Patented Apr. 24, 1934 1,955,791

UNITED STATES PATENT OFFICE

1,955,791

HIGH-STRENGTH CAST IRON AND METHOD OF MAKING SAME

George F. Comstock, Niagara Falls, N. Y., assignor to The Titanium Alloy Manufacturing Company, New York, N. Y., a corporation of Maine

No Drawing. Application September 22, 1932, Serial No. 634,364

4 Claims. (Cl. 75—45)

My invention relates to the novel treatment of gray cast iron so as to strengthen same while producing by less costly methods a high-strength iron that may be readily and economically machined.

The objects of my invention are, among other things, to provide a novel and economical method of treating cast iron mixes used to produce high-strength gray cast iron, whereby increased transverse and tensile strength are obtained in the resulting product along with increased hardness, but such improved product remains easily machinable notwithstanding the increased hardness. In the production of castings according to my invention, I add titanium and chromium in suitable quantities to a molten iron mixture, the titanium being added in the form of fusible alloy of titanium, iron and silicon.

The addition of titanium to cast iron has been found to impart improved mechanical properties to the iron, due largely to a refining action on the graphite particles. It is also known that titanium, like silicon, does not harden iron by increasing the proportion of combined carbon, but on the contrary tends to counteract any chilling action by promoting the formation of graphite and ferrite. In the past, however it has been difficult to take advantage of the beneficial effects of titanium in cast iron because the common ferro-alloy of this element is of too high carbon content to be readily soluble in the iron at ordinary foundry temperatures, and the low-carbon titanium alloy available up to this time contains appreciable amounts of aluminum which is not desirable in cast iron.

Chromium in cast iron is known to have a strengthening effect, the increase in strength being in part a result of holding more of the carbon in the combined state. Therefore strengthening of cast iron by chromium is accompanied by a marked tendency to harden, which increases the difficulty of machining. Titanium additions to cast iron have also been found to strengthen the iron, but in an entirely different way, for titanium does not increase the proportion of combined carbon, but tends to promote graphitization. Strengthening of cast iron by titanium is due to a reduction in the size of the graphite particles. This results in some increase in hardness, but the machinability is not impaired as with chromium and may even be improved.

In commercial practice, chromium additions for strengthening cast iron are usually accompanied by nickel, which is a graphitizer and corrects the bad effect of chromium on machinability while preserving, when added in proper amount, the improvement in strength. My improvement consists in the use of titanium with chromium, whereby the strength of the chromium-bearing iron is not only maintained but also increased on account of the additional effect of titanium in refining the grain; at the same time the machinability is improved since the titanium counteracts the tendency of chromium to hold too much carbon in the combined form.

Hence my invention comprises a new method to improve cast iron by adding to it a small percentage of a low-melting alloy of titanium, iron, silicon, and carbon, the titanium and silicon contents of the alloy ranging from 15 to 25% each, with less than 1% each of carbon and aluminum, along with chromium. This titanium alloy dissolves readily in cast iron at ordinary foundry temperatures, and imparts all the benefits of titanium, such as refinement of the graphite particles and improved strength, without producing any of the undesirable effects of aluminum.

In cast iron containing 3 to 3.5% carbon and about 2% silicon, with other elements in normal amounts, it is sufficient to use 1% of this titanium alloy. Better results may be obtained however in iron of somewhat lower silicon, and using 2% of the titanium alloy. The amount of titanium varies with the amount of silicon in the iron. The alloy should be added, in a finely divided condition, to the molten iron as it flows from the cupola spout into a large ladle; or if the iron is melted in an electric furnace, the addition should be made in a ladle holding at least 150 pounds, and precautions should be taken to ensure thorough distribution of the alloy.

I have also discovered that it is particularly advantageous to use this titanium alloy with ferrochromium to produce a gray cast iron of fine grain and high strength, containing about 0.4% to 0.8% of chromium and about 0.10% to 0.15% of titanium. With this combination, chromium adds strength by its effect on the combined carbon; the titanium improves the strength still further by refining the graphite, and it also counteracts the hardening and chilling effect of the chromium so that good machinability is maintained in spite of the high strength. A more easily machinable high-strength iron is produced with chromium and titanium according to my methods than with other alloys, such as chromium and nickel, or molybdenum, and at a lower cost.

One method of making my improved high-strength cast iron may be set forth as follows:

The titanium is added in the form of a comparatively fusible alloy of titanium, iron, and silicon, containing 15 to 25% each of titanium and silicon, and 0.1 to 1% each of carbon and aluminum. This alloy is thoroughly mixed with the iron as it flows from the cupola, or in a ladle, by any well-known means such as stirring or pouring from one ladle into another.

Alloys previously available to introduce titanium into cast iron have either been difficultly fusi-

ble on account of high carbon content, or have contained to much aluminum which is not desirable in cast iron. The former is the well-known ferro-carbon-titanium with 6 to 9% carbon, and long experience has shown that except at abnormally high temperatures this alloy takes too long to dissolve in cast iron so that instead of the titanium being easily absorbed into the iron, it floats on the top of the bath forming an oxide slag and causes a waste without strengthening or other beneficial effects. The latter alloy containing 4 to 7% aluminum is likewise objectionable since aluminum in cast iron has a tendency to produce dirtiness and a tough skin on the molten metal, giving surface flaws and other defects as well as unsoundness in the castings.

The low-carbon and low-aluminum alloy which I use is free from these objections, and is readily fusible and has a cleaning effect without the formation of a tough skin on the melt. Usually one percent is sufficient for treating gray iron of 2 to 3% silicon content, but with under 1.8% to 1.5% silicon, 2% of the low-carbon ferrotitanium may be better.

Chromium is added in the same manner as I have described for the titanium, and any available alloy of iron and chromium may be used that is not of high aluminum content. The common ferrochromium containing 60 to 75% chromium and 4 to 8% carbon is suitable and enough should be added to give a chromium content of 0.4% to 0.8%, while the actual titanium content of the iron treated with the low-carbon and low-aluminum ferrotitanium alloy is generally between 0.075% and 0.15%. An analysis of the titanium alloy used showed the following composition:—17.7% titanium, 20.3% silicon, 60.6% iron, 0.3% aluminum, 0.2% carbon, 0.1% chromium, 0.1% phosphorus, 0.07% manganese.

As an example of the results obtained in comparative tests of iron treated according to my methods and the same iron untreated, the following tabulation is given: The iron was all taken from a single electric-furnace melt and contained about 2.1% silicon and 3.4% total carbon. All tests were made on bars cast about 1¼ in. in diameter and 15 in. long. The titanium-treated iron received in addition of 1% of the hereinbefore described low-carbon ferrotitanium the titanium content being raised from 0.05% in the untreated iron to 0.14%. The chromium-bearing samples contained about 0.6% chromium; the nickel-bearing iron contained 135%; and the molybdenum iron 0.46% molybdenum.

Table A

Kind of Iron	Transverse strength, pounds	Increase over untreated	Tensile strength lbs. per sq.inch	Increase over un. treated	Brinell hardness	Relative resistance to machining	
						Drilling	Turning
		Percent		*Percent*			
Untreated	4,450		33,820		187		
Titanium	4,673	5.0	35,660	5.4	196		
Chromium	4,823	8.4	36,520	8.0	202		
Cr-Ti	5,004	12.4	38,700	14.4	207	19.0	22.5
Cr-nickel	4,789	7.6	38,640	14.2	207	20.5	28.0
Molybdenum	5,093	14.4	38,960	15.2	202	20.5	27.0

It will be observed that there was some increase in strength (both transverse and tensile) by using titanium alone as well as with chromium alone, but that when both titanium and chromium were used together according to my invention the increase in strength was nearly equal to, or even greater than, the sum of the effects of the separate additions of these elements.

A further advantage is the reduced cost over the use of the higher priced nickel and molybdenum whereby the additions of titanium and chromium alloys work a desired economy in ordinary foundry practice.

The results I have obtained with titanium in cast iron may be summarized as follows: It has been found to decrease the size of the graphite flakes, and to promote graphitization and the formation of ferrite. The first effect strengthens the iron, but the latter effect may weaken it. Therefore in most irons of ordinary composition it is better to use a hardener, such as chromium, with titanium, if the maximum strength is desired. Chromium has been found to counteract the graphitizing effect of titanium, and also strengthens cast iron by making the pearlite more sorbitic; titanium counteracts the hardening or chilling effect of chromium, and also strengthens the iron by reducing the size of the graphite flakes. With the combination of titanium and chromium in cast iron, a more easily machinable as well as less costly high-strength cast iron has been made than by the use of other alloys such as chromium and nickel, or molybdenum.

I claim as my invention:—

1. In the method of making machinable high-strength gray cast iron, the step which consists in adding to the molten cast iron ferrochromium and a solid low-melting ferro-alloy containing 15% to 25% each of titanium and silicon, less than 1% each of carbon and aluminum, and the balance iron with slight impurities, and holding the molten charge until solution occurs to permit the chromium in solution in the melt to counteract the graphitizing effect of the titanium and the titanium in solution in the melt to counteract the hardening or chilling effect of the chromium, whereby the strength of the so treated iron after pouring and solidification is increased from 10 to 20% and its hardness is also increased with easy machinability.

2. In the method of making machinable high-strength gray cast iron, the step which consists in adding to the molten cast iron ferrochromium and a solid low-melting ferro-alloy containing 15% to 25% each of titanium and silicon, less than 1% each of carbon and aluminum, and the balance iron with slight impurities, and holding the molten charge until solution occurs to permit the chromium in solution in the melt to counteract the graphitizing effect of the titanium and the titanium in solution in the melt to counteract the hardening or chilling effect of the chromium, whereby the strength of the so treated iron after pouring and solidification is increased from 10 to 20% and its hardness is also increased with easy machinability, the amount of said ferro-alloy being about 1% to 2% of said molten iron.

3. The method of making machinable high-strength gray cast iron which comprises adding a solid ferro-chromium alloy containing 60 to 75% chromium, 4 to 8% carbon and the balance substantially iron, and a solid low-melting ferro-alloy containing 15 to 25% each of titanium and silicon, less than 1% each of carbon and aluminum and the balance substantially iron to the

molten cast iron, and then holding the molten mixture until solution occurs to permit the chromium in solution in the melt to counteract the graphitizing effect of the titanium and the titanium in solution in the melt to counteract the hardening or chilling effect of the chromium, whereby the strength of the so treated iron after pouring and solidification is increased from 10 to 20% and its hardness is also increased with easy machinability.

4. The method of making machinable high-strength gray cast iron which comprises adding a solid ferrochromium alloy containing 60 to 75% chromium, 4 to 8% carbon and the balance substantially iron, and a solid low-melting ferro-alloy containing 15 to 25% each of titanium and silicon, less than 1% each of carbon and aluminum and the balance substantially iron to the molten cast iron, and then holding the molten mixture until solution occurs to permit the chromium in solution in the melt to counteract the graphitizing effect of the titanium and the titanium in solution in the melt to counteract the hardening or chilling effect of the chromium, whereby the strength of the so treated iron after pouring and solidification is increased from 10 to 20% and its hardness is also increased with easy machinability, the amount of said ferro-alloy added being from about 1% to 2% of said molten iron.

GEORGE F. COMSTOCK.