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ALLOY STEELS

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Fig.1.

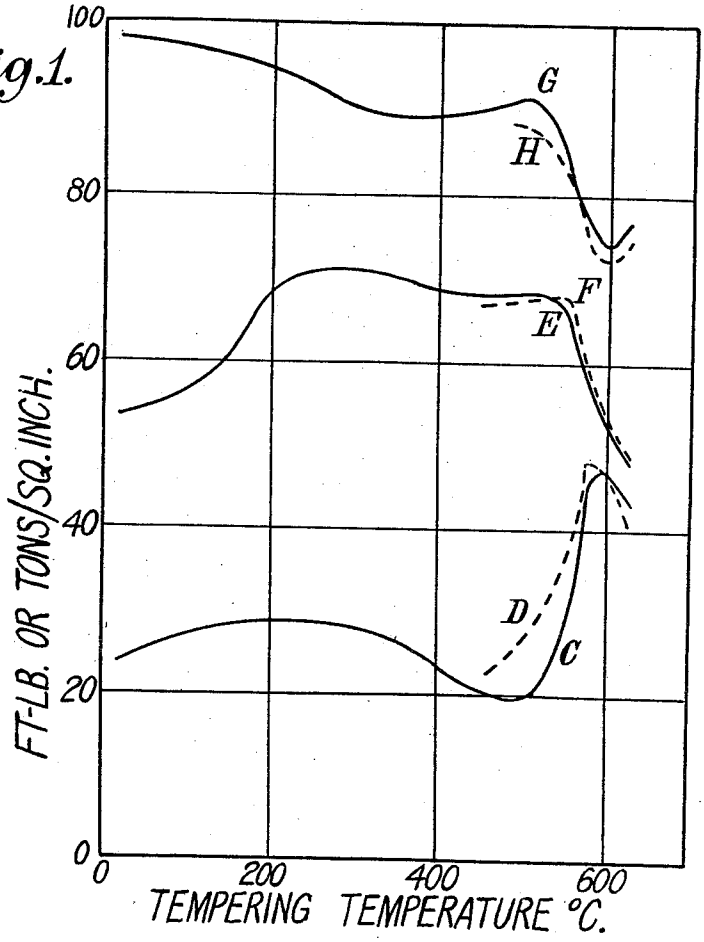
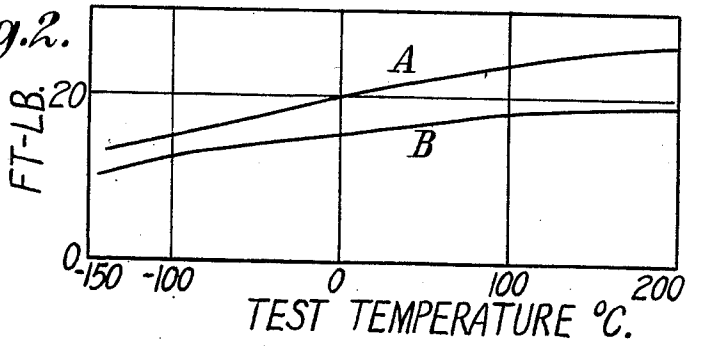


Fig.2.



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ALLOY STEELS

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5 Claims. (Cl. 75—128)

The invention relates to alloy steels.

The invention provides in one of its aspects an alloy steel having the following composition.

Carbon	0.05–0.30%.
Silicon	Not more than 0.35%.
Manganese	0.60–0.80%.
Nickel	8.00–9.00%.
Chromium	0.25–1.5%.
Molybdenum	0.30–1.5%.
Iron	Substantial remainder apart from usual impurities.

The alloy steel provided by the invention has high hardenability. It possesses good low temperature impact properties at high tensile levels when formed into articles of thick section.

This steel is particularly applicable to the manufacture of large high tensile turbine wheels for turbo-alternator plant, although it may be used for rotor shafts and other components where low transition temperatures, however defined, but normally estimated from notched impact tests carried out over a range of temperatures, are necessary or desirable. Above the transition temperature, fractures are predominantly ductile, but below the transition temperature there is an increasing tendency to brittle fracture. Good low temperature impact properties imply a low transition temperature.

The normal alloy steels used for the applications mentioned above suffer from the disadvantage that as the tensile level increases above 60–65 tons/in.^{2} (ultimate tensile strength) the transition temperatures become unacceptably high. It has now been found that by addition of certain amounts of chromium and molybdenum to certain nickel steels, an alloy is obtained having improved low temperature impact properties at tensile levels of 60–100 tons/in.^{2} (ultimate tensile strength), after heat treatments consisting preferably of tempering following slow cooling from austenitizing temperature.

