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ALLOY AND PROCESS

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The present invention has reference to steel-like alloys, and the processes of making and treating same. The object of the invention is the production of novel alloys having excellent physical properties, in an economical manner, and further objects include the process of producing and refining and of heat treating the said alloys and articles composed of same.

The alloys can be considered as being of two types, namely (*a*) what I term "semi-alloy steel," which is high in carbon and silicon, and (*b*) what I term "alloy steel," which is low in carbon and silicon. The said alloys also contain manganese and molybdenum. These alloys may also contain only trace quantities of boron, added during the manufacture of the alloys. Heretofore alloys of this general type have usually had chromium or nickel or both added, and in the prior art it was generally considered that the chromium or nickel or both were needed to give a good alloying of some of the other metals. I find that the use of these metals can be wholly omitted. The said metals, chromium and nickel are not only highly expensive, but they produce certain undesirable properties in the alloys. That these two expensive metals could be omitted, and the properties of the alloys improved, was not obvious from the prior art. Chromium is particularly objectionable since it imparts "surface embrittlement" to the alloys. Also without the chromium and nickel, the heat treatment of the alloys can be conducted at higher temperatures and longer heat treating times, than when these (Cr and Ni) are present, and improved physical properties in the heat treated alloys can be secured thereby.

Preferably I also omit the addition of aluminum, vanadium, titanium, columbium, beryllium and alkali metals, all of which are expensive and would be injurious in my products.

The "semi-alloy steel," of the present case contains the following:

	Per cent
Carbon	2.25 to 3.25
Silicon	1.75 to 2.25
Manganese	0.60 to 0.75
Molybdenum	0.35 to 0.60

The balance is made up essentially of iron, together with such small amounts of impurities as are usually found present therein.

The semi-alloy steel can be prepared for example, by mixing together pig iron or cast iron of high total carbon and silicon contents, with ferromanganese and ferromolybdenum, in such amounts as to give the analysis above.

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Processing

To the solid mixture of components, a small amount, such as 0.02% to 0.04% of calcium boride can be added, e. g. before melting the mixture to form the alloy. Or the same amount of the boride can be added to the solid semi-alloy steel, which is to be melted by heating in a furnace. A better plan is to first melt the semi-alloy steel and to then add the said amount of calcium boride, preferably at the bottom of the batch, say while the molten metal is in a ladle or crucible. This acts as a deoxidizer but does not leave more than traces of boride in the molten alloy. The treatment imparts very useful properties thereto. When using these small amounts of the boride, usually not more than a minute trace (if any) of boron will be found in the steel after treatment and removal of the slag.

Also at the bottom of the mass of molten alloy, it is very advisable to add 0.04% to 0.06% of ferroboron. This latter (and the calcium boride also, if desired) is preferably first placed in a closed container, e. g. into a sheet iron box (e. g. a "tin" can), the cover being soldered shut. In making experimental batches, I have used empty tin tobacco cans, of the pocket size and also pound size, each attached to the end of a heavy copper wire. When this box is plunged to the bottom of the melted metal alloy in a ladle, the can melts, the can contents melt and the lower end of the copper wire melts and these of course dissolve in and react with the molten alloy, to purify and improve same.

The molten alloy can be cast in semi-steel and cast or forged into the desired shaped articles or cast as ingots and rolled or otherwise made into sheets, rods, rails, etc. in alloy steel.

Heat treatment

The shaped articles can then be given a heat treatment to improve and temper the same.

In this, the first step is to "normalize" the alloy, and consists in heating same to about 1600° F. to about 1700° F. for a period equal to seven hours for each inch in thickness of the shaped article. This can be done in a furnace, and it is not necessary to provide a special atmosphere of inert or reducing gas in said furnace, prior to this step.

Then the article is allowed to cool (preferably slowly) down to about 1200° F. to 1250° F. Depending on the size of the articles and the rate of cooling, the time for this step varies considerably.

