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SHOCK RESISTING STEEL CONTAINING CHROMIUM AND NICKEL

John Lyons Hurley, Stockholm, N.J., assignor to The International Nickel Company, Inc., New York, N.Y., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

A high strength steel combining toughness and hardness which is adaptable as a shear blade for cutting heavy metal sections contains specified amounts of carbon, manganese, vanadium, silicon, nickel, chromium, molybdenum, the balance being mainly iron. An illustrative steel contains 0.45% carbon, 0.34% manganese, 2.5% silicon, 3.5% nickel, 1.4% chromium, 0.35% molybdenum, 0.1% vanadium, the balance being mainly iron.

This invention relates to a novel, shock resisting steel having a good combination of high strength, ductility, toughness, and hardness, and particularly to shear blades fabricated therefrom.

Shock resisting steels find particular application as shearing tools such, for example, as shear blades, cutoff tools on forging or heading machines, trimming dies, blank dies, slitters, punches and piercers. Such applications subject the steel to high stresses which increase as the stock thickness increases and, consequently, the steel must possess sufficient hardness and toughness to maintain the original edge contour and dimensions.

Shear blades for shearing heavy metal sections, e.g., blades for shearing nickel cathodes, is an application requiring the steel to perform under extreme conditions. In order for the steel to avoid deformation or spalling and to otherwise perform adequately in this operation, it must have a good combination of strength, ductility, toughness and wear resistance. In this regard, the steel should have a minimum yield strength of about 280,000 p.s.i., an ultimate strength of at least about 325,000 or 330,000 p.s.i., a minimum Charpy C-notch toughness of about 90 foot-pounds at room temperature, a minimum elongation of about 5% in 1 inch, a minimum reduction of area of about 20%, a minimum notch tensile strength of about 190,000 p.s.i., and a minimum hardness of about Rc 57. A minimum hardness of about Rc 57 is particularly important since below this hardness the blade edge rapidly deforms in service resulting in short blade life and poor shearing characteristics. Low blade hardness or inferior toughness has been a particular drawback experienced in shearing cathodes. When the steel most commonly used commercially, is tempered to a hardness of Rc 57–58, spalling quickly results. Consequently the steel has been used at a hardness of Rc 50–54, sacrificing resistance to deformation and wear resistance to develop toughness. Even at Rc 50–54 the shearing edge too quickly deforms in service and this "edge flow," apart from resulting in short blade life, markedly contributes to poor cutting action and irregularly cut cathodes.

In addition to the foregoing, the steel should be air hardenable in two inch sections to minimize distortion and cracking. For optimum performance, however, a shear blade for cutting heavy metal sections should have a yield strength of at least about 290,000 p.s.i., an ultimate strength of at least about 335,000 p.s.i., a Charpy C-notch toughness of at least about 120 foot-pounds at room temperature, a reduction of area of about 25%, a notch tensile strength of at least about 200,000 p.s.i., an elongation of at least about 8% in 1 inch, and a hardness of at least about Rc 58.

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It has now been discovered that a special shock resisting steel of a particular composition can be provided with a highly satisfactory combination of properties including high strength, ductility, toughness, and hardness.

It is an object of the present invention to provide a new and improved steel.

Another object of this invention is to provide a tool steel characterized by a highly satisfactory combination of strength, ductility, toughness, and hardness.

Still another object of this invention is to provide a steel shear blade characterized by a good combination of shock and wear resistance.

Generally speaking, and in accordance with the present invention, the combination of properties referred to above is obtainable with shock resisting steels of the following composition based on weight percent: about 0.40% to 0.50% carbon, about 0.2% to 0.8% manganese, about 2.3% to 3.8% silicon, about 2.4% to 3.8% nickel, from 0.25% to 1.8% chromium, about 0.3% to 0.7% molybdenum, the molybdenum content being at least 0.4%, e.g., at least 0.45%, when the chromium is less than 0.5%, about 0.07% to 0.3% vanadium, and the balance essentially iron with residual impurities.

