for heat 4029-71. The large difference between these effects can be explained by the fact that wire rod from heat 3421-71 has not been worked sufficiently, i.e. the austenite has not been transformed
5 to martensite in sufficient quantities prior to tempering.

The alloy in this invention has mainly been developed in order to improve the cold workability of precipitation hardenable stainless Cr-Ni-Al steels. Within the area ABCD in Figure 2 the composition can be set
10 so that annealing in the temperature range $600\text{-}950^\circ\text{C}$ leads to a rise in the M_s temperature due to carbide precipitation. The material can subsequently be cooled to ambient or subzero temperatures in order to obtain a transformation to martensite which can then be tempered.

15 A particularly interesting application is cold heading where tensile strengths as low as $540 - 560 \text{ N/mm}^2$ have been measured on material annealed at 1050°C . This is true for both heats 3423-71 and 4029-71.

The technical result of the invention is that the
20 drawability is considerably improved at the same time as the precipitation hardening effect is retained. It is reasonable to assume that the good weldability can be improved by additions of zirconium and uranium instead of titanium. Since the alloy has an extremely sluggish
25 martensitic transformation in the annealed state the material can be stored and transported outdoors under cold weather conditions without risk of spontaneous martensite formation.

Chromium and nickel contents should lie within the area ABCD as shown in Figure 2 where chromium can be partly replaced by molybdenum with up to 2%, and nickel can be partly replaced by manganese according to the
5 formula $\% \text{Ni} = 1/2 \cdot (\% \text{Mn} - 1\%)$. In one, particularly preferred, form of the alloy chromium and nickel should lie within the area ABCD in Figure 2.

The alloy according to the invention is annealed within the temperature range 600 - 950°C, quenched and
10 cooled to below room temperature. The alloy can then be precipitation hardened by tempering.

The alloy can also be quenched direct after hot rolling and subsequently cold worked and precipitation hardened by tempering.

CLAIMS

1. Austenitic, precipitation hardenable, stainless chromium-nickel-aluminium steel with good cold workability and characterized by containing Cr 13 - 22% and Ni 5 - 17%
5 and C up to 0.15%, Si up to 3.0%, Mn up to 8.0%, P up to 0.045%, S up to 0.040%, Mo up to 2.0%, N up to 0.15%, Al 0.5 - 2.5% and preferably one or more of the metals Ti, Zr and U up to 2%, with the balance of iron and impurities normally occurring in stainless steels and the sum of Ni
10 and Mn expressed as $Ni' = \%Ni + 1/2 (\% Mn - 1)$ and the sum of Cr and Mo expressed as Cr' according to the formula $Cr' = \%Cr + \%Mo$ lies within the area ABCD in the enclosed diagram Figure 2.

2. Steel according to claim 1, characterized by the
15 fact that it contains either Ti up to 0.5% or Zr up to 0.5% or U up to 1%.

3. Steel according to claims 1 and 2, characterized by a chromium content of 22% corresponding to a nickel content between 5.25 and 12.5% and a chromium content of
20 13% corresponding to a nickel content between 10.15 and 17%.

4. Steel according to claims 1 and 2, characterized by the fact that the chromium content lies between 16.5% and 18.2% and the nickel content between 8.25% and 9.75%.



European Patent
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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	<u>US - A - 3 253 908</u> (TANCZYN) * Claim 1 * --	1	C 22 C 38/40 38/44 38/58
	<u>US - A - 3 071 460</u> (TANCZYN) * Claim 1 * --	1	
	<u>US - A - 3 347 663</u> (BIEBER) * Claim 1 * --	1,2	
	<u>US - A - 3 117 861</u> (LINNERT et al.) * Claim 1 * --	1,2	C 22 C 38/40 38/44 38/58
A	<u>US - A - 2 505 762</u> (GOLLER) * Claim 1 * --	1	
A	<u>US - A - 3 408 178</u> (MYERS et al.) * Claim 1 * ----	1,2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.³)
			CATEGORY OF CITED DOCUMENTS X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
The Hague	06-04-1981	LIPPENS	