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UNITED STATES PATENT OFFICE.

HARRY E. WALTERS, OF PITTSBURGH, PENNSYLVANIA, ASSIGNOR TO UNITED ENGINEERING & FOUNDRY COMPANY, OF PITTSBURGH, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA.

CHILLED-IRON ROLL.

No Drawing. Application filed March 23, 1927. Serial No. 177,836.

This application is a continuation in part of my applications, Serial No. 100,715, filed April 8, 1926, and Serial No. 136,728, filed September 20, 1926.

The present invention relates to chilled iron rolls for use in rolling mills, and more particularly to chilled cast iron alloy rolls having unusual strength and toughness and a fine grained hard chill. The roll is made by casting in a chill mold, a charge of high carbon iron containing chromium and molybdenum, and having low limits of sulphur and phosphorus.

I have found that a small amount of molybdenum, when used in connection with chromium and the low limits of sulphur and phosphorus, produces a chilled cast iron roll of remarkably increased strength and having a tough close grained white iron primary chill which shades off gradually and without a distinct line of demarcation into a tough hard and wear-resisting secondary chill having a grain structure closely approximating that of the primary chill and having a depth greater than the sub-structure chill of the ordinary chilled roll.

The charge is usually made up of pig iron and scrap, together with the alloy additions, and is melted in a furnace, such as an air furnace, in which the charge is not in contact with coke, but may be made in open hearth, cupola or electric furnaces.

The character of the chill will depend somewhat upon the amount of chilling to which the metal is subjected in the casting mold. When cast in a heavy chill mold, such as employed in casting the usual chilled rolls, a white iron surface or primary chill is formed, which merges gradually into a hard secondary chill somewhat softer, however, than the white iron primary chill. When cast in a lighter chill mold, such, for example, as employed in making the so-called condensed grain rolls, the chilled surface of the roll will be grayer than the primary chill formed by casting in a heavy chill mold and will more closely resemble the secondary chill which is formed when the roll is cast in a heavy chill mold.

In all cases, however, the chill is of an unusually fine grain. It has a much greater toughness and resistance to spalling and fire cracking than that of the usual chilled iron rolls, and can be used in places where steel rolls have heretofore been required. The roll, nevertheless, is distinctly an iron roll, as distinguished from a high carbon steel roll or a so-called "Adamite" roll. The roll has the hard surface chill and the smooth close grained surface texture which are characteristic of an iron roll and which are demanded for finishing purposes, and which give much greater wear than a high carbon steel or Adamite roll.

The metal of my roll contains carbon preferably somewhat higher than that of the usual hot rolls and nearer the carbon content of cold rolls. The carbon may run from, say, about 2.75 to 4 per cent, preferably about 3.00 or 3.25 to 3.75 per cent. The silicon is that of the usual ranges for iron rolls, say, about .50 to 2.50 per cent, preferabove .75 per cent. The silicon will be varied in accordance with the usual foundry practice, depending upon the size of the casting and the character of the roll desired. In general, the higher the silicon, the softer the roll, and the lower the silicon, the harder the roll. The silicon should be sufficient so that the unchilled portions of the roll have a gray or mottled iron structure. The manganese is also that of the usual ranges of iron rolls, say, about .15 to 1.50 per cent, preferably about .20 to .50 or even .80 per cent. The phosphorus is kept much lower than usual in iron rolls and should not exceed about .20 per cent, preferably not over about .10 per cent, and for the best results should not be over about .06 per cent. The sulphur is preferably somewhat lower than the usual ranges in iron rolls. The sulphur should not exceed about .20 per cent, preferably not over about .15 per cent, and for the best results should not be over about .08 or .10 per cent. The phosphorus and sulphur are kept within the desired low limits by carefully selecting the pig iron and scrap used for the charge. The chromium may range from about .50 to 1.75 per cent, preferably from about .70 to 1.25 or even 1.50 per cent, and for best results should be about .90 to 1.25 per cent. The molybdenum may vary from about .05 to even 2.00 per cent. I have found that the best results, consistent with a minimum use of this expensive alloying metal, may be

obtained with molybdenum from about .15 to .80 per cent. There is apparently no particular advantage in using molybdenum over about .50 per cent, although the molybdenum may be increased without detriment except for increasing the cost of the roll.

The following are specific examples of analyses which have been used in making rolls, showing the percentages of the alloying metals and the metalloids:

A chilled roll of 31 inches diameter and 63 inches long for rolling sheet bar: C. 3.48; Si. 1.10; S. .041; P. .034; Mn. .36; Cr. 1.02; Mo. .25.

A chilled roll of 16 inches diameter and 22 inches long for rolling hot strip; C. 3.52; Si. 1.15; S. .034; P. .060; Mn. .31; Cr. 1.15; Mo. .25.

A chilled roll of 15 inches diameter and 20 inches long for rolling angles: C. 3.49; Si. 1.42; S. .045; P. .022; Mn. .34; Cr. 1.04; Mo. .26.

A chilled roll of 10 inches diameter and 20 inches long for rolling shapes: C. 3.38; Si. 1.39; S. .029; P. .014; Mn. .31; Cr. 1.00; Mo. .26.

A lighter chilled or so-called condensed grain roll of 24 inches diameter and 60 inches long for rolling rounds: C. 3.48; Si. 1.58; S. .042; P. .065; Mn. .36; Cr. 1.10; Mo. .25.

A lighter chilled or so-called condensed grain roll of 23 inches diameter and 51 inches long for rolling beams: C. 3.41; Si. 1.29; S. .051; P. .051; Mn. .36; Cr. 1.08; Mo. .264.

