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PHOSPHORUS TITANIUM STEEL

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2 Claims. (Cl. 75—125)

This invention relates to a new and useful iron alloy or steel. More particularly, it relates to such a steel containing carbon, phosphorus, titanium, manganese, silicon and copper.

For structural steels that must be exposed to the weather in service it is well recognized that a high yield point in tension and good resistance to corrosion are of primary importance. A reasonable amount of ductility as insurance against failure under slight overloading or suddenly applied loads is also desirable. It is well known that a certain amount of phosphorus in the steel contributes to these desirable qualities and can be used safely if the carbon content is not too high. However, for steels which are fabricated by welding, the property of maintaining toughness when rapidly cooled from high temperatures, or absence of air-hardening, also becomes of great importance. Many of the low-alloy high-strength steels, which are now in use and which rely on phosphorus as a strengthening and anti-corrosion agent, are not specially desirable for welded structures because they are apt to crack, harden and lose too much ductility when rapidly cooled in air from the welding temperature.

These difficulties can be overcome by providing a new alloy steel containing carbon, phosphorus, titanium, silicon, manganese and copper in certain well defined and limited percentages.

As in the case of many alloys, greater tolerance is permitted in the case of some of these alloying elements than with others. Thus the quantity of carbon should be most strictly limited, followed by phosphorus, titanium, silicon, manganese and copper in order of importance. If the carbon is allowed to drop too low, the strength of the resulting steel will be impaired. If it is allowed to rise too high, the steel becomes much too brittle when rapidly cooled from high temperatures, as in welding. With low phosphorus, the steel will not be sufficiently anti-corrosive; with high phosphorus, the steel becomes brittle as with high carbon. Low amounts of titanium can be permitted only if the carbon and phosphorus are also low, while excessive amounts of titanium should be avoided from the standpoint of expense. High silicon tends to make the steel brittle. High copper causes precipitation hardening on slow cooling, and creates difficulty in maintaining smooth surfaces in rolling.

In accordance with this invention the broad and preferred quantities of these alloying elements are as follows:

	Broad	Perferred
	Percent	*Percent*
Carbon	0.06 to 0.12	0.08 to 0.11
Phosphorus	0.08 to 0.20	0.10 to 0.16
Titanium	0.20 to 0.70	0.40 to 0.60
Silicon	0.10 to 0.30	0.15 to 0.25
Manganese	0.30 to 1.50	0.85 to 1.25
Copper	0 to 1.20	0.45 to 0.60

Most of the balance of the alloy is iron, but small amounts of chromium, nickel, molybdenum, vanadium, zirconium and/or columbium, and perhaps also other elements, may be incorporated without detracting from the desirable characteristics of the present alloy. Some of these elements, such as chromium, may in fact enhance these characteristics slightly, but any improvement attained does not usually justify the expense of these elements.

The present alloy is characterized by its resistance to corrosion, a high yield point of at least 50,000 pounds when cooled in still air (normalized) from 1650° F., high tensile strength, high ductility and high resistance to impact, with an Izod impact value of at least 20 when quenched in water from 2000° F.

The following Table I illustrates various alloys according to this invention. In each case substantially the balance of the alloy is iron.

Table I

Example	C	P	Ti	Si	Mn	Cu
1	.100	.145	.585	.16	1.34	.07
2	.092	.147	.57	.21	.87	.58
3	.102	.147	.54	.18	.33	1.01
4	.092	.142	.48	.20	1.22	.44
5	.088	.128	.42	.24	1.12	.5
6	.070	.12	.315	.15	.99	.5
7	.080	.080	.442	.22	1.11	.5
8	.080	.083	.315	.19	1.15	.53

In the following Table II, some of the physical characteristics of these alloys are indicated:

Table II

Example No.	Normalized at 1,650° F.			
	Yield point	Tensile strength	Brinell hardness	Impact value
1	51,300	69,700	144	143
2	51,900	71,000	141	136
3	52,600	71,000	138	144
4	57,000	76,500	149	148
5	55,800	70,700	143	150
6	59,900	71,300	149	163
7	53,500	68,900	143	148
8	57,000	71,600	143	152

