Patented July 7, 1936

2,046,914

UNITED STATES PATENT OFFICE

2,046,914

HARD FERROUS-LINED TUBE

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No Drawing. Application May 17, 1935, Serial No. 21,963

7 Claims. (Cl. 29—182)

This invention relates to hard alloy lined metal products and has for its object the production of a new article of manufacture consisting of a preformed mild or tough steel or iron body lined on its working face with an integrally bonded layer of an extremely hard, low melting point boronized ferrous alloy, and preserving without impairment the original characteristics of the preformed steel or iron body. A particular product of the invention is in the form of pump and engine cylinders and working barrels and other hollow iron or steel bodies centrifugally lined on the inside with the hard ferrous alloy, and whereby engines and pumps so fitted, especially internal combustion engines and reciprocating oil well and slush pumps, will have many times the wearing qualities of the best steel and iron cylinders and working barrels heretofore generally used.

This case represents a continuation in part of our copending application filed under Serial No. 707,036 on January 17, 1934, it being drawn to the subject matter of the article claims thereof ordered divided by the Examiner, and is also a continuation in part of our copending application filed under Serial No. 741,996 on August 29, 1934, but is drawn with somewhat more complete specification, and a generally more restricted range of active ingredients in the alloy, and also combines in the product or article the advantages of the improved alloy of our companion case filed concurrently herewith under Serial No. 21,962, itself a continuation in part of our copending application filed under Serial No. 707,035 on January 17, 1934.

The lining of pipes, etc. with other metals such as tin, zinc and lead, and other soft metals, is old and well-known, but the integrally bonded lining of engine and pump cylinders with extremely hard alloys to resist great abrasive action, is not well known and has never come into use. Attempts have heretofore been made to line steel tubes with alloys such as Stellite and other hard alloys, but on account of the high melting point of such alloys such linings were difficult to apply properly and, besides, the very high cost of such hard alloys made their use practically impossible; and while the prior art shows that much experimental work has been done to determine the effect of boron on iron and steel, and it was known to impart hardness, yet the products of the earlier investigators in the art were never developed or applied in a manner to form an extremely hard, wear-resisting lining for steel tubes or cylinders, as the earlier products either were not of sufficient hardness, or were too brittle, or the melting point was never determined or was too close to that of a steel tube so as to have required special revolving molds or supporting means for the tube which would itself have become melted by the heat required.

Boron-treated steel and iron have heretofore generally been of low carbon content, or of low boron content, or both, so it may be said that a knowledge of the correct balance or range of permissible and desirable percentage additions of boron, carbon, iron, as well as nickel and other elements to yield a proper hard ferrous lining alloy did not exist, nor did there exist any appreciation of such an alloy's very low melting point and bonding properties together with other advantages in the lining of steel tubes or cylinders as used for pumps and engine cylinders and similar purposes, and it was through our experiments and the working out of the proper alloy that its application to the lining of steel and iron tubes and cylinders was discovered.

The success of our invention of providing steel or iron tubes with an integrally bonded lining of a ferrous alloy of substantially unmachinable hardness was therefore based on the working out of the relation of the constituents of the lining alloy itself, particularly the boron-carbon range, or the boron-carbon nickel range, as treated of more completely in our companion application Serial No. 21,962, as the present case refers more particularly to the new composite article or hard lined tube.

However, it may be here stated that the alloy which we use to form the lining of our hard lined tubes and cylinders is composed principally of iron containing carbon within the cast iron range—that is from about 2 to 4% by weight, boron ranging from about 0.2 to 2½% and in most cases nickel from about 1½% to 9%. Any other ingredients may be considered as adulterants insofar as our particular invention is concerned, though some other metals such as chromium, tungsten, manganese, vanadium, molybdenum, cobalt, etc., may be tolerated or used in the alloy in various amounts where the most favorable characteristics combined with the low cost of production of cylinders lined with our alloy are not paramount.

On the other hand some of the usual elements found in cast iron, such as sulphur and phosphorus, should preferably be excluded as far as practicable, or if present should not exceed about

0.1% for sulphur and 0.3% for phosphorus. In practical work we keep these elements each below 0.05%, as both have a deleterious effect on the hardnes and quality of the alloy. The same applies somewhat to silicon, except that this element may be present in amounts up to 1.5% without showing appreciable injury to the alloy, though about 2½% of silicon is about the maximum amount which could be tolerated and this with the higher percentages of boron, as otherwise graphitic carbon may be precipitated in the alloy and which is to be avoided. A highly satisfactory grade of the alloy for the purpose of forming our cylinder linings contains but about 1% of silicon. The carbon-boron range should be such as to not substantially exceed about 4½%of these combined ingredients, and in no case over 6%.

