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COPPER-CONTAINING STEEL

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8 Claims. (Cl. 148—31)

The invention relates to alloys which are composed mainly of iron and contain copper with small additions of other metals.

It is among the objects of the invention to provide steels which have relatively high strength and a high rate of carburization as compared to carbon steel, and which are capable of being age hardened.

The alloys may be considered generally as high copper, low carbon steels containing additions of manganese from about 0.5% to about 2.0%. Copper is present from about 2.0% to 3.0%. More than about 0.25% carbon produces brittleness. Carbon is commonly present in ferrous alloys but the smallest possible amounts of carbon may be present in these alloys. However, 0.05% carbon is mentioned as approximating the lower limit attained in commercially manufacturing the alloys, but less carbon may be present. Care should be taken in the preparation of the steel to avoid oxidation since iron oxide is an undesirable constituent in steel and has a tendency to produce hot shortness.

More than about 3.0% copper renders the steels practically useless for carburizing purposes. With 3.0% copper, the steel gives excellent carburized cases but with materially larger amounts, such as 3.4% copper, the carburized layer is too shallow for present commercial uses. As contents of 3.0% copper are approached, the steels have the best age hardening properties.

As compared to carbon steels, the alloys carburize rapidly and produce a sufficient hardness when at least 0.5% of manganese is present. More than 0.5% manganese to about 2.0% increased the rate of carburization and toughened the core of the carburized material. It was found that chromium in amounts up to 0.5% gave the optimum grain size of 2 to 4 as referred to the McQuaid and Ehn classification. It materially increased the speed of carburization and the depth of the case. The smaller amounts of manganese alone give at least as great a speed of carburization as that commonly found in carbon steels. Higher amounts of manganese increase the speed of reaction. The chromium appears to intensify the action of the manganese but with more than about 0.5% chromium, there is a loss of toughness in the core. The strongest cores are found when the larger amounts of manganese and chromium are present, and greater toughness is imparted by less manganese and chromium. The hardness of the cases developed by carburizing and heat treatment was about 63 to 65 Rockwell C which is about the hardness developed by carburizing and heat treating the best carbon steels.

By quenching from about 850° C. core strengths of about 200,000 pounds per square inch and good ductility are given especially with high manganese, carbon and chromium. The alloys are relatively easy to machine and forge in the unquenched condition.

After quenching, for example, to harden the case or otherwise cooling from a high temperature such as 850° C. so as to bring the copper into solid solution with the iron, the alloys may be age hardened by heating the machined, forged or carburized articles throughout for a short time to temperatures of about 400° C. to 500° C. and cooling in air. Larger articles require about 2 hours' heating while some small specimens show age hardening with a treatment of 10 minutes. The articles are not distorted but the strength is greatly increased by this heat treatment. For example, specimens of the alloy in the lower manganese range were carburized, quenched and age hardened. The age hardening increased the core strength from about 95,000 pounds per square inch in the quenched condition to about 135,000 pounds per square inch. The most pronounced age hardening is found in the alloys which contain less than about 1.0% manganese. In the age hardened condition, the structure consists of a copper-iron solid solution throughout which a copper or a copper rich phase is finely dispersed.

The alloys may be carburized at about 925° C. They take a case more readily than the carbon steels in that a case of 1 to 1.2 millimeters thick is commonly produced in less time than with carbon steels. There is a gradual change from the composition and hardness of the outer layers of the case to the alloy of the core and no abrupt change is produced when the alloys are carburized. The carburized cases have a normal hypereutectoid structure, with grain sizes of about 2 to 4 as referred to the McQuaid and Ehn classification.

The term, McQuaid and Ehn classification as used in the specification and claims refers to a standardized test for grain size. When applied the test is conducted by carburizing the alloy test piece for eight hours at 1700° F. The carburized layer is polished and etched to make the granular structure visible under the microscope. The image of the structure is magnified 100 times and for convenience the image may be projected upon a screen. The image is compared with a pattern which is ruled off in hexagons of known

areas. A grain size of 2 corresponds to the pattern which has 2 hexagons per square inch, a grain size of 4 corresponds to the pattern which has 8 hexagons per square inch, and a grain size of 1 corresponds to a pattern in which each hexagon is one square inch in area.

I claim:

1. A carburized alloy steel which, after carburization at 1700° F. for eight hours and slow cooling, has grains of such size that the average cross-sectional area of the grains in the carburized case is one-eighth to one-half ten-thousands of a square inch, composed of 2.0% to 3.0% copper, 0.5% to 2.0% manganese, and a small amount of carbon but not more than 0.25%, the balance being substantially all iron.

2. A carburized alloy having a core composed of about 2% to 3% copper, 0.5% to 2.0% manganese, and carbon, but not more than 0.25%, the balance being substantially all iron.

3. A carburized alloy having a core composed of about 2.0% to 3.0% copper, 0.5% to 2.0% manganese, carbon and chromium, but not more than 0.25% carbon and 0.5% chromium, the balance being substantially all iron.

4. A carburized alloy having a core and a case having a higher carbon content than the core, said core being composed of about 2.0% to 3.0% copper, 0.5% to 2.0% manganese, and carbon, but not more than 0.25%, the balance of the core being substantially all iron.

5. A carburized alloy having a core and a case having a higher carbon content than the core, said core being composed of about 2.0% to 3.0% copper, 0.5% to 2.0% manganese, carbon, but not more than 0.25% and chromium, but not more than 0.5%, the balance being substantially all iron.

6. A carburized alloy having a core containing copper between about 2.0% and 3.0%, manganese about 0.5% to 2.0%, and carbon between about 0.05% and a small material amount, such as about 0.1% in excess of 0.05%, the balance being substantially all iron.

7. A carburized, age-hardened alloy having a core composed of about 2.0% to 3.0% copper, 0.5% to 2.0% manganese, and carbon, but not more than 0.25%, the balance being substantially all iron.

8. A carburized, age-hardened alloy having a core composed of about 2.0% to 3.0% copper, about 0.5% to 1.0% manganese, and a small amount of carbon, but not more than 0.25%, the balance being substantially all iron.

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