In carrying the invention into practice, the carbon should not be less than about 0.40%, and preferably not below about 0.42%, e.g., about 0.45%, to maintain adequate strength. Carbon contents above about 0.50%, and even above about 0.49%, result in a loss in toughness without a useful increase in strength. Manganese is added for good steel making practice and should be present in amounts of about 0.2% to 0.8%, and preferably not more than about 0.5%, e.g., about 0.3% to 0.5%, e.g., about 0.35%, to avoid difficulty in annealing and reduction in toughness. Excessive amounts of manganese cause a substantial amount of retained austenite to remain in the quenched and tempered steel resulting in a decrease in hardness. Silicon contents below about 2.3% do not consistently provide the steel with sufficient resistance to softening to develop the optimum combination of strength and toughness. Higher silicon contents, e.g., above about 3.8%, reduce toughness and notch tensile strength without substantially increasing tensile or yield strength. Where the optimum in notch tensile strength is necessary, the silicon content should not exceed about 3%. Results obtained in respect of alloys of substantially the same composition except for silicon content (which was varied over the range of about 2.5% to 3.8%) indicated a drop in notch tensile strength from about 260,000 to 210,000 p.s.i. Advantageously, the steel contains about 2.35% to 2.7%, e.g., about 2.5% silicon.

The minimum amount of nickel is about 2.4% which is necessary to provide the steel with adequate hardenability and sufficient toughness. Nickel also lowers the critical temperature, reduces decarburization, and promotes a fine austenite grain size by allowing austenitizing treatments to be carried out at lower temperatures. On the other hand, nickel in amounts above about 3.8% cause undesirable amounts of retained austenite to be present in the steel. Advantageously, the nickel should be maintained between about 2.8% and about 3.6%, e.g., about 3.5%. Chromium, particularly in amounts of at least 0.5%, contributes to hardenability, retards tempering, provides the steel with resistance to decarburization and helps the steel develop low hardness during annealing. But, as indicated above, chromium can be lowered to 0.25% provided the steels contain at least 0.4% molybdenum. Chromium contents above about 1.8% reduce toughness. For the most advantageous results, therefore, the chromium content should be about 0.8% to 1.7%, e.g., about 1.4%. A minimum molybdenum content of about 0.3% contributes to the hardenability of the steel while amounts above about 0.7% hinder the dissolution of carbides at relatively low austenitizing temperatures. Preferably, the molybdenum should be maintained between about 0.35% and 0.6%. Vanadium, in amounts of at least about 0.08%, e.g., about 0.1%, assures resistance to grain coarsening at ordinary heat treating temperatures while amounts in excess of about 0.3% lower hardenability at normal hardening temperatures. Advantageously, the vanadium content should not exceed about 0.2%. Aluminum in amounts up to 0.15%, beneficially between 0.01% and 0.1%, e.g., about 0.05%, promotes optimum ductility in the steel. In any event, deoxidation is advantageously carried out with aluminum although calcium and silicon produce satisfactory results.

To achieve maximum mechanical properties, the steels of the invention should be austenitized at about 1600° F. to 1700° F., e.g., about 1650° F., quenched, e.g., oil quenched or air quenched, refrigerated to assure maximum transformation of retained austenite, and tempered at least once on the order of about 600° F. for about 2 hours, although higher tempering temperatures, e.g., up to 700° F., can be employed. At the higher temperatures some loss in strength might occur. Advantageously, the steel is austenitized at about 1650° F. for about 1 hour, oil quenched, refrigerated, e.g., below about minus 100° F. or lower for about 1 hour, and double tempered at about 600° F. for about 2 hours at each temper. Refrigeration can be conducted below about 32° F. down to at least as low as minus 300° F.

For the purpose of giving those skilled in the art a better understanding of the invention and a better appreciation of the advantages of the invention, there is given herein data illustrative of the markedly improved combination of properties characteristic of the steels within this invention. In Table I below, there is presented a series of compositions in weight percent. Steels B, C, D,

E, F and G are beyond the compositional scope of the invention and are included for comparative purposes with Steels 1 to 7 which are within the scope of the invention. With the exception of Steels D and E, each of the steels shown in Table I was prepared by air melting in an induction furnace followed by deoxidation. The steels were then mechanically worked, slowly cooled, machined to oversize blanks, annealed and, finally, test specimens were machined from the blanks. Steels D and E are prior art steels.