Following is a description by way of example only of methods of carrying the invention into effect.

EXAMPLE 1

A bar ¾ inch in diameter was formed from an alloy steel according to the invention having the following composition:

Carbon	0.18%.
Silicon	0.30%.
Manganese	0.76%.
Nickel	8.40%.
Chromium	0.99%.
Molybdenum	0.51%.
Iron	Substantial remainder apart from usual impurities.

Portions of this bar were subjected to the following three heat treatments.

No. 1.—The bar was austenitized at a temperature of 900° C. for ½ hour, cooled to room temperature at a rate of 10° C./hour, tempered at 600° C. for one hour and then water quenched.

No. 2.—The sample was austenitized at a temperature of 900° C. for ½ hour and then air-cooled to 200° C. at

which temperature the sample was maintained for one hour. The sample bar was then tempered at 600° C. for four hours and finally water quenched.

No. 3.—The sample was austenitized at 900° C. for ½ hour and then air cooled to 200° C., the temperature of the bar being maintained at 200° C. for one hour. The sample was then air-cooled to room temperature.

The properties of the bore resulting from these heat treatments are given in the following tables.

Mechanical Properties

Heat Treatment No.	0.5% Proof Stress	Ultimate Tensile Strength	Elongation, Percent	Reduction in Area, Percent
1	58.0	70.6	24.5	64
2	54.0	64.8	25.5	66
3	73.8	92.0	19.5	54

Charpy Impact Values

Test Temp., ° C.	Charpy V Notch Value, ft. lb.		
	Heat Treatment 1	Heat Treatment 2	Heat Treatment 3
100	67	77	39
20	58	65	41
−20	59	68	39
−60			39
−78	51		
−90		64	34
−120	48		
−196	33	44	27

EXAMPLE 2

A ¾" bar was formed from an alloy steel according to the invention having the composition:

	Percent
Carbon	0.19
Silicon	0.13
Manganese	0.68
Nickel	8.33
Chromium	0.97
Molybdenum	1.0
Balance Iron.	

Portions of this bar were subjected to the following four heat treatments.

No. 4.—The sample was austenitized at 830° C. for ½ hour, air cooled to room temperature, tempered at 600° C. for 4 hours and then water quenched.

No. 5.—The sample bar was austenitized at 830° C. for ½ hour, air cooled to room temperature, tempered at 600° C. for 4 hours and then cooled to room temperature at a rate of 10° C. per hour.

No. 6.—The bar was austenitized at 830° C. for ½ hour, air-cooled to room temperature, tempered at 500° C. for 4 hours and then water-quenched.

No. 7.—A sample of the bar was austenitized at 830° C. for ½ hour, air-cooled to room temperature, tempered at 500° C. for 4 hours and then cooled to room temperature at a rate of 10° C. per hour.

The properties of the bars resulting from these heat treatments are given in the following tables.

Mechanical Properties

Heat Treatment No.	0.5% Proof Stress	Ultimate Tensile Strength	Elongation, percent	Reduction in Area, percent
4	63.0	73.0	24	62
5	57.7	67.5	23	51
6	72.7	86.0	18	46
7	74.0	87.0	17	42

Charpy Impact Values

Test Temp., ° C.	Charpy Impact Value, ft. lb.			
	Heat Treatment No. 4	Heat Treatment No. 5	Heat Treatment No. 6	Heat Treatment No. 7
20	50	38	35	36
−78	48	17	29	36

EXAMPLE 3

A 1-ton cast of alloy steel was made according to the invention having the following composition:

Carbon	0.21%.
Silicon	0.23%.
Manganese	0.67%.
Nickel	8.55%.
Chromium	0.92%.
Molybdenum	0.93%.
Iron	Substantial remainder apart from usual impurities.

From this cast, ⅝ inch Gothic bar and 6 inch diameter billet were prepared. Portions of the bar were subjected to the following heat-treatments.

No. 8.—The bar was austenitized at a temperature of 850° C. for ½ hour, air cooled to room temperature and tempered at various temperatures up to 625° C. After tempering, the samples were water-quenched.

No. 9.—The bar was austenitized at a temperature of 850° C. for ½ hour and cooled to room temperature at 10° C./hour.

Tempering was carried out at various temperatures in the range 450°–625° C. After tempering the samples were water quenched.