Then the article is quenched in oil, by immersion, down to a temperature of about 400° F. to about 450° F.

Then the articles are reheated to about 800° F. to 900° F. for a period of about 2 hours for each inch of thickness.

The articles are then quenched, e. g. in water, or a water fog or are cooled by a blast of cold air down to a temperature of about 75° F. to 100° F.

Properties of product

The articles, made as above described, from the "semi-alloy steel" are found to have the following properties:

Tensile strength	pounds	70,000 to 80,000
Yield	do	40,000 to 50,000
Elongation	per cent	3 to 5
Reduction in area	do	1.5 to 3
Brinell hardness		550 to 600

I give the following example of the "alloy steel."

Composition

	Per cent
Carbon	.55 to .75
Silicon	.55 to .65
Manganese	.75 to 1.25
Molybdenum	.60 to .90

Chromium, nickel, aluminum, vanadium, absent. Balance, iron and such impurities as are commonly present in iron.

Preparation and processing

The alloy can be prepared by methods analogous to those given for the above "semi-alloy steel," or by adding low carbon, low silicon iron to the semi-alloy steel, of the above stated composition.

This alloy steel can be purified and processed similarly to the above, but using about 0.03% to 0.06% of calcium boride and about 0.05% to 0.07% of ferroboron.

The alloy steel after casting etc. as above, preferably is subjected to a heat treatment, as follows:

For "normalizing" the steel is heated to about 1750° F. to 1850° F. for a period of about 2 to 3 hours for each inch of thicknes of the metal article.

The metal articles are then allowed to cool down to about 1550° F. to 1650° F. The articles are then quenched by dipping in oil, until the temperature of same has fallen to about 450° to 500° F.

Then the articles are reheated to about 900° F. to 1000° F. for about 1.5 hours for each one inch of thickness of said articles. Then the articles are quenched in water or fog of water particles, or cooled in air down to about 75° F. to 100° F.

It will be noted that in the processing of the alloy steel, somewhat more of the chemicals are used, and in the heat treatment of the alloy steel, the temperatures are somewhat higher, both as compared with the treatment of the semi-alloy steel.

The treated alloy steel is found to have the following physical properties:

Tensile strength (square inch)	pounds	190,000 to 230,000
Yield	do	170,000 to 200,000
Elongation	per cent	7.5 to 10
Reduction in area	do	8 to 9
Brinell hardness		425 to 525

Thus it is seen that the "alloy steel," after the heat treatment, is much strogner than the treated "semi-alloy steel."

Both alloys, treated as above, are highly abrasive resistant, highly shock resistant, and they are suitable for making high speed gears, grinding media, armour plates, grinding mills, drilling bits, and various other articles.

It will be noticed that the physical properties for semi-alloy steel are limited in ductility, that is the semi-alloy steel has a very high abrasion resistance which is measured by its hardness. The other physicals are much lower than those of the alloy steel. Its use is therefore indicated when high abrasion resistance is necessary and some shock resistance can be given up for the extra abrasion resistance obtained. Where some abrasion resistance can be sacrificed for additional shock resistance, the use of alloy steel is indicated as noted from the high physicals and the lower hardness obtained. The chemical constituents, the processing and the heat treatment in combination, are varied to the extent as given in order to attain the physical properties noted.

The indicated uses for semi-alloy steel are grinding media for use in the mining fields, paint production, cement, lime and asbestos field, inner shell wearing plates of grinding mills, in the grinding of talc and all hard ceramic materials. The indicated uses for the alloy steel are transmission chain, caterpillar treads, gears, especially high speed, pins, bushings, grinding rolls, grinding rings, tires for trunnions, pulleys. In enumerating these uses, I do not want to limit either the use of semi-alloy steel or alloy steel but I wish to use them for all applications where a high abrasion resistant steel is required in semi-alloy steel or a high shock resistant steel is required in alloy steel.

