

[54] **LOW NICKEL HIGH-STRENGTH SILICON STEEL**

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[*] Notice: The portion of the term of this patent subsequent to July 4, 1989, has been disclaimed.

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[51] Int. Cl. **C22c 39/20**, C22c 39/44

[58] Field of Search 148/37; 75/125, 126 B, 75/126 Q, 128 A, 128 C

[56] **References Cited**

UNITED STATES PATENTS

1,892,384	12/1932	Cox et al.	75/126 Q
2,789,049	4/1957	De Long et al.	75/126 B
3,674,468	7/1972	Ota	75/125 X

3,681,058	8/1972	Dulis et al.	75/128 A
3,736,131	5/1973	Espy	75/126 B

OTHER PUBLICATIONS

"Steel and Its Heat Treatment," Vol. III, Bullens, 1949, p. 26.

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[57] **ABSTRACT**

A low nickel high-strength silicon alloy steel age hardened for 8 hours at 750°F to a Vickers Brinell Hardness of 600, said alloy steel consisting essentially of C in an amount of not more than 0.03 percent, 4–6% Si, 1–5% Mn, 1.8–4.8% Ni, 6–18% Cr, 1–4% Cu, optionally one or more of Mo, V and B in an amount of not more than 2 percent each, and the residual essentially Fe, in which the weight ratio of the total amount of Ni, Mn and Cu to Si and the weight ratio of Cr to Si are varied about 2.5 and 3 respectively, wherein the Ac3 transformation point of said steel is less than 1,210°F.

1 Claim, No Drawings

LOW NICKEL HIGH-STRENGTH SILICON STEEL

BACKGROUND OF THE INVENTION

The present invention is related to an improvement over my High-strength Silicon Steel disclosed and claimed in my U.S. Pat. No. 3,674,468 granted on July 4, 1972.

My U.S. patent relates to an invention of high-strength silicon steel consisting essentially of:

cent and by controlling the total amount of the essential elements Ni, Mn and Cu to be 2.5 times the Si content whereby the Ac3 transformation point surprisingly will be less than 1,210°F notwithstanding the reduction of the amount of nickel in the alloy. These surprising results are attributed to the inclusion in the alloy of from 1 to 4 percent copper with the proviso that the amount of copper together with nickel and manganese be 2.5 times the silicon content.

Table 1

Kind of Steel	Mark	Chemical Composition(%)							Ac3 Transformation Point (°F)
		C	Si	Mn	Ni	Cr	Mo+V	Cu	
Low Ni High-strength Si Steel according to Present Invention	A	0.016	4.08	4.85	3.36	12.86	1.05	1.96	1260
	B	0.022	4.83	4.12	4.08	11.75	0.68	3.22	1210
High-strength Si Steel Pat. 3674468	—	0.018	4.58	2.75	6.63	10.48	2.21	0.18	1160
NiCrMo Steel 4337	—	0.274	0.23	0.65	3.13	1.16	0.32	0.22	1440

Ingredient	Weight Percent
C	Up to 0.03
Si	4-6
Ni	5-10
Cr	6-18 and about 2.5 times Si content
Mn, Mo and Cu	Up to 4 respectively
V	Up to 2
Fe	Essentially the remainder
Ni + Mn	Two times Si content

wherein the Ac3 transformation point of said steel is less than 1,210°F.

SUMMARY AND PREFERRED DISCRIPTION OF THE INVENTION

The present invention relates to a low nickel high-strength silicon steel which can be produced more economically than the above mentioned high-strength silicon steel by lowering the Ni content to less than 5 per-

cent and by controlling the total amount of the essential elements Ni, Mn and Cu to be 2.5 times the Si content whereby the Ac3 transformation point surprisingly will be less than 1,210°F notwithstanding the reduction of the amount of nickel in the alloy. These surprising results are attributed to the inclusion in the alloy of from 1 to 4 percent copper with the proviso that the amount of copper together with nickel and manganese be 2.5 times the silicon content.

Table 1 indicates chemical composition and transformation point of steel according to the present invention comparing with those of the patented steel 3,674,468 and NiCrMo steel 4337.

Table 2 shows the mechanical properties of steels in Table 1 at various conditions and it will be appreciated that the Quality Factors of the low nickel high-strength silicon steels according to the invention are slightly lower than those of the above-mentioned high-strength silicon steel in the solution-treated state but they are much higher than those of the heat-treated NiCrMo steel 4337.

To give high strength-and-toughness, plentiful forgeability and corrosion resistance to a two-phase alloy consisting of Ferrite and Austenite, it is necessary to have a suitable structure of about 40-50 percent Ferrite to Austenite at the solution treated state as described in the following Table 3.

