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ALLOY STEEL FORGING DIE

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This invention relates to a thick-section cast forging die formed of tungsten-chromium steel and particularly to a die of this type containing a small amount of boron to both increase the hardenability of the die and allow lower than conventional austenitizing temperatures.

Chromium hot work die steels are commonly used today for large forging dies because they can be heat treated conveniently at relatively low temperatures, typically in the 1850° F. to 1900° F. range. However, tungsten-chromium hot work die steels possess considerably better wear or washout resistance due to their greater carbide content and superior resistance to tempering. Despite this fact, they currently are not being used for large forging dies because commercial equipment for heat treating such dies normally is limited to a maximum temperature of about 1850° F. or 1900° F. These relatively low temperatures are unsatisfactory for heat treating tungsten-chromium steel, tungsten high-speed tool steel and certain other high-alloy steels since these steels normally require an austenitizing temperature of about 1950° F. to 2300° F. It is considered necessary to austenitize large-section castings at these comparatively high temperatures for four to six hours in order to fully develop various properties of these steels, such as red hardness, temper resistance, hardenability, etc. For example, when a typical commercial tungsten-chromium hot work die steel is austenitized at a temperature of about 1900° F., it ordinarily is hardened to a depth of only about ¾-inch. This relatively thin layer of hardened steel is insufficient for large forging dies.

Therefore, a principal object of the present invention is to provide a thick-section forging die formed of highly wear-resistant tungsten-chromium steel which can be austenitized successfully at a temperature not in excess of about 1900° F. to produce a hardened layer of considerable depth. This and other objects of the invention are attained with a large, cast forging die formed of an alloy steel having a high tungsten content and containing a small amount of boron which simultaneously increases the hardenability of the die and reduces the required austenitizing temperature of the steel. A die of this type can be produced in a very large size and heat treated with equipment conventionally used today.

Tungsten is the most important element in the composition from the standpoint of the desired carbide content and hardenability of the die and, in general, the tungsten content of the new die may range from approximately 8% to 12%. However, for optimum results with respect to carbide formation and resultant washout resistance, the amount of tungsten should be maintained between about 8.5% and 10.5%. Chromium likewise increases the hardenability of the die and promotes the formation of carbide. It also improves the oxidation resistance of the steel at the operating temperatures of forging dies. Consequently, we prefer a chromium content of approximately 3% to 3.5% and have found that this element is beneficial in an amount as low as 2% and as high as 5%.

A forging die of such a tungsten-chromium steel should contain carbon, manganese and silicon, with vanadium preferably also being present. The carbon and manganese contents normally are about 0.25% to 0.4% and 0.1% to 0.6%, respectively, while the amount of silicon present typically can vary between approximately 0.1% and 1%. Vanadium in an amount between about 0.1% and 1% increases the hardenability of the die and also functions as a grain refiner. The hardenability of the new tungsten-chromium die steel appears to be further improved by the presence of molybdenum in a quantity not in excess of approximately 1%. A molybdenum content of about 0.2% to 0.6%, however, has been found to be desirable.

As indicated above, the presence of a small amount of boron is highly important to increase the hardenability of the steel and allow a reduced austenitizing or solution temperature. The amount of boron added need be only sufficient to lower the austenitizing temperature to approximately 1900° F. With steel forging dies containing the aforementioned amounts of tungsten it is necessary to use at least 0.0003% boron, and the boron content may be as high as about 0.004%. The larger amounts of boron tend to embrittle the steel to an excessive extent, however, and a boron range of about 0.0005% to 0.0025% is generally preferred.

Tungsten-chromium cast steels devoid of boron were compared with steels of similar composition containing the desired amount of this element to determine their relative hot hardness and impact resistance. For example, a steel having the following composition was evaluated and compared with the same steel to which have been added 0.0025% boron: 0.28% to 0.35% carbon, 0.15% to 0.40% manganese, 0.20% to 0.50% silicon, 3.00% to 3.50% chromium, 0.20% to 0.60% vanadium, molybdenum not in excess of 0.60%, 8.75% to 10.00% tungsten, phosphorus not in excess of 0.03%, sulphur not in excess of 0.03%, and the balance iron. Die specimens of each composition were solution treated at a temperature of 1900° F. for six hours and subsequently tempered three times at 1000° F. for eight hours each. The specimens were cooled below the M_f temperature of the steel between each temper. Other samples of the boron-free steel were austenitized at 2200° F. for six hours followed by the triple tempering at 1050° F. for a period of eight hours each temper.