I claim:

1. A process of heat treating an iron alloy having the approximate composition in the range of:

	Per cent
Carbon	.5 to 3.25
Silicon	.55 to 2.25
Manganese	.60 to 1.25
Molybdenum	.35 to .9

the balance consisting essentially of iron and usual impurities, and formed by adding a deoxidizer and introducing solid ferroboron into the bottom of a melt thereof in quantity of 0.04 to 0.07%, to convert said iron alloy to a product of high shock and abrasion resistant character, comprising heating the iron alloy to a normalizing temperature in the range of about 1600 to 1850° F., cooling the normalized iron alloy to an intermediate temperature in the range of about 1200 to 1650° F., quenching in oil to the range of 400 to 550° F., reheating the iron alloy to an intermediate temperature in the range of about 800 to 1000° F. and finally quenching to a temperature below about 100° F.

2. A process of heat treating an iron alloy having the approximate composition in the range of:

	Per cent
Carbon	.5 to 3.25
Silicon	.55 to 2.25
Manganese	.60 to 1.25
Molybdenum	.35 to .9

the balance consisting essentially of iron and usual impurities, and formed by adding a deoxidizer comprising calcium boride in proportion of 0.02% to 0.06% to a melt thereof and intro-

ducing into the bottom of the melt ferro-boron in proportion of .04 to .07%, to convert said iron alloy to a product of high shock and abrasion-resistant character, comprising heating the iron alloy to a normalizing temperature in the range of about 1600 to 1850° F., cooling the normalized iron alloy to an intermediate temperature in the range of about 1200 to 1650° F., quenching in oil to the range of about 400 to 550° F., re-heating the steel to an intermediate temperature in the range of about 800 to 1000° F. and finally quenching to a temperature below about 100° F.

3. A process of heat treating an iron alloy having the approximate composition in the range of:

	Percent
Carbon	0.55 to 0.75
Silicon	0.55 to 0.65
Manganese	0.75 to 1.25
Molybdenum	0.6 to 0.9

the balance consisting essentially of iron and usual impurities, and formed by adding to the melt thereof about 0.03 to .06 percent of calcium boride and by introducing ferro-boron into the bottom of a melt thereof in quantity of about .05 to .07 percent to convert said steel to a product of high shock and abrasion resistant character, comprising heating the iron alloy to a normalizing temperature in the range of about 1750 to 1850° F., cooling the normalized iron alloy to an intermediate temperature in the range of about 1550 to 1650° F., quenching in oil to lower the temperature to the range of about 450 to 550° F., re-heating the iron alloy to an intermediate temperature of about 900 to 1000° F. and finally quenching to a temperature below about 100° F.

4. A process of treating an iron alloy having the approximate composition in the range of:

	Percent
Carbon	2.75 to 3.25
Silicon	1.75 to 2.25
Manganese	.60 to .75
Molybdenum	.35 to .6

the balance consisting essentially of iron and usual impurities, and formed by introducing a solid non-oxidized compound of boron into the bottom of a melt thereof in quantity of .02 to .1%, to convert said iron alloy to a product of high shock and abrasion resistant character, comprising heating the iron alloy to a normalizing temperature in the range of about 1600° F. to 1700° F. for a period equivalent to about seven hours for each inch of iron alloy thickness, allowing the iron alloy to cool to a temperature in the range of about 1200° F. to 1250° F., quenching in oil to a temperature in the range of about 400° to 450° F., reheating the iron alloy to an intermediate temperature in the range of about 800° F. to 900° F. for a period of about two hours for each inch of iron alloy thickness and finally quenching to a temperature not substantially exceeding 100° F.