Table 2

Kind of Steel	Mark	Heat-treatment	Mechanical Properties					Quality Factors	
			T.S. lb/sq.in	Elong %	R.A. %	T.S.× Elong.	T.S.× R.A.		
Low Ni High-strength Si Steel according to Present Invention	A	1920°×1 hr W.Q.	150,000	45	75	6750000	11250000		
		1920°×1 hr A.C.	140,000	40	65	5600000	7700000		
	B	1830°×1 hr W.Q.	158,000	42	70	6640000	11060000		
		1830°×1 hr A.C.	145,000	38	58	5510000	8410000		
High-strength Si Steel Pat. 3674468	—	1650°×1 hr W.Q.	165,000	48	74	7900000	12000000		
		1650°×1 hr A.C.	150,000	52	68	7800000	10200000		
		1560°×1 hr O.Q.	150,000	52	68	7800000	10200000		
NiCrMo Steel 4337	—	1200°×1 hr O.Q.	160,000	25	61	4000000	9800000		

Table 3

Content of Alloying Element in %				Ac3 point in °C	Structure* Ratio of F to A	Characteristics of Alloy**			
Ni	Mn	Cu	Si			Forge-ability	T.S.	I.V.	Corrosion Resistance
>5	+	0	Ni+Mn=2 Si	500-650	2/5-½	Good	High	Good	Fairly
<5	+	+	Ni+Mn+Cu<2.5 Si	>650	>½	Poor	Too High	Poor	Poor
<5	+	+	Ni+Mn+Cu=2.5 Si	500-650	2/5-½	Good	High	Fairly	Good
<5	+	+	Ni+Mn+Cu>2.5 Si	<500	<2/5	Good	Low	Good	Better

N.B.

* F: Ferrite, A: Austenite

**T.S.: Tensile Strength, I.V.: Impact Value, Corrosion Resistance:

For H₂SO₄.

500-650°C=900-1200°F

In this invention, therefore, the Si content is decided against the Ni, Mn, Cu and Cr to come the Ac3 transformation point of the alloy in the range of 500°–650°C. In case of the Ac3 point below 500°C, the alloy have too much Austenite and the strength is lowered almost to full Austenite alloy such as AISI 316-L, and on the contrary, the Ac3 point above 650°C, the forgeability and corrosion resistance are fatally dropped. This is the reason that the total amount of the Ni, Mn and Cu to the Si and the Cr to the Si are determined to 2.5 and 3 respectively.

To compensate the weak action of lowering Ac3 transformation point by alloying Cu compared with Ni, the ratio of the total amount of Ni, Mn and Cu to the Si content is increased 0.5 percent than that of U.S. Pat. No. 3,674,468.

The low nickel high-strength silicon steel according to the invention has a peculiar characteristic on aging and can harden so high hardness as Vickers Brinell Hardness of 600 by aging for 8 hours at 750°F after cold-rolled to ½ inch thickness from five-eighths inch, without practically any loss of ductility and corrosion-resistance as described in the following Table 4.

Table 4

Condition	Mechanical Properties				Corrosion Loss		
	Hardness Hv	T.S. lb/sq. in	Elong %	R.A. %	5% H ₂ SO ₄ gr/m ² /gr	5% HCl gr/m ² /hr	5% HNO ₃ gr/m ² /hr
As Cold-rolled to ½ in. thickness from ⅝ in.	480	228,000	28	45	6	80	0.3
As Solution-treated after Cold-rolled	300	135,000	55	80	4	60	0.2
As Aged for 8 hours at 780°F	630	205,000	33	55	5	130	0.3

In addition to the foregoing mechanical and corrosion-resisting properties, it has been confirmed that the low nickel high-strength silicon steel according to the invention has the following excellent characteristics and properties:

- It is rich in castability and well adapted for precision casting of thin and complex-formed machine parts such as turbine blades.
- It has an ample forgeability and permits the manu-

facture of a piano-wire having tensile strength of 205,000 lb/sq.in. and plentiful toughness by applying strain-aging at 750°F.

- It has a very high toughness of more than 15 kg.m/sq.cm of Charpy Impact Value in as-cast condition and suitably used for high-strength steel castings such as marine propeller high-strength steel castings.

The present invention may be applied to the manufacture of a wide variety of ferrous products and articles which will be apparent to those skilled in the metallurgy of steel from the properties of this steel provided by the invention. These products and particles include machine parts such as reaction vessel for chemical industry, turbine-disc of jet engine, chassis of cars, plates for shipbuilding, corrosion-resisting high-tension wire-rope and PWS for suspension bridge and ocean-development, many kinds of springs and various rust-resisting instruments for medical and home uses.

What I claim is:

1. A low nickel high-strength silicon alloy steel age hardened for 8 hours at 750°F. to a Vickers Brinell Hardness of 600, said alloy steel consisting essentially of C in an amount of not more than 0.03 percent,

4–6%Si, 1–5% Mn, 1.8–4.8% Ni, 6–18%Cr, 1–4% Cu, optionally one or more of Mo, V and B in an amount of not more than 2 percent each, and the residual essentially Fe, in which the weight ratio of the total amount of Ni, Mn and Cu to Si and the weight ratio of Cr to Si are varied 2.5 and 3 respectively, and wherein the Ac3 transformation point of said steel is less than 1,400°F.

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