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ALLOY STEEL

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7 Claims. (Cl. 75—123)

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This invention relates to alloy steels and more particularly to low alloy, high tensile strength steels adapted for manufacture of plates suitable for welding by commercial methods.

An object of the invention is the provision of a low alloy, high tensile strength steel particularly adapted to be welded by commercial processes without undesirable hardening in the zone of the weld.

A further object of the invention is the provision of such an alloy steel wherein a specific combination of alloying elements can be varied within definite ranges to provide proper weldability and strength for varying thicknesses of plate.

The foregoing objects are achieved in the present invention by the provision of a new and useful combination of alloying elements which together with iron are combined to give an alloy steel having the desirable tensile properties, toughness and ductility common to present day low alloy or mild alloy steels together with improved welding characteristics.

High tensile alloy steels intended for welded plate fabrication have heretofore been subject to serious shortcomings. When a plate of steel is welded by gas, metallic or carbon arc, or electrical resistance methods, a zone called the heat affected zone, next to the fused weld metal, is heated to temperatures ranging from the lower critical point up to the melting range of the alloy. After the welding operation, as this zone cools, the steel therein may under certain conditions become excessively hard, even to the extent of acquiring cracks which are sometimes referred to as underbead cracks. The hardening tendency in the heat affected zone is aggravated when the carbon content of the alloy is increased or certain alloying elements are added to raise the strength of the steel.

In the past, it has been necessary for the steel industry to adopt one or more costly and laborious expedients to avoid excessive hardening and cracking during welding operations. One such expedient is to restrict the carbon content of the steel to less than about 0.12 per cent. The actual percentage of certain widely used alloy steels fabricated into plate is about 0.09 to 0.11 per cent. When the carbon content is restricted in this manner, it is necessary to add relatively large and costly amounts of alloying elements to provide strength in the ultimate composition.

Present commercial high tensile steels intended for welding contain relatively large amounts of manganese, chromium, nickel, copper, and phosphorus. Manganese and chromium are potent hardening elements, particularly when individually present in amounts largely in excess of .75 per cent, and both elements impart proportionately much greater increases in hardenability than in strength. Nickel is costly and strategic. Large amounts of copper cause red shortness and aging. According to practice of the prior art, it is necessary to add between 0.5 and 1.5 per cent copper to assist in obtaining the desired strength properties. As is well known, such additions of copper necessitate almost equally great additions of nickel in order to provide satisfactory hot working properties. Further, prior art practice frequently necessitates the addition of between 0.08 and 1.5 per cent phosphorus in order to take advantage of its potent strengthening effect.

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Certain high strength steels of the prior art are so hardenable in welding that it is necessary to preheat them, or to employ expensive austenitic chromium nickel alloy steel electrodes.

According to our invention, a low alloy steel is provided of high tensile properties and of suitable ductility and toughness without the hardenability common to the manganese steels of the prior art. Our steels contain between 0.12 and 0.20 per cent carbon and between 0.40 and 0.90 per cent manganese.

Whereas in the prior art, steels with .90 per cent manganese or less have not been satisfactory from the point of view of strength and yield point, we have discovered a combination of alloying elements which enables us to limit the manganese content to 0.90 per cent or below while at the same time obtaining the necessary physical properties.

Our invention obviates the necessity of adding any chromium in obtaining the desired properties and we prefer to keep chromium as low as possible and, in any case, not over 0.25 per cent of the steel.

In obtaining the benefits of the invention for the preparation of steel intended for plates of thickness up to ½ inch, it is unnecessary to employ nickel. However, nickel is frequently present as a residual element owing to its presence in steel scrap used in production of the final product. As a residual element, the amount of nickel present usually varies between a trace and 0.20 per cent. As an added alloying element, we have found that nickel has the property of imparting mild improvement in strength without critically increasing the hardenability of our steels. Thus, in the preparation of steels for the production of steel of thickness between ¾ of an inch and 2½

inches, we sometimes find it desirable to increase the tensile strength of the ultimate composition by the addition of nickel sufficient to raise the total nickel content to between 0.50 and 1.0 per cent. Such addition does not critically increase the hardening characteristics of the alloy in the heat affected zone of the weld.

In the practice of our invention, it is unnecessary to employ copper as an alloying ingredient unless relatively minor amounts are desired for improving the corrosion resistance of light sheets and plates. In no case do we find it necessary and desirable to add over 0.35 per cent copper. In the normal practice of our invention, our steels will contain only residual amounts of phosphorus common to acid or basic melting practice. We sometimes add small amounts of phosphorus to our high strength steel in order to take advantage of its strengthening effect, but in such event, the total phosphorus is maintained below a maximum of 0.08 per cent.

Our steels contain between 0.50 and 1.50 per cent silicon and in formulation of individual heats according to our invention we prefer to adjust the amount of manganese employed within the limits above stated in proportion to the amount of silicon. Thus, when 0.50 per cent of silicon is employed we use in the neighborhood of 0.40 per cent of manganese which is near the lower limit of the operable range of amounts, while, on the other hand, when higher percentages of silicon are employed, the amount of manganese is proportionately increased.

In our steels, improved welding properties are obtained by the addition of titanium in conjunction with another alloying element. The element used in conjunction with titanium can be molybdenum or vanadium or columbium or zirconium. The amount of titanium employed is between 0.03 and 0.20 per cent of the steel and the amount of the additional element used in conjunction therewith is between 0.10 and 0.45 per cent.

Thus, a steel prepared according to our invention will conform to the following analysis:

	Percentage
Carbon	0.12 to 0.20
Manganese	0.40 to 0.90
Silicon	0.50 to 1.50
Molybdenum or columbium or zirconium or vanadium	0.10 to 0.45
Titanium	0.03 to 0.20
Phosphorus	0.08 maximum
Sulphur	0.04 maximum
Nickel	Trace to 1.00
Copper	Trace to 0.35
Chromium	0.20 maximum

The remainder is iron containing impurities incidental to the commercial production of steel.

We have found that alloy steels within the foregoing ranges will provide a high tensile steel having yield strengths comparable to or superior to other high strength steels now used in the industry together with greatly reduced hardenability characteristics under the influence of welding. Thus, careful hardness measurements made with a Knoop or Vickers diamond indenter scarcely ever show a hardness in excess of 300 in the heat effected zone after welding. Likewise, steel formulated with the above alloying ingredients in the range of proportions stated exhibit freedom from underbead cracking even under severe welding conditions.

In order more particularly to define the nature

of our invention, we have discovered that a combination of carbon, manganese, and silicon within the above ranges together with a combination of titanium and another alloying element selected from the group consisting of molybdenum, zirconium, vanadium and columbium provides a novel combination of high strength and improved weldability in steel together with freedom from objectionable alloying elements. In practicing our invention, titanium is combined with one of the elements in the aforesaid group in a ratio of about 1 part titanium to between 3 and 8 parts of said element. Thus, the steel may contain, for example, 0.10 per cent vanadium and 0.03 per cent titanium, or as another example 0.05 per cent titanium may be combined with 0.18 per cent molybdenum, and a third example is the use of 0.04 per cent titanium with 0.12 per cent zirconium. In using columbium, we prefer to employ about 0.40 per cent in conjunction with 0.05 per cent titanium. We prefer that the amount of titanium plus the amount of one of the aforesaid four elements with which it is combined should be limited to a total of between 0.13 and 0.50 per cent of said steel.

It will be seen that alloy steels made in accordance with these principles readily provide considerably higher yield points together with improved weldability than is possible under the present art. For example, practically all the present commercially developed high strength steels are made to only 45,000 p. s. i. minimum in plates over one-half inch thick. Using our invention we have readily produced seven-eighths inch thick plates having yield points of 50,000 to 63,000 pounds per square inch. A steel prepared in these ranges had the following chemical analysis and physical properties:

Analysis

C	Mn	P	S	Si	Cr	Ni	Cu	Ti	V
.14	.68	.018	.027	.55	.10	.16	.17	.04	.11

Properties

Yield Point	Tensile Strength	Per Cent Elongation in 8 inches	Per Cent Red Area
49,700	71,200	26.7	58.2

A preferred composition for the production of one-half inch plate of improved welding characteristics is obtained from a heat corresponding to the following analysis:

	Percentage
Carbon	0.14
Manganese	0.65
Silicon	0.75
Molybdenum	0.18
Titanium	0.05
Phosphorus	0.06 maximum
Sulphur	0.04 maximum

For a more detailed presentation of the advantages of low weld hardenability coupled with high-tensile strength properties, reference is made to our article entitled: "Some observations on the welding of manganese steels," The Welding Journal Research Supplement, October, 1944.

Steels conforming to the analyses herein described and claimed exhibit Jominy curves very

similar to that shown for heat 421 in Fig. 7 of the reference article.

Having thus described our invention with the aid of illustrative examples, it is to be understood that our invention is not to be taken as limited thereto, the scope of the invention being defined by the appended claims wherein the particular ranges of amounts specified may be, of course, subject to slight variations without departing from the spirit of the invention.

We claim:

1. A low alloy, high tensile steel suitable for the production of plates having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, from a trace to 1.0 per cent nickel, from a trace to 0.35 per cent copper, 0.03 to 0.20 per cent titanium, 0.10 to 0.45 per cent of an element selected from the group consisting of molybdenum, zirconium, vanadium and columbium, the remainder being substantially all iron.

2. A low alloy, high tensile steel suitable for the production of plates having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, from a trace to 1.0 per cent nickel, from a trace to 0.35 per cent copper, titanium and an element selected from the group consisting of molybdenum, zirconium, vanadium and columbium, the ratio of the amount of titanium present to that of said element being between 1 to 3 and 1 to 8 and the total amount of titanium and said element being from 0.13 to 0.50 per cent of said steel, the remainder being substantially all iron.

3. A low alloy, high tensile steel suitable for the production of plates up to about one inch thick having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, 0.25 per cent maximum nickel, from a trace to 0.35 per cent copper, 0.03 to 0.20 per per cent titanium and 0.10 to 0.45 per cent of an element selected from the group consisting of molybdenum, zirconium, vanadium and columbium, the remainder being substantially all iron.

4. A low alloy, high tensile steel suitable for the production of plates from about ¾ inch thick to about 2½ inches thick having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, 0.50 to 1.0 per cent nickel, from a trace to 0.35 per cent copper, 0.03 to 0.20 per cent titanium and 0.10 to 0.45 per cent of an element selected from the group consisting of molybdenum, zirconium, vanadium and columbium, the remainder being substantially all iron.

5. A low alloy, high tensile steel suitable for production of plates having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.12 to 0.25 per cent molybdenum, 0.03 to 0.20 titanium, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, from a trace to 1.00 per cent nickel and from a trace to 0.35 per cent copper, the remainder being substantially all iron.

6. A low alloy, high tensile steel suitable for the production of plates having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.10 to 0.20 per cent zirconium, 0.03 to 0.20 per cent titanium, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, from a trace to 1.00 per cent nickel and from a trace to 0.35 per cent copper, the remainder being substantially all iron.

7. A low alloy, high tensile steel suitable for the production of plates having improved weldability, said steel containing 0.12 to 0.20 per cent carbon, 0.40 to 0.90 per cent manganese, 0.50 to 1.50 per cent silicon, 0.20 to 0.45 per cent columbium, 0.03 to 0.20 per cent titanium, 0.08 per cent maximum phosphorus, 0.04 per cent maximum sulphur, 0.20 per cent maximum chromium, from a trace to 1.00 per cent nickel and from a trace to 0.35 per cent copper, the remainder being substantially all iron.

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