Example No.	Yield point	Quenched in water from 2,000° F.			
		Tensile strength	Reduction of area	Brinell hardness	Impact value
			Percent		
1	82,100	102,000	61.5	232	52
2	89,200	111,400	60.2	238	41
3	89,900	107,200	64.5	241	41
4	100,300	123,000	55.0	302	64
5	103,700	121,300	59.0	285	80
6	112,600	125,200	58.0	285	50
7	101,900	112,300	65.9	265	80
8	116,400	127,500	61.3	302	64

The yield point and tensile strength are given in pounds per square inch, and the impact value is the Izod impact resistance in foot-pounds.

The inferior nature of alloys resulting when some of the alloy constituents fall outside the ranges indicated are shown from similar tests made on such alloys. For example, an alloy containing 0.094% carbon, 0.15% phosphorus, 0.45% titanium, 0.50% silicon, 0.88% manganese, and 0.47% copper, with the remainder iron, showed an impact value of only 5 when quenched in water from 2000° F., showing the effect of high silicon. An alloy containing 0.095% carbon, 0.791% phosphorus, 0.60% titanium, 0.21% silicon, and 0.38% manganese, with the remainder iron, shows the effect of high phosphorus. A sample of this alloy, when quenched in water from 2000° F., was so brittle that it broke in machining prior to testing. The effect of low titanium is shown by an alloy containing 0.07% carbon, 0.127% phosphorus, 0.218% titanium, 0.18% silicon, 1.09% manganese, and 0.52% copper, with the remainder iron. When quenched in water from 2000° F., this alloy had an impact value of only 11. Finally, the effect of too high carbon is shown in the following Table III:

Table III

C	P	Ti	Si	Mn	Impact value
.134	.10	.555	.16	.40	18
.124	.15	.585	.22	.40	5
.124	.20	.57	.15	.40	4

As with the other alloys discussed, the remainder is substantially iron.

As is well known in steel making practice, titanium and carbon combine to form titanium carbide (TiC), and in this respect titanium is similar to zirconium, columbium and vanadium. However, titanium is cheaper and more readily available than these metals. In addition, titanium has a marked effect on the phosphorus in the alloy, in particular reducing the tendency of the latter to make the steel brittle. The titanium may be added to the steel in the form of low-carbon or medium-carbon ferro-titanium. The latter, being less expensive, is preferred whenever the carbon content of the steel will not be unduly raised by its addition.

By the practice of the present invention structural steels of high yield point and good weldability may be obtained. They may be quenched in water from high temperatures without great increase in hardness or loss in resistance to impact. They have excellent resistance to corrosion.

As many variations are possible within the scope of this invention, it is not intended to be limited except as defined by the appended claims. It is understood, for example, that the present invention contemplates the addition of small amounts of chromium, nickel, molybdenum, vanadium, zirconium and/or columbium, where such additions do not change the fundamental characteristics of the alloy.

I claim:

1. An iron-base alloy or steel consisting of 0.06% to 0.12% carbon, 0.08% to 0.2% phosphorus, 0.2% to 0.7% titanium, 0.1% to 0.3% silicon, 0.3% to 1.5% manganese, an appreciable amount up to 1.2% copper, and the balance iron, characterized by its resistance to corrosion, a yield point of at least 50,000 pounds per square inch when normalized at 1650° F., high tensile strength, high ductility, and an Izod impact resistance value of at least 20 foot-pounds when quenched in water from 2000° F.

2. An iron-base alloy or steel consisting of 0.08% to 0.11% carbon, 0.1% to 0.15% phosphorus, 0.4% to 0.6% titanium, 0.15% to 0.25% silicon, 0.85% to 1.25% manganese, 0.45% to 0.6% copper, and the balance iron, characterized by its resistance to corrosion, a yield point of at least 50,000 pounds per square inch when normalized at 1650° F., high tensile strength, high ductility, and an Izod impact resistance value of at least 20 foot-pounds when quench in water from 2000° F.

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