TABLE I

Steel	C	Mn	Si	Ni	Cr	Mo	V	Al	W
1	0.48	0.4	2.50	3.60	1.4	0.34	0.13	0.04	
2	0.44	0.38	2.55	3.50	1.72	0.31	0.09	0.03	
3	0.47	0.48	2.74	3.60	1.40	0.32	0.12		
4	0.45	0.48	2.55	3.50	0.51	0.30	0.09	0.08	
5	0.44	0.48	2.87	3.50	0.50	0.30	0.09	0.02	
6	0.48	0.50	3.40	3.60	0.51	0.30	0.10	0.02	
7	0.44	0.50	3.77	3.60	0.51	0.32	0.08	0.06	
B	0.62	0.43	2.47	3.70	1.45	0.54	0.10	0.02	
C	0.39	0.39	2.37	3.65	1.40	0.53	0.11	0.02	
D	0.53	0.32	0.27		1.19		0.20	0.01	2.07
E	0.5-0.6	0.36	0.95	2.1	0.8	0.5	0.07		
F	0.53	0.39	2.55	3.50	1.70	0.31	0.08	0.03	
G	0.52	0.35	1.60	3.50	2.72	0.31	0.08	0.03	

Various heat treatments were employed as is shown in connection with the data presented in Table II. The data shown in Table II were obtained from tests conducted on the steels shown in Table I. In Table II below, the superscripts for the steels indicate the thermal treatment the steel received; the yield strength, ultimate tensile strength and notch tensile strength are reported in thousands of pounds per square inch (K.s.i.); and the Charpy C-notch toughness was measured at room temperature.

TABLE II

Steel	Y.S., K.S.I.	U.T.S. K.S.I.	Elong., percent	R.A. percent	N.T.S. K.S.T.	Charpy "C" Notch	Hardness (Rc)
1 [1]	293	340	7.5	33.0	211	136	58.0
1 [2]	258	310	10.0	37.0	244	185	55.0
1 [3]	296	343	8.0	28.0	209	123	58.0
2 [1]	301	349	5.0	20.0	205	130	58.0
2 [7]							27.0
3 [3]	295	336	7.0	23.0	212	92	58.0
3 [5]	254	300	10.5	30.0	240	161	55.0
4 [1]	285	328	9.0	38.0	263	183	57.0
5 [1]	286	333	8.0	38.0	250	164	57.5
6 [1]	289	339	7.5	32.0	227	147	57.5
7 [1]	293	342	7.0	30.0	208	134	57.5
A [1]	285	328	9.0	38.0	263	183	57.0
C [4]	272	319	10.0	38.5	257	178	57
D [4]	250	287	8.0	30.5	180	107	54
E [6]	286	327	3				
F [1]	308	358	4.5	14.5	149	103	59
G [1]	320	360	1.5	4.0	142	43	59.5

[1] Austenitized at 1,650° F. for 1 hour, oil quenched, refrigerated at −106° F. for 1 hour, double tempered at 600° F. for 2 hours each temper.
[2] Austenitized at 1,650° F. for 1 hour, oil quenched, double tempered at 600° F. for 2 hours each temper.
[3] Austenitized at 1,650° F. for 1 hour, air quenched, refrigerated at −106° F. for 1 hour, double tempered at 600° F. for 2 hours each temper.
[4] Austenitized at 1,700° F. for 1 hour, air quenched, refrigerated at −106° F. for 1 hour, double tempered at 600° F. for 2 hours each temper.
[5] Austenitized at 1,700° F. for 1 hour, air quenched, double tempered at 600° F. for 2 hours each temper.
[6] Austenitized at 1,700° F., oil quenched, refrigerated at −100° F. for 8 hours, tempered at 700° F. for 1 hour.
[7] Heated to 1,450° F. for 2 hours, cooled at 50° F. per hour to 1,000° F., air cooled to room temperature.