When the boron-containing tungsten-chromium die steel was tested it was found to have a hot hardness comparable to that obtained with the boron-free tungsten-chromium die steel, but the former did not suffer the usual loss of impact resistance. Moreover, the steel specimens which did not contain boron were hardened to an average depth of only ¾-inch in 3¼-inch thick cast sections when austenitized at a temperature of 1900° F. for six hours. On the other hand, the cast dies containing 0.0025% boron were hardened completely through 6½-inch thick sections when heat treated in an identical manner.

The hot hardness of cast tungsten-chromium steel forging dies prepared in accordance with this invention is considerably greater than that obtained with a typical chromium hot work die steel. An example of the latter type commercially used toway is one composed of about 0.32% to 0.38% carbon, 0.20% to 0.50% manganese, 0.80% to 1.20% silicon, 4.75% to 5.50% chromium, vanadium not in excess of 0.50%, 1.30% to 1.80% molybdenum, 1.00% to 1.75% tungsten, phosphorus not in excess of 0.03%, sulphur not in excess of 0.03%, and the balance iron. Forging die specimens of this chromium steel composition were prepared and were solution treated at a temperature of 1850° F. for a period of six hours followed by tempering at 1050° F., 1100° F. and 1140° F. for eight hours each. These specimens were then subjected to a ten-minute hot hardness test (D.P.H.) at both 1000° F. and 1200° F. At the former temperature they exhibited an average hardness of 165 and had an average hardness reading of only 102 at 1200° F. When the above-described tungsten-chromium steel castings containing 0.0025% boron were tested in exactly the same manner, the average hot hardness readings at 1000° F. and 1200° F. were 339 and 246, respectively. The boron-containing tungsten-chromium steel also proved to have greater room-temperature hardness than the chromium steel and comparable impact resistance.

Thus it will be seen that a thick-section cast forging die formed of the tungsten-chromium steel described above in accordance with the present invention has improved hot hardness without a reduction in toughness as compared with chromium steel dies commercially used today in forging operations. Hot hardness of a large forging die is particularly significant since this property is indicative of superior washout resistance. Moreover, these desirable properties can be obtained by austenitizing with heat treat equipment conventionally used for large forging dies. In general, austenitizing for four to six hours is sufficient, depending on the size and shape of the dies; and 300-pound dies can be successfully heat treated in this period of time. As hereinbefore explained, the boron-free tungsten-chromium die steels require an excessively high austenitizing temperature to harden to the required depth and would necessitate the use of special heat treat furnaces.

While our invention has been described by means of certain specific examples, it is to be understood that its scope is not to be limited thereby except as defined by the following claims.

We claim:

1. A forging die which is characterized by the property of being hardened to a depth of at least three inches when austenitized at a temperature of 1900° F. for six hours, said die being formed of a steel consisting essentially of about 0.0003% to 0.004% boron, 8% to 12% tungsten, 2% to 5% chromium, 0.25% to 0.4% carbon, 0.1% to 0.6% manganese, 0.1% to 1% silicon, and the balance substantially all iron.

2. A large steel forging die which is characterized by the property of being hardened to a depth of at least three inches when austenitized at a temperature of 1900° F. for six hours, said die being cast from an alloy steel consisting essentially of about 0.0005% to 0.0025% boron, 8.5% to 10% tungsten, 3% to 3.5% chromium, 0.25% to 0.35% carbon, 0.15% to 0.40% manganese, 0.2% to 0.5% silicon, 0.1% to 1% vanadium, 0.2% to 0.6% molybdenum, phosphorus not in excess of 0.03%, sulphur not in excess of 0.03% and the balance substantially all iron.

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