The properties of the bars resulting from these heat-treatments are graphically illustrated in FIGURE 2. In this graph, curve A is a plot of Charpy V-notch values in ft. lbs. in a tangential direction against the Test Temperature in ° C., and curve B is a plot of Charpy V-notch values in ft. lbs., in an axial direction, against the Test Temperature. Both in tensile properties and in room temperature Charpy V-notch impact tests, there is little difference between specimens air-cooled or slowly cooled after tempering.

When a steel is to be used in massive sections, it is desirable to ensure the formation of the required transformation product on cooling from the austenitizing temperature; this is done by cooling at such a rate that residual stresses are introduced into the section. The tempering temperature then has to be such that these stresses relax during tempering. With the alloy steel provided by the invention, the high hardenability makes it possible to use a slow cooling rate from the austenitizing temperature. The residual stresses remaining in the section are therefore negligible, tempering may be carried out at a low temperature. In pursuance of this idea, a disc 12 inches in diameter and 5 inches thick was produced by upsetting a suitable length from the 6 inch diameter billet. This disc was subjected to the following heat treatment.

No. 10.—The disc was austenitized at a temperature of 830° C. for 1 hour and cooled to room temperature at 10° C./hour. Tempering was carried out at 300° C. for 4 hours, followed by cooling at 10° C./hour to room temperature.

Axial and tangential specimens were cut from the disc after heat treatment, and the various mechanical properties of these specimens are graphically illustrated in FIGURE 1. In this graph, curve C is a plot of Charpy V-notch values in ft. lbs. against Tempering Temperature (° C.) on a specimen cooled at a rate of 10° per hour. from 850° C., and curve D is a similar plot for a specimen air cooled from 850° C. Curve E is a plot of the

0.2% proof stress in tons/sq. in. against Tempering Temperature (° C.) on a specimen cooled at a rate of 10° per hour from 850° C., and curve F is a similar plot for a specimen air cooled from 850° C. Curve G is a plot of maximum stress in tons/sq. in., against tempering temperature (° C.) on a specimen cooled at a rate of 10° per hour from 850° C., and curve H is a similar plot for a specimen air-cooled from 850° C.

Heat Treatment No.	Test Position	0.5% proof stress, tons/sq. in.	Ultimate tensile strength, tons/sq. in.	Elongation, percent	Reduction in Area, percent
10	Axial	85.6	90.8	7	20
	Tangential	79.0	90.2	16	46

Thus, by means of a low temperature tempering treatment, an attractive combination of high tensile strength, ductility and low temperature properties may be obtained in the steel of this invention.

We claim:

1. A high hardenability alloy steel having the following critically balanced composition:

Carbon	0.05–0.30%.
Silicon	Up to a maximum of 0.35%.
Manganese	0.60 to 0.80%.
Nickel	8.00 to 9.00%.
Chromium	0.25 to 1.50%.
and	
Molybdenum	0.30 to 1.50%.

the remainder being substantially iron with the usual impurities in ordinary amounts.

2. A high hardenability alloy steel having the following critically balanced composition:

	Percent
Carbon	About 0.18
Silicon	About 0.30
Manganese	About 0.76
Nickel	About 8.40
Chromium	About 0.99
and	
Molybdenum	About 0.51

the remainder being iron with the usual impurities in ordinary amounts.

3. A high hardenability alloy steel having the following critically balanced composition:

	Percent
Carbon	About 0.19
Silicon	About 0.13
Manganese	About 0.68
Nickel	About 8.33
Chromium	About 0.97
and	
Molybdenum	About 1.02

the remainder being iron with the usual impurities in ordinary amounts.

4. A high hardenability alloy steel having the following critically balanced composition:

	Percent
Carbon	About 0.21
Silicon	About 0.23
Manganese	About 0.67
Nickel	About 8.55
Chromium	About 0.92
and	
Molybdenum	About 0.93

the remainder being iron with the usual impurities in ordinary amounts.

5. A process for the manufacture of a high harden-

ability alloy steel, which process comprises making an alloy having the following composition:

Carbon	0.05–0.30%.
Silicon	Up to a maximum of 0.35%.
Manganese	0.60 to 0.80%.
Nickel	8.00 to 9.00%.
Chromium	0.25 to 1.50%
Molybdenum	0.30 to 1.50%.

heating the alloy within the range 800° C. to 950° C., cooling the alloy at a maximum rate of 10° C. per hour to a temperature within the range 0° C. to 250° C., heating the alloy at a temperature of 300° C. to 650° C. and subsequently cooling to room temperature.

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