A ferrous alloy compounded of the ingredients named and within the ranges given has a melting point ranging from about 1950° to 2050° F., which is several hundred degrees F. below that of ordinary steel and iron pipes, tubes, and cylinders, yet has a hardness ranging from about 500 to over 1000 as measured by the Monotron Diamond Brinell scale, so that it is substantially unmachinable except by grinding. The alloy also exhibits a remarkable resistance to wear extending to ten times that of plain cast iron, and shows a thermal conductivity of less than a third the thermal conductivity of iron or steel. This latter quality contributes greatly to its value in a lined cylinder as of an internal combustion engine, as the exceptionally low thermal conductivity minimizes the expansion under heat and consequent distortion so that exceptionally fine clearances may be maintained.

Another feature contributing to the success of steel and iron tubes and cylinders lined with this alloy is its self-bonding qualities, as it will make a perfect bond with clean heated iron or steel bodies upon simply melting thereagainst without requiring a flux, though any of the usual fluxes may be used if desired where the surface to be lined is not properly cleaned.

The most useful range of ingredients of the alloy for the lining of tubes and cylinders is, by weight:

Carbon from about 2½ to 3½%
Boron from about 0.75 to 1½%
Nickel from about 2½ to 6%
Silicon not over 1½%
Sulphur not over 0.05%
Phosphorus not over 0.05%

Substantially the remainder of the alloy being iron.

If the nickel is left out there is a considerable reduction of hardness, though it still has great hardness suitable for many purposes. As previously suggested, other metals may be tolerated in small proportions but show no particular advantage. Aluminum should be kept out of the alloy as a small quantity of it causes an appreciable loss of hardness and therefore any use of ferro-boron made by the thermite process, which might contain appreciable amounts of aluminum as an ingredient of our alloy, should be avoided. Copper in the alloy in amounts much over 1% decreases the hardness.

The alloy may be made by variously bringing the elements together under the action of heat so as to fuse the same, and particularly by the process set out in our companion case before mentioned.

In forming the hard alloy linings in steel or iron tubes, or cylinders, we preferably crush thin clean slabs of our alloy to small pieces, introduce the desired amount of the broken pieces of the metal (depending on how thick a lining is desired) into the steel or iron tube or cylinder which has previously been thoroughly cleaned internally as by pickling or otherwise, close the end or ends of the cylinder with steel disks or plugs which may be forced in, welded, or otherwise secured in place, and one of which should have a very small central vent hole for escape of gases or heated air. In some cases a small quantity of sodium carbonate, sodium borate, calcium fluoride, etc., may also be introduced with the metal charge to pick up any non-metallics present, though if the cylinder is properly cleaned this will not be necessary. It is also desirable to introduce a small quantity of some volatilizable liquid which will form a non-oxidizing gas to drive out the contained air, methyl alcohol being very suitable for the purpose.

The closed cylinder is then gradually and evenly heated in a furnace while being slowly revolved, until just above the melting point of the charge, then the red hot cylinder is quickly withdrawn from the furnace and placed between horizontally disposed centers of a spinning lathe or supported and revolved on horizontal rolls, and in either case immediately revolved at a speed of about 2000 peripheral feet per minute for about half a minute, more or less, and at which time it will have lost enough heat by radiation to solidify the molten charge of ferrous alloy into a smooth even layer within the cylinder. After completely cooling, one or both ends of the cylinder may be cut open and the hard lining ground to exact dimensions desired, and of course the outside of the cylinder may be machined in any manner desired.

The hard linings thus produced may be very thin such as $\frac{1}{32}$nd of an inch in thickness or less, or extremely thick, depending on how much alloy was placed inside, and in any case they will be found to be integrally bonded with the metal of the tube or cylinder walls at all points so that sections of the lined article may be ruptured or broken away without separation of the lining layer. A particular feature of the invention is that the exact inner diameter of the lining may be so predetermined by the use of the correct weighed quantity of the charge placed in the cylinder, and the surface is perfectly round due to the spinning and so smooth due to the character of the ferrous alloy that very little grinding is required to bring the bore to exact dimensions, and the importance of which is very great, for an account of the excessive hardness of the linings any appreciable grinding required would make the cost of production prohibitive.