The results shown in Table II indicate that the shock resisting tool steel within this invention displays an excellent combination of high strength, ductility, toughness and hardness. The use of refrigeration treatment is recommended, if indeed not necessary, to attain yield strength of 280,000 p.s.i. and above. This is reflected by the data in respect to Steel 1² (refrigeration not employed). Steels 4 through 7 reflect the decrease in notch tensile strength resulting from increasing the silicon level from 2.55% to about 3.8%. Alloys 1 to 7 can be annealed to a hardness below about Rc 35 to enable machining prior to hardening by slowly cooling to about room temperature after hot working, reheating to about 1450° F., slowly cooling to about 1000° F. and, thereafter, air cooling to room temperature. When heat treated in this manner, Steel 2, as shown in Table II, had a hardness of Rc 27.

Shock resisting tool steels of the present invention are suitable for use in a wide variety of applications. They are particularly adaptable for use as shear blades for cutting heavy metal sections such, for example, as nickel cathodes, if refrigerated prior to tempering. The steels of this invention can be commercially prepared by conventional methods for making tool steels.

As will be readily understood by those skilled in the art, the term, "balance" when used to indicate the amounts of iron in the alloy steels, does not exclude the presence of other elements commonly present as incidental elements, e.g., deoxidizing and cleaning elements, and impurities ordinarily associated therewith, in small amounts which do not adversely affect the basic characteristics of the steels.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

What is claimed is:

1. A steel consisting of about 0.40% to 0.50% carbon, about 0.2% to 0.8% maganese, about 2.3% to 3.8% silicon, about 2.4% to 3.8% nickel, about 0.25% to 1.8% chromium, about 0.3% to 0.7% molybdenum, provided that the molybdenum content is at least 0.4% when the chromium content is less than 0.5%, about 0.07% to 0.3% vanadium, the balance consisting essentially of iron.

2. A steel in accordance with claim **1** which contains at least 0.5% chromium and up to 0.15% aluminum.

3. A steel according to claim **1** wherein the steel contains about 0.42% to 0.49% carbon, about 0.3% to 0.5% maganese, about 2.35% to 2.7% silicon, about 2.8% to 3.6% nickel, about 0.8% to 1.7% chromium, about 0.35% to 0.6% molybdenum, and about 0.1% to 0.2% vanadium.

4. A steel according to claim **3** wherein the steel contains about 0.45% carbon, about 0.35% manganese, about

2.5% silicon, about 3.5% nickel, about 1.4% chromium, about 0.35% molybdenum, about 0.1% vanadium, about 0.05% aluminum, and the balance essentially iron.

5. A shock resisting steel according to claim **1** having at least about 280,000 p.s.i. yield strength, at least about 325,000 p.s.i. ultimate strength, at least about 5% elongation, a Charpy C-notch toughness of at least about 90 foot-pounds, at least about 190,000 p.s.i. notch tensile strength, and at least a hardness of about Rc 57 after austenitizing at about 1600° F. to 1700° F. for about 1 hour liquid, quenching, refriegrating below minus 100° F., and tempering at least once at about 600° F. for about 2 hours.

6. A shock resisting steel shearing blade in accordance with claim **5**.

7. A steel in accordance with claim **5** which contains 0.5% chromium and up to 0.15% aluminum.

8. A steel in accordance with claim **5** containing about 0.42% to 0.49% carbon, about 0.3% to 0.5% manganese, about 2.35% to 2.7% silicon, about 2.8% to 3.6% nickel, about 0.8% to 1.7% chromium, about 0.35% to 0.6% molybdenum, and about 0.1% to 0.2% vanadium.

9. A steel in accordance with claim **8** wherein the steel contains about 0.45% carbon, about 0.35% manganese, about 2.5% silicon, about 3.5% nickel, about 1.4% chromium, about 0.35% molybdenum, about 0.1% vanadium, about 0.05% aluminum, and the balance iron.

References Cited

UNITED STATES PATENTS

2,327,490	8/1943	Bagsar	75—128.9 X
2,339,368	1/1944	Bagsar	75—128.9
2,791,500	5/1957	Foley	75—124
3,027,253	3/1962	Yeo	75—128.9

HYLAND BIZOT, Primary Examiner

U.S. Cl. X.R.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,489,552 Dated January 13, 1970

Inventor(s) John Lyons Hurley

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Table II, delete the following data:

"A^1	285	328	9.0	38.0	263	183	57.0"

and substitute therefor

--B^4	306	358	4.5	14.0	161	60	59.4--

SIGNED AND SEALED
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(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents