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FERROUS ALLOY CONTAINING ALUMINUM CHROMIUM AND MANGANESE HAVING AN EMBEDDED CORE

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ATTOREYS
FERROUS ALLOY CONTAINING ALUMINUM CHROMIUM AND MANGANESE HAVING AN EMBEDDED CORE

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6 Claims

ABSTRACT OF THE DISCLOSURE

An alloy steel having anti-gas cutting and anti-gas drilling properties and being especially useful as the basic material of construction in burglar-proof safes, said alloy steel consisting essentially of 0.35—0.60 C, less than about 1% Si, 5—16% Mn, 16—20% Cr, 1.0—2.0% Al, 0.1—0.4% N, up to 3.0% Ni, less than 0.07% P and less than 0.03% S impurities, and the balance being iron.

This invention relates to a ferrous alloy having anti-drilling and anti-gas cutting properties, and a burglar-proof material for a safe having anti-arc cutting property by using the said alloy in combination with some other materials.

Recently, a safe is increasingly broken with a gas torch, a drill and the like. So that the present invention is to obtain an alloy steel for a safe resistable against burglary break with a gas torch or a drill, and is also to produce a burglar-proof material for safe having anti-arc property in using the said alloy in combination with some other materials.

From FIG. 1 to FIG. 3 are typical examples of microphotographs of alloy steels which were obtained early in the research and experimental works.

FIGS. 4 and 5 are the micro-photographs of alloy steel according to the present invention.

FIG. 6 is the perspective view of test piece to test the alloy steel according to the present invention.

FIG. 7 is the partly enlarged plan view of a safe door of steel plate lined with the alloy steel according to the present invention.

FIG. 8 is a cash box cast of the alloy steel according to the present invention.

FIG. 9 is a section of protective plate having a core plate of graphite or copper cast in the alloy steel according to the present invention.

A group of FIG. 10 shows the test results obtained from the burglar-proof plate of alloy steel having a core plate of graphite.

A group of FIG. 11 shows the test results obtained from the burglar-proof plate of alloy steel having a core plate of copper.

Details concerning the FIGS. 10 and 11 groups will be explained later.

To achieve the object of this invention, at the beginning, an experimental work was started with a normalized alloy steel ("A" alloy steel) of 13% chrome molybdenum having 3% vanadium and tungsten.

For further improvement of anti-gas cutting property, aluminum was added to the "A" alloy steel because aluminum has strong antioxidation property. Aluminum added to the alloy steel ("B" alloy steel) was progressively improved in its anti-gas cutting and anti-drilling properties as long as its aluminum contents do not exceed over 2%, but by increasing aluminum contents from 4 to 6%, its anti-gas cutting and anti-drilling properties were made rather low owing to the conversion of matrix from molybdenite-bainite into ferrite (as shown in photograph 1).

For further improvement, manganese more than 10% was added to the "B" alloy steel, and was quenched at the temperature higher than 1,000° C. Its structure was consisted of austenitic matrix, and its anti-gas cutting and anti-drilling properties have satisfied the stipulations of Nippon Bank Standard Specification. However, it has revealed a weakness susceptible to crack by heat shock (photograph 2).

Then next, carbide forming elements such as tungsten and vanadium were eliminated from the "B" alloy steel. The resultant alloy steel ("C" alloy steel) showed lower hardness but its anti-gas cutting and anti-drilling properties have almost been deteriorated. But owing to the carbide precipitation at the austenitic crystal boundaries, the "C" alloy steel still had a property susceptible to crack (photograph 3).

Then, carbon content of the alloy steel was lowered progressively and Cr content was raised up to 16%. This new alloy steel ("D" alloy steel) was made to have austenitic matrix containing large quantity of Cr in solid solution, while carbide, troostite and pearlite had precipitated at the crystal boundaries (photograph 4).

Precipitation of carbide and troostite at the crystal boundaries makes the metal liable to crack when the metal is heated partially for an extensive length of time with an oxyacetylene gas torch, while it can easily be drilled.

Then, 0.2% of nitrogen which is maximum soluble amount to the metal was added to stabilize austenite and in the meantime to prevent the above precipitation of troostite. Meanwhile to stabilize the austenite, manganese was increased to 12% or made it to 6% and added 2% Ni.

This new alloy ("E" alloy) steel has achieved the best performances of anti-gas cutting and anti-drilling behaviour as the material for safes (photographs 4 and 5).

Besides that, the latter has shown better weldability than the former alloy steel which is high in manganese content while it has no Ni.

Since the most of tests in here were conducted in accordance with the stipulations of Nippon Bank Standard Specification for the material of safe, it will be useful to describe its principal items. They are as follows:

SKH9 is a high speed tool steel chemically composed in weight percent as follows:

C, 0.75—0.90; Si, <0.35; Mn, <0.60; P, <0.030; S, <0.030; Cr, 3.50—4.50; Mo, 4.00—6.00; W, 6.00—7.00; V, 1.80—2.30; Cu, 0.25; Ni, 0.25.

And: HRC denotes Rockwell hardness measured by C scale of diamond top, angle 120° radius 0.3 mm., base load 10 kgs., test load 150 kgs.

Drilling and gas cutting tests for the protect plate of safe—

(1) Drilling test

Horizontally supported 30 mm. thick plate shall be tested under the following conditions:

Drill:

High speed tool steel, SKH9.

Diameter, 12 mm.

Toll angle, 118°.

Relief angle, 10°.

Drilling machine revolution, 500 r.p.m.

Drilling pressure, 50 kg. wt.

Drilling duration (to be continued for) 3 min.

The test result is shown by the drilled depth. The depth is measured by the cylindrical wall from the surface of
plate to the bottom of hole, except the conical surface of hole bottom. The depth of hole shall be less than 3 mm.

(2) Gas cutting test

Dimensions of test piece, 200 mm. x 200 mm. x 30 mm.
The test piece shall be supported vertically and its horizontal center line shall be held 1 meter high. The gas cutting torch shall be held at an angle of 45° from the perpendicular to the surface of test piece at the horizontal center line. The gas cutting torch shall be moved horizontally when the edge of the test piece began to melt.

Gas torch: Hand operating medium pressure oxyacetylene torch. Nozzle diameter, 3 mm.

Oxygen pressure: 6 kg./sq. cm. Purity of oxygen 99.5%.
(700 l., 150 kg./sq. cm., bomb shall be used.)

Pressure of acetylene: 0.4 kg./sq. cm.

Duration of heating: To be continued for 10 min.

Test result: As shown in FIG. 6, 6 shall be 50 mm. or less; c shall be 35 mm. or more. Melt shall not exceed 30 cc.

Chemical compositions, hardness and drilling resistances of alloy steels tested are as follows:

(1) An alloy steel shown in FIG. 1

Chemical composition (percent):
C, 1.28; Si, 0.99; Mn, 15.1; P, 0.047; S, 0.012; Cr, 15.7;
Mo, 1.67; V, 0.44; W, 2.56.

Hardness:
HRA, 36–39; Hs, 35–35.


Gas cutting test:
As shown in FIG. 6, a gas torch was applied at angle “A” to the 30 mm. thick test piece for 10 minutes, and the development of cut away is shown by dimensions (a) (b) (c) (d) (hereafter will be expressed in the same way).

\[
\begin{align*}
\text{a} &= 35 \text{ mm.} \\
\text{b} &= 35 \text{ mm.} \\
\text{c} &= 19 \text{ mm.} \\
\text{d} &= 12 \text{ mm.}
\end{align*}
\]

Volume of melt = 7.8 cc.
The disadvantage of alloy: Cracks developed during the gas cutting test.

(2) An alloy steel shown in FIG. 2

Chemical composition:
C, 0.85; Si, 0.95; Mn, 15.8; P, 0.040; S, 0.018; Cr, 15.8; Al, 0.95.

Hardness:
HRA, 31–34; Hs, 43–47.

Drilling test: Hardly drilled.

Gas cutting test:
\[
\begin{align*}
\text{a} &= 35 \text{ mm.} \\
\text{b} &= 40 \text{ mm.} \\
\text{c} &= 18 \text{ mm.} \\
\text{d} &= 9 \text{ mm.}
\end{align*}
\]

Volume of melt = 15.1 cc.
The disadvantage of alloy: Liable to crack during the test.

(3) An alloy steel shown in FIG. 3

Chemical composition:
C, 0.56; Si, 0.76; Mn, 11.6; P, 0.056; S, 0.010; Cr, 15.6;
Al, 1.28; N, 0.20.

Hardness:
HRA, 19–23; Hs, 36–40.

Drilling test:
Depth drilled as far as the drill tip. (Satisfied the N.B.S. specification.)

Gas cutting test:
\[
\begin{align*}
\text{a} &= 33 \text{ mm.} \\
\text{b} &= 36 \text{ mm.} \\
\text{c} &= 12 \text{ mm.} \\
\text{d} &= 7 \text{ mm.}
\end{align*}
\]

Volume of melt = 13.5 cc.
The above test result is still unsatisfactory.

(4) An alloy steel according to the present invention which is shown in FIG. 4

Chemical composition:
C, 0.66; Si, 1.05; Mn, 15.2; P, 0.058; S, 0.009; Cr, 16.1;
Al, 0.95; N, 0.20.

Physical properties:
Tensile strength, 58.0 kg./sq. mm.
Elongation, 10.5%.
Hardness, HRA, 20–23; Hs, 36–40.
Charpy impact test (notched), 2.1 kg.-m./sq. cm.

Drilling test, hardly drilled.
Gas cutting test:
\[
\begin{align*}
\text{a} &= 33 \text{ mm.} \\
\text{b} &= 35 \text{ mm.} \\
\text{c} &= 10 \text{ mm.} \\
\text{d} &= 4 \text{ mm.}
\end{align*}
\]

Volume of melt = 12.5 cc.
Obtained full satisfaction in all respects.

(5) An alloy steel according to the present invention which is shown in FIG. 5

C, 0.46; Si, 1.02; Mn, 6.38; P, 0.019; S, 0.017; Cr, 17.8;
Ni, 2.11; Al, 1.0; N, 0.3.

Physical properties:
Tensile strength, 70.5 kg./sq. mm.
Elongation, 12.2%.
Hardness, HRA, 18–21; Hs, 32–33.
Charpy impact test (notched), 2.8 kg.-m./sq. cm.
Drilling test, hardly drilled (satisfied the N.B.S. Spec.)
Gas cutting test:
\[
\begin{align*}
\text{a} &= 25 \text{ mm.} \\
\text{b} &= 30 \text{ mm.} \\
\text{c} &= 10 \text{ mm.} \\
\text{d} &= 4 \text{ mm.}
\end{align*}
\]

Volume of melt = 11.2 cc.
Obtained full satisfaction in all respects, and shown good weldability.

From the above test results, it is obvious that the final metal according to the present invention has the most superior quality. The alloy steel according to the present invention is generally usable as a burglar proof material after it was quenched from 1000°~1100° C. But it can be used in as cast condition, since it has austenitic matrix and resistant against cracking due to arc gouging if it is cast as thin as 30 mm. or thinner and contains nitrogen in the metal.

The alloy steel according to the present invention is stronger than normalized Cr, Mo tool steel, and it is not breakable with hammer. When it is heated with oxyacet-
ylene flame (flame temperature 2300° C.), aluminum together with Cr and Mn in the metal will be oxidized. Since the metal is covered with these oxidized products having very high melting points, the further oxidation of metal will be prevented. Accordingly, anti-gas cutting property of alloy steel according to this invention is far better than that of high manganese steel.

The alloy steel according to the present invention develops no crack even locally heated for a length of time less than 30 minutes because of its austenitic structure is stabilized by nitrogen contained in the metal, and it is unable to drill even with the drill of high speed steel. 18 Cr–8 Ni, and 25 Cr–12 Ni heat resisting steel can be drilled, but austenitic steel containing manganese higher than 5% is hard to drill because it has high work harden-

property.
FIG. 7 shows the inside of safe lined with the alloy steel according to the present invention in which (1) is the concrete wall of safe having entrance opening, and (2) is the other side concrete wall of the same safe. (3) is the door of safe made of steel plate lined with the alloy steel (4) according to the present invention and (4) is lined with concrete reinforced with asbestos and metal lath, so that the door (3) has strong anti-drilling and anti-gas cutting properties. (6) is the figure of the chamber for motor to operate the door, and (7) is the handle of the door.

In the above embodying example of present invention, the alloy steel according to the present invention was used only to the door plate, but the chamber of safe, of course, can be lined entirely with the alloy steel according to the present invention if so required.

FIG. 8 shows the cash box cast of the alloy steel according to the present invention, it is 677 mm. high, 860 mm. long, 530 mm. wide and 25 mm. thick.

For the protection of safe against burglary, the contents of chemical elements in the alloy steel shall be controlled as follows on account of the following reasons:

1. Carbon shall be 0.3% to 0.60%

Carbon content even exceeds 2% has almost no effect on the anti-gas cutting property, however, anti-drilling property is lowered when carbon content is lowered, and an adequate amount of carbon will be more than 0.35%.

In the alloy steel containing carbon more than 0.20%, its anti-drilling property is raised by the precipitated chromium carbide. If the alloy steel contains carbon more than 0.60%, it becomes liable to crack due to rapid heating or cooling because the precipitated chromium carbide develops by a continuous net work at the austenitic crystal boundaries and the toughness of alloy steel is deteriorated.

2. Manganese shall be 5.0% to 16.0%

Austenite in a high manganese steel is stabilized when the manganese coexist with 16% Cr. Such an alloy steel has strong anti-drilling property like that of high manganese steel. This shows that manganese is the principal element for an assurance of anti-drilling property of alloy steel and the manganese content 12% is the best for it. To stabilize austenite against heat, manganese content shall be more than 11% if Ni is not present, but the anti-drilling property can be assured with manganese at least as 5% coexist with 2% Ni. However, if it contains more than 16% manganese, the melting point of Cr oxide film is lowered by coexisting large amount of manganese oxide, so that manganese content in the alloy steel according to the present invention is confined at 16% in maximum.

3. Chromium shall be 16% to 20%

Cr does not act to lower the melting point of iron, meanwhile gas cutting of this alloy steel is made difficult because oxygen is hardly penetrated into the metal through the coating of compact chromium oxide film. Therefore, chromium is the principal element to give anti-gas cutting property to an alloy steel. However, chromium content shall be more than 16% in order to give sufficient anti-oxidation property to an alloy steel after compensating the deteriorating effect of manganese. Anti-gas cutting property is enhanced increasingly by the chromium contents, but 16% is the best while 20% is the maximum for the austenite structure.

Anti-drilling property and toughness are extremely lowered, if 30% of austenite structure decomposes to troostite and pearllite, and it will have no anti-drilling property if an alloy steel has manganese less than 10% and more than 20% Cr, and the structure consist wholly of s-ferrite.

4. Nickel shall be less than 3.0%

Capability of nickel to stabilize austenite is twice of the same as manganese, and anti-oxidation property of nickel is also better than manganese. It is desirable that some part of manganese may be replaced by nickel as far as it does not affect the work hardening property of alloy steel, because such an alloy steel has better toughness in as cast condition, and the best is to have 1-3% nickel for this purpose.

When nickel content exceeds 3% and the structure appears close to heat resisting steel, its hardness and work hardening property are lowered and anti-drilling property is divested.

By the same reason, 18-8 Cr, Ni, austenite heat resisting steel can be drilled very easily.

(5) Alumnium shall be less than 2.0% and preferably 0.1 to 0.4%

Aluminium is more powerful element to elevate the anti-oxidation property than Cr, and produces compact oxide film. During gas cutting operation, aluminium together with chromium produces Al2O3 rich thick oxide film, and heat of gas torch is intercepted and further oxidation of metal is prevented with this film. In this way, aluminium performs a very important function in assuring the anti-gas cutting property of alloy steel. But austenite of alloy steel will decompose into troostite and pearllite if the aluminium is contained over 2%, and its anti-drilling property is debased.

(6) Nitrogen shall be less than 0.4%

Nitrogen is the element to stabilize austenite of alloy steel the same as C, Mn and Ni, and it is used to stabilize austenite which is made unstable by Cr exceeding 18% in coexistence with Al. The nitrogen in the alloy steel is contained as nitride of metallic elements, and aluminium nitride decomposes into aluminium and nitrogen when the alloy steel is cut with gas, and both of them act as anti-gas cutting agent as it was already stated. 0.1% nitrogen is able to act actively as an austenite stabilizing agent, but it will make gas hole in a casting if the nitrogen content is made over 0.6%, and it is desirable to be around 0.4% or less.

To make safe protecting plate as a burglar proof, it is considered that it shall be anti-gas cutting and anti-drilling.

But it is presumable that a portable oxy-arc cutter may be developed and used for burglar proof in some future. The following is the entirely new material which will prevent such a burglar break of safe.

Since the temperature of arc is very high, almost no steel or alloy steel can resist against it.

However, a portable arc cutter for burglar purposes could not be very powerful, and the plate would be heated only locally. On the other hand, it is known that extremely good heat transmission material such as graphite or a pure copper is exceedingly resistable against are gouging when it has large area.

FIG. 9 shows an enclosed 10 mm. thick core of graphite or copper 12 which was cast in a protective plate (E) of alloy steel according to the present invention 11.

When graphite or copper plate has very large area, it shall be perforated with 10 mm. holes at 50 mm. distances, so that shielding alloy steel covering both side of core will be linked as one body through these holes, and they will never separate because the alloy steel according to the present invention has sufficient elongation. In the figure, 14 is supporting nail, 15 is a gate, 16 is a feeder, 17 is a sand mould.

The test result obtained in the test conducted on anti-arc cutting of the above (E) plate.

The conditions of test. (E) plate is held vertically, and 4 mm. diameter pole is held apart at 15 mm. It was test with electric current 30 v. 180 amp for 3 min.

FIG. 10 and FIG. 11 are the test results shown with photographs. The shielding metal is melted by shifting a pole but graphite or copper core is not affected in any noticeable extent.
Accordingly, a protective plate for safe in which graphite or copper core plate is cast in and encrusted with the alloy steel according to the present invention has the best anti-drilling and anti-gas cutting properties as the burglar proof material for safe.

FIG. 10b is a part of protective plate, a graphite core plate is cast in it and encrusted with the alloy steel according to the present invention, and shows the result of gas and arc cutting tests.

Fig. 10c is a projection view of pit denoted by (b) in Fig. 10a and developed in the arc gouging test.

In Fig. 10b, f=25 mm, g=30 mm, volume of melt was 5.3 cc. In Fig. 10c, 11 is the encrust alloy steel according to the present invention, 12 is a graphite core cast in 11, h=34 mm, i=10 mm, j=10 mm, k=25 mm, and the volume of melt was 9.7 cc.

Fig. 11a is a projection view of pit in Fig. 11c, 11 is the encrust alloy steel according to the present invention, and shows the result of gas and arc cutting tests.

Fig. 11b is a projection view of pit (b) in Fig. 11a, and developed in the arc gouging test.

In Fig. 11b, j=20 mm, k=25 mm, volume of melt was 40 cc.

In Fig. 11c, 11 is the encrust alloy steel according to the present invention, 12 is the copper plate cast in 11, h=40 mm, i=22 mm, j=10 mm, k=26 mm, the volume of melt was 9.7 cc.

As was stated in above, the alloy steel according to the present invention, without any troublesome heat treatment such as annealing, quenching and tempering, has sufficient anti-drilling and anti-gas cutting properties, and it will have anti-arc property when a graphite or copper core plate embedded in this alloy steel. In any respect, the alloy steel and the combined plate with some material according to the present invention are the best protective materials for safe of burglar proof.

Having described my invention, I claim:

1. A safe having door and walls which are cast with an alloy consisting essentially of by weight:

   C, 0.35-0.60%  
   Si, less than about 1%  
   Mn, 11-16.0%  
   Cr, 16-20%  
   Al, 1-2%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron.

2. A safe having door and walls which are cast with an alloy consisting essentially of by weight:

   C, 0.40-0.60%  
   Si, less than about 1%  
   Mn, 5-11%  
   Cr, 16-20%  
   Ni, 1.0-3.0%  
   Al, 1.0-2.0%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron.

3. A safe having a door and walls wherein the material comprises an alloy consisting essentially of:

   C, 0.35-0.60%  
   Si, less than about 1%  
   Mn, 11-16.0%  
   Cr, 16-20%  
   Al, 1-2%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron, said alloy being bonded in the cast condition to another metal.

4. A safe having a door and walls comprising an alloy consisting essentially of by weight:

   C, 0.40-0.60%  
   Si, less than about 1%  
   Mn, 5-11%  
   Cr, 16-20%  
   Ni, 1.0-3.0%  
   Al, 1.0-2.0%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron, said alloy being bonded in the cast condition to another metal.

5. An alloy steel having anti-gas cutting and anti-drilling properties consisting essentially of by weight:

   C, 0.35-0.60%  
   Si, less than about 1%  
   Mn, 11-16.0%  
   Cr, 16-20%  
   Al, 1-2%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron, said alloy steel having as a core or lined plate, a heat transmissible material selected from the group consisting of graphite or copper.

6. An alloy steel having anti-gas cutting and anti-drilling properties consisting essentially of by weight:

   C, 0.40-0.60%  
   Si, less than about 1%  
   Mn, 5-11%  
   Cr, 16-20%  
   Ni, 1.0-3.0%  
   Al, 1.0-2.0%  
   N, 0.1-0.4%  
   P, <0.07%  
   S, <0.03%  

   and the balance being essentially iron, said alloy steel having as a core or lined plate, a heat transmissible material selected from the group consisting of graphite or copper.

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H. BIZOT, Primary Examiner

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