5. A process of heat treating an iron alloy having the approximate composition in the range of:

	Percent
Carbon	.55 to .75
Silicon	.55 to .65
Manganese	.75 to 1.25
Molybdenum	.60 to .9

the balance consisting essentially of iron and usual impurities, and formed by introducing a solid non-oxidized compound of boron into the bottom of a melt thereof in quantity of .03 to .13%, to convert such iron alloy to a product of high shock and abrasion resistant character, heating the iron alloy to a normalizing temperature in the range of about 1750° F. to 1850° F. for a period of about two to three hours for each inch of thickness of the iron alloy, cooling the same to about 1550° F. to about 1650° F., quenching in oil to lower the temperature to the range of about 450° F. to 550° F., reheating to the range of 900° F. to 1000° F. for a period of about one to two hours for each inch of thickness of the iron alloy and then quenching to a temperature below about 100° F.

6. An iron alloy product of high abrasion and shock resistant character having the approximate composition in the range of:

	Percent
Carbon	.5 to 3.25
Silicon	.55 to 2.25
Manganese	.60 to 1.25
Molybdenum	.35 to .9

the balance consisting essentially of iron and usual impurities, said iron alloy being formed by introducing a solid non-oxidized compound of boron into the bottom of the melt in quantity of .02 to .13%, heating the cold solidified melt to a normalizing temperature in the range of about 1600° to 1850° F., cooling the normalized iron alloy to an intermediate temperature within the range of about 1200 to 1650° F., quenching in oil to lower the temperature to the range of about 400 to 550° F., re-heating the iron alloy to an intermediate temperature in the range of about 800 to 1000° F. and finally quenching to below about 100° F.

7. An iron alloy product of high abrasion and shock resistant character having the approximate composition in the range of:

	Percent
Carbon	2.25 to 3.25
Silicon	1.75 to 2.25
Manganese	0.60 to 0.75
Molybdenum	0.35 to 0.60

the balance consisting essentially of iron and usual impurities, said iron alloy being formed by introducing a solid non-oxidized compound of boron into the bottom of the melt in quantity of .02 to .1%, heating the cold solidified melt to a normalizing temperature in the range of about 1600 to 1700° F., cooling the normalized iron alloy to an intermediate temperature in the range of about 1200 to 1250° F., quenching in oil to a temperature in the range of about 400 to 450° F., re-heating the iron alloy to an intermediate temperature in the range of about 800 to 900° F., and finally quenching to below about 100° F.

8. An iron alloy product of high abrasion and shock resistant character having the approximate composition in the range of:

	Percent
Carbon	0.55 to 0.75
Silicon	0.55 to 0.65
Manganese	0.75 to 1.25
Molybdenum	0.6 to 0.9

the balance consisting essentially of iron and usual impurities, said iron alloy being formed by introducing a solid non-oxidized compound of boron into the bottom of the melt in quantity of .03 to .13%, heating the cold solidified melt to a normalizing temperature in the range of about 1750 to 1850° F., cooling the normalized iron alloy to an intermediate temperature in the range of about 1550 to 1650° F., quenching in

oil to lower the temperature to the range of about 450 to 550° F., re-heating the iron alloy to an intermediate temperature in the range of about 900 to 1000° F., and finally quenching to below about 100° F.

9. A process of heat treating an iron alloy having the approximate composition in the range of:

	Percent
Carbon	.5 to 3.25
Silicon	.55 to 2.25
Manganese	.60 to 1.25
Molybdenum	.35 to .9

the balance consisting essentially of iron and usual impurities, formed by introducing a solid non-oxidized compound of boron into the bottom of a melt thereof in proportion of .02 to .13%, comprising heating the iron alloy to a normalizing temperature in the range of about 1600° to 1850° F. for a period of two to about seven hours for each inch of thickness of the iron alloy, cooling the same from a higher normalizing temperature to the range of about 1200° to 1650° F., quenching in oil to lower the temperature to the

range of about 400–500° F., reheating to the range of 800–1000° F. for a period of about 1–2 hours for each inch of thickness of the iron alloy, and then quenching to a temperature below about 100° F.

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