Patented July 27, 1954

2,684,900

# UNITED STATES PATENT OFFICE

2,684,900

## INTERMEDIATE ALLOY AND PROCESS FOR FORMING WEAR-RESISTANT CAST IRON

Fred J. Webbere, Royal Oak, Mich., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

No Drawing. Application May 15, 1952, Serial No. 288,007

8 Claims. (Cl. 75—123)

1

This invention relates to ferrous base alloys and particularly to a ladle addition process for forming a highly wear-resistant cast iron.

As is well known in the art, the wear resistance of cast iron is substantially improved by the addition of small amounts of phosphorus and titanium. United States Patents Nos. 2,179,695 and 2,225,997, which issued November 4, 1939, and November 24, 1940, respectively, in the name of Walter E. Jominy, disclosed examples of this type of cast iron. Heretofore, however, the use of titanium in cast iron has been limited by the difficulty encountered in introducing the titanium into the melt because of the affinity of titanium for oxygen and nitrogen. Large quantities of slag are formed and a high percentage of the titanium is lost as a result of this affinity.

Prior to the present invention these alloying components were generally added separately in the form of ferro-titanium, silicon-titanium or ferro-phosphorus alloys. Inasmuch as these alloys are high melting point combinations of elements, they must be subjected to a relatively high temperature for a considerable period of time in order to place them in solution. Hence these hardening alloys necessarily are added directly to the furnace. Such a procedure usually results in a titanium recovery, for example, of approximately only 50%. On the other hand, when the above elements are combined in certain relatively low-melting intermediate alloys and added to the ladle in accordance with my invention, almost 100% of the titanium may be recovered because the phosphorus present in the intermediate alloy permits a rapid rate of solution which effectively precludes oxidation of the titanium.

It is therefore a principal object of my invention to provide an intermediate alloy containing titanium and phosphorus which can be added to cast iron to increase its wear resistance. A further object of my invention is to provide a method of adding a titanium-containing intermediate alloy to cast iron which will result in high titanium recoveries.

The final cast irons formed in accordance with my invention not only possess the resistance to scoring characteristic of cast iron, but also excellent properties of wear-resistance under severe operating conditions. These cast irons are especially adapted for such parts as cylinder liners, piston rings, pistons, valves, valve guides, tappets, bearings and other parts ordinarily subjected to wear.

The above and other objects are attained in accordance with my invention by a process in which a single intermediate alloy containing titanium and phosphorus is added to the ladle immediately prior to pouring molten cast iron. The presence of titanium, together with phosphorus, in my intermediate alloy improves the wear resistance of the resultant cast iron by beneficially modifying the phosphorus eutectic. More specifically, I have found that titanium losses into the slag may be greatly reduced and the wear resistance of the cast iron accordingly increased if an intermediate ferrous-base alloy containing titanium and phosphorus is added to the molten cast iron in the ladle immediately prior to casting. This ladle addition is possible because of the relatively low melting point of the alloy due to the percentage of phosphorus present.

2

For optimum wear resistance, moreover, I prefer to use a ferrous-base intermediate alloy which contains minor proportions of nickel as well as titanium and phosphorus. The increased wear resistance of the final cast iron is principally due to the presence of a hard network of a titanium-containing phosphorus eutectic. Regardless of the exact chemical composition of this hard phase, its presence is primarily responsible for the further increase in wear resistance. Hence the pesent invention provides a cast iron having physicial characteristics which satisfy all requirements of the aforementioned wearing parts.

Wear resistance, of course, is a function of both the size and distribution of the aforementioned hard network. Inasmuch as the size and distribution of the network are dependent on such factors as the metal viscosity, solidification rate and method of alloying, the preferred procedure for preparing cast iron in accordance with my invention provides a cast iron having maximum wear resistance with minimum attrition. Thus, I have found that superior results are obtained by introducing the phosphorus, nickel and titanium in the form of a solid phosphorus-nickel-titanium-iron intermediate alloy hardener.