The hard-lined tubes are adaptable for use as engine and pump cylinders or working barrels, particularly of pumps handling liquids containing sand, also inserted sleeves in internal combustion engine cylinders, brake drums, sheet steel shells and all similar hollow articles subject to severe abrasive action, and under which condition these hard-lined tubes frequently show over a half dozen times the life of the unlined construction. Such tubes and cylinders of tough iron or steel lined with a layer of inseparable substantially unmachinable iron alloy are cheap to produce, and in most cases equal in wear resistance, and in some cases are superior in that respect to the high-priced alloys heretofore tried

out more or less experimentally, and are the only hard ferrous alloy lined steel or iron tubes or cylinders ever produced with a lining melted into place at a temperature several hundred degrees F. below the fusing point of the outer preformed tube or cylinder, so that all the physical qualities originally present in the outer shell remain substantially unimpaired. Therefore, although iron and steel with various percentages of boron incorporated therewith were previously known in the art, no knowledge of a ferrous alloy with boron having a substantially unmachinable hardness, yet possessing a melting point several hundred degrees F. below ordinary steel or iron tubes appears in the literature, nor any knowledge of the importance of the carbon and boron relation to control its hardness, nor the outstanding effect of nickel, nor was anything known of its extraordinarily low thermal conductivity and self-bonding qualities which contribute directly to the outstanding performance of industrial tubes and cylinders lined with it in the manner set out, and view of the commercial importance of our invention to industry heretofore depending on such alloys and metals as Stellite, tungsten, molybdenum, cobalt, chromium, and similar refractory and costly materials for linings if they were to be produced at all, we feel entitled to claim the invention broadly.

In our appended claims the words "integrally bonded" are to be taken to mean such a bond or union between the hard substantially unmachinable layer or lining and the tough steel or iron tube or cylinder as is effected by maintaining the molten lining metal in contact with the heated steel or iron tube or cylinder so as to fuse it thereto.

We therefore claim:

1. A new article of manufacture comprising a preformed body of tough steel or iron lined on one side with an integrally bonded layer of a hard substantially unmachinable ferrous alloy consisting principally of iron and containing by weight combined carbon ranging from about 2 to 4%, boron from about 0.2 to 2½%, silicon from a trace to about 2½%, sulphur from 0. to about 0.1% and phosphorus from 0. to about 0.3%, said alloy characterized by a hardness above 500 as measured by the Monotron Diamond Brinell scale, and a melting point substantially below that of said body.

2. A new article of manufacture comprising a preformed hollow tubular body of tough steel or iron lined on the inner side with an integrally bonded layer of a hard substantially unmachinable ferrous alloy consisting principally of iron and containing by weight combined carbon ranging from about 2 to 4%, boron from about 0.2 to 2½%, silicon from a trace to about 2½%, sulphur from 0. to about 0.1% and phosphorus from 0. to about 0.3%, said alloy characterized by a hardness above 500 as measured by the Monotron Diamond Brinell scale, and a melting point substantially below that of said body.

3. A new article of manufacture comprising a preformed tough steel or iron cylinder lined on the inside with an integrally bonded layer of hard substantially unmachinable ferrous alloy consisting principally of iron and containing by weight combined carbon in amount ranging from about 2 to 4%, and boron from about 0.2 to 2½%, the melting point of said alloy being below 2050° F. and several hundred degrees F. below that of the iron or steel cylinder and thereby preserving substantially unimpaired the original qualities of the cylinder metal, the lining further characterized by a hardness above 500 as measured by the Monotron Diamond Brinell scale.

4. A new article of manufacture comprising a preformed tough steel or iron cylinder lined on the inside with an integrally bonded layer of a hard substantially unmachinable ferrous alloy consisting principally of iron and containing by weight combined carbon in amount ranging from about 2 to 4%, boron from about 0.2 to 2½%, and nickel from about 1½ to 9%, the melting point of said alloy being below 2050° F. and several hundred degrees F. below that of the iron or steel cylinder and thereby preserving substantially unimpaired the original qualities of the cylinder metal, the lining further characterized by a hardness above 700 as measured by the Monotron Diamond Brinell scale.

5. A new article of manufacture comprising a preformed tough steel or iron cylinder lined on the inside with an integrally bonded layer of a hard substantially unmachinable ferrous alloy consisting principally of iron and containing by weight combined carbon in amount ranging from about 2½ to 3½%, boron from about 0.75 to 1½%, and nickel from about 2½ to 6%, the melting point of said alloy being below 2050° F. and several hundred degrees F. below that of the iron or steel cylinder and thereby preserving substantially unimpaired the original qualities of the cylinder metal, the lining further characterized by a hardness above 700 as measured by the Monotron Diamond Brinell scale.

6. A new article of manufacture comprising a preformed tough steel or iron cylinder lined on the inside with an integrally bonded layer of a hard substantially unmachinable ferrous alloy consisting principally of iron containing minor percentages of combined carbon, boron and nickel, said alloy being substantially free from graphitic carbon, and having a hardness exceeding 800 as measured by the Monotron Diamond Brinell scale, a melting point below 2100° Fahrenheit, and exhibiting a silvery white fracture.

7. An article of manufacture as set out in claim 1, plus an addition of nickel to the lining alloy ranging from about 1½ to 9%, and the lining showing a hardness above 700.

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