An intermediate hardening alloy which I have found to be highly satisfactory is one comprising 3.5% to 18% titanium, 15% to 35% phosphorus and the balance substantially all iron. If nickel is substituted for a portion of the iron in this hardening alloy in an amount which is preferably approximately equal to the titanium content, the wear resistance of the resultant cast iron is further improved, as hereinbefore indicated. For example, an alloy consisting essentially of 3.5% to 18% titanium, 6% to 13% nickel, 15% to 35%

phosphorus and the balance substantially all iron provides the cast iron with outstanding wear-resistance properties. In order to obtain optimum results, however, I have found that the titanium content of the intermediate alloy should be maintained within a preferred range of 6% to 13% by weight of the intermediate alloy.

A very highly wear-resistant cast iron is produced when such a hardener is introduced as a ladle addition to a ferrous base metal which, for example, contains between 2.5% to 4% carbon, 1.5% to 3% silicon, 0.5% to 1% manganese, and 0.1% to 1% chromium. This cast iron may also initially contain small quantities of nickel and phosphorus, these elements frequently being present in amounts in the order of 0.05% to 0.1% and 0.05% to 0.25%, respectively. The intermediate alloy is preferably added in an amount sufficient to permit the aforementioned 3.5% to 18% titanium content to constitute between 0.05% and 0.35% of the final cast iron. Hence a 1% to 2% alloy addition has proved effective to accomplish this result.

Inasmuch as the quantity of the intermediate alloy employed is very small as compared with the amount of cast iron to which it is added, the percentages of the alloying constituents originally present in the cast iron remain substantially unaltered in the final alloy. Hence, a cast iron comprising approximately 2.5% to 4% carbon, 1.5% to 3% silicon, 0.5% to 1% manganese, 0.1% to 1% chromium, 0.05% to 0.35% titanium, 0.3% to 0.7% phosphorus and the balance substantially all iron possesses a high degree of wear resistance. If the aforementioned proportion of nickel is substituted for an equivalent amount of iron in the intermediate alloy, the resultant very highly wear-resistant cast iron preferably contains 0.1% to 0.45% nickel. As hereinbefore stated, excellent results are obtained with an intermediate alloy having a titanium content between 6% and 13%, and the use of this preferred hardener alloy composition results in a final cast iron which contains 0.08% to 0.15% titanium.

For particular purposes it may be desirable to include a small amount of vanadium in the cast iron and, if this is done, it should be included in the original ferrous metal melt in an amount between 0.05% to 0.15%. This vanadium content is approximately the same both before and after the hardening alloy addition because of the relatively small amount of the intermediate alloy required. It will be understood, of course, that the cast iron formed may also contain other incidental impurities such as sulfur, but for best results the sulfur content should not exceed approximately 0.2%.

As an example of a specific nickel-containing intermediate alloy which may be used in accordance with my improved process to provide a highly wear-resistant cast iron, one containing 9.1% titanium, 9.1% nickel, 20.4% phosphorus and the balance iron has proved to be highly satisfactory. This alloy is added in an amount calculated to yield approximately 0.15% titanium in a cast iron containing 3.2% carbon, 2.5% silicon, 0.75% manganese and 0.35% chromium. Approximately 0.1% vanadium may also be included in the original cast iron melt and provides a final casting which has good working properties as well as high wear resistance.

When the above-described intermediate alloy is added to the ladle containing the aforementioned ferrous metal immediately prior to the pouring operation, the resultant cast iron has



been found to be considerably more wear-resistant than the same ferrous metal to which the intermediate alloy has not been added. As an illustration of the improved physical properties of the former, wear test samples of the above-described cast iron formed in accordance with my invention and cast into sand-resin molds yield an average wear loss of between 0.012 gram and 0.016 gram when tested in a standard wear test machine. These wear losses indicate results which are superior to those obtained with the same initial cast iron to which my titanium-phosphorus-nickel-iron intermediate alloy has not been added. The latter cast iron shows wear losses which are between approximately two and three times as great as those obtained with my improved cast iron. For example, using the same wear testing procedures and equipment indicated above, the cast iron samples containing no titanium, phosphorus or nickel show an average wear loss between 0.035 and 0.06 gram.

The results of the above and other tests on cast irons prepared in accordance with my invention and containing as little as 0.05% titanium show that the above-described intermediate alloy imparts to cast iron a wear resistance superior to conventional cast irons which contain considerably more titanium in the final casting. An even greater amount of titanium must be initially added in these latter instances, moreover, because of the low titanium recoveries resulting from the separate addition of the alloying components. Hence, it should be noted that adding titanium, phosphorus and iron in the form of my complex alloy not only permits the ladle addition of titanium and thereby substantially increases the percentage of titanium recovered, but provides the cast iron with a wear resistance superior to that obtained by the separate addition of the alloying ingredients.

Except as otherwise indicated, the exact alloying procedure to be employed with reference to temperatures used and mechanical steps to be taken may be conventional in nature and, being well known in the art, requires no further explanation. However, inasmuch as it is desirable to cast the intermediate alloy in shapes which will dissolve most readily in the molten cast iron, I find it advantageous to form intermediate alloy castings having a high ratio of surface area to volume, such as crushed material having particle diameters of ¾ inch or less. It will be understood, of course, that this intermediate alloy can be added in other forms, but that the above procedure facilitates the alloying operation and results in maximum titanium recovery. Any suitable melting furnace may be used; and normal tapping temperatures may be employed, such as those between 2700° F. and 3000° F.

It also will be understood that, although my invention has been described my means of certain specific examples of cast irons and intermediate alloys for forming cast iron characterized by high wear resistance, the scope of my invention is not to be limited thereby except as defined in the appended claims.

I claim:

1. A method of forming a highly wear-resistant cast iron which comprises adding to the ladle immediately prior to pouring an intermediate alloy containing minor proportions of titanium and phosphorus.

2. A method of forming a highly wear-resistant cast iron which includes adding to a ladle containing cast iron immediately prior to pouring

operations an alloy comprising approximately 3.5% to 18% titanium, approximately 15% to 35% phosphorus, and the balance substantially all iron.

3. In the production of wear-resistant cast iron, the improvement which comprises the step of adding to a ladle containing iron and the usual iron alloying ingredients an intermediate alloy comprising about 3.5% to 18% titanium, about 6% to 13% nickel, about 15% to 35% phosphorus, and the balance substantially all iron.

4. A method of forming a highly wear-resistant cast iron which comprises adding to cast iron an intermediate alloy comprising approximately 3.5% to 18% titanium, 6% to 13% nickel, 15% to 35% phosphorus and the balance iron, said intermediate alloy being added to the ladle immediately prior to pouring operations in an amount constituting between 1% and 2% by weight of the final cast iron.

5. The method of producing a highly wear-resistant cast iron which includes melting in a furnace a mixture comprising approximately 2.5% to 4% carbon, 1.5% to 3% silicon, 0.5% to 1% manganese, 0.1% to 1% chromium and the balance substantially all iron, transferring said molten mixture to a ladle, subsequently adding to said ladle immediately prior to pouring operations an intermediate alloy in the solid state in an amount constituting between 1% and 2% by weight of the final cast iron, said intermediate alloy consisting essentially of 6% to 13% titanium, 6% to 13% nickel, 15% to 35% phosphorus and 39% to 73% iron, permitting said alloy to melt in said ladle, and thereafter casting the resultant molten mixture.

6. A composition of matter for addition to ferrous metals to provide high wear resistance thereto, said composition comprising approximately 3.5% to 18% by weight of titanium, approximately 15% to 35% by weight of phosprorus and the balance subsctantially all iron.

7. An intermediate alloy for addition to ferrous metals to provide high wear resistance thereto, said alloy comprising about 3.5% to 18% titanium, about 6% to 13% nickel, about 15% to 35% phosphorus, and the balance substantially all iron.

8. An intermediate alloy for ladle addition to molten cast iron immediately prior to pouring operations, said alloy consisting essentially of 6% to 13% titanium, 6% to 13% nickel, 15% to 35% phosphorus, and 39% to 73% iron.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 2,137,863 | Strauss | Nov. 22, 1938 |
| 2,169,193 | Comstock | Aug. 8, 1939 |