A lighter chilled or so-called condensed grain roll of 52 inches diameter and 8¼ inches long for rolling beams: C. 3.50; Si. 2.19; S. .041; P. .050; Mn. .42; Cr. .89; Mo. .244.

A lighter chilled or so-called condensed grain roll of 22 inches diameter and 62 inches long for rolling tubes: C. 3.48; Si. 1.22; S. .027; P. .050; Mn. .29; Cr. 1.03; Mo. .26.

While it is preferred to use a metal having the alloying constituents set forth above, it is possible to have present some quantities of other alloying metals. For example, nickel may be added to the mixture without any particular effect on the roll other than reducing the amount of clear chill unless the silicon is lowered to take care of the nickel addition. Other alloying metals may be used as toughenners or scavengers, such, for example, as vanadium.

I will now describe in greater detail the characteristics of the roll, first with particular reference to the chill formed when the roll is cast in a heavy chill mold. As is well known in the roll making art, in making a chilled roll, the wearing surface of the roll is cast against a heavy metal ring or cylinder which causes a rapid cooling of the metal and produces the well known chilled iron roll. The surface layer of the roll is of white iron in which the carbon is substantially all in the combined form and which is known as the primary chill. Beneath the primary chill of the usual iron roll there is a sub-structure commonly termed the mottled chill, which contains some free graphite in flake form. This sub-structure or mottled chill is of a rather coarse grain. It is hard and soft in spots, and is not suitable for a wearing surface. When turning down the usual iron roll, and especially in cutting the grooves in rolls for finishing shapes, the roll has to be discarded when the mottled chill is reached. The interior or core of the roll which is not subjected to the rapid cooling is of gray or mottled iron, the carbon being principally in the graphitic form.

My roll has a primary and secondary chill which are modified from and have characteristics which are distinctly different from and an improvement over the chills of the usual chilled iron roll. In the usual chilled iron roll there is a distinct line of demarcation between the primary and sub-structure or mottled chills. While in the usual roll the primary chill is of clear white iron, the sub-structure or mottle chill is distinctly mottled and is characterized by the presence in a white iron matrix of distinct and fair sized flakes or bands of graphitic carbon which are readily distinguishable to the naked eye.

In my chilled rolls there is no distinct line of demarcation between the primary and secondary chills, but the two chills merge together so that it is practically impossible to distinguish any boundary between them. The character of the iron gradually changes from the surface through the primary and secondary chills, appearing to the eye to be practically all white iron in both chills. Of course, in going from the surface to the core of the roll, the percentage of combined carbon gradually decreases and the percentage of free carbon increases, until at the inner part of the secondary chill and at the core, the metal is a gray or mottled iron. Any free carbon which may be precipitated in the chilled portions of my roll is precipitated in the form which is or resembles temper carbon, the carbon being in the form of microscopic nodules which are practically indistinguishable to the naked eye.

The primary chill is harder than that of the primary chill of the usual chilled rolls used for hot rolling. The hardness closely approaches that of the so-called cold rolls which are chilled rolls containing especially large amounts of carbon and sulphur to give an exceedingly hard surface for cold rolling. This hardness, however, is attained in cold rolls with a sacrifice of toughness and strength so that the iron cold rolls which have hertofore been made with such hard-

ness, have not been adapted for hot rolling in the usual rolling mill use. The primary chill of my rolls has a finer grain than the primary chill of the ordinary iron roll. It has a much greater strength and toughness than that of the usual iron roll. It is practically non-spalling and has a much better resistance to fire cracking than the chill of the usual iron roll. It has a remarkable resistance to abrasion under heat and the thermal changes to which the rolls are subjected in rolling hot metal. It also has a much greater resistance to shearing and crushing than the metal of the usual gray iron or chilled iron rolls, and this particularly adapts it for shape work where tongues or grooves are cut on the rolls. The improved wearing qualities are shown by the fact that my rolls are giving from two to four times the tonnage of the ordinary chilled rolls, before requiring redressing. The texture of the roll surface, however, is distinctly that of an iron roll and renders the roll particularly adapted for finishing purposes, although on account of their unusual strength, the rolls may be used for intermediate rolls or even roughing rolls where a close grain wear-resisting surface is desired.

I have found, particularly in the higher carbon ranges, that there is a small amount of what appears to be temper carbon in the primary chill. This is probably due to the rather higher carbon content which is used and which imparts a greater hardness than usual in the ordinary chilled iron rolls used in hot rolling. This carbon exists in the form of microscopic nodules so fine as to be individually indistinguishable to the naked eye, as contrasted with graphite which is precipitated in the form of flakes or bands. When examined under a microscope, the rounded nodules of what appears to be temper carbon may be distinguished, but when the surface is etched as with a 10 per cent solution of nitric acid and alcohol, such carbon is completely masked and invisible, the etched structure apparently consisting of but cementite and pearlite, or in other words, white cast iron. The same thing is true of what appears to be the temper carbon in the secondary chill. The closer grained tougher and stronger structure of the metal allows the carbon to be raised to a point above that usually permissible in hot rolls, and the presence of what appears to be temper carbon is apparently concommitant with the higher carbon ranges. Due, however, to its fine nodular form and to the fine grain of the metal, the carbon apparently does not soften or weaken the structure of the chill, as in the case of carbon precipitated as graphite in the usual chilled or mottled cast irons.

The secondary chill is practically a continuation of the primary chill and has, in general, the same type of grain structure. The secondary chill is of course characterized by more free carbon than the primary chill, since it is not subjected to as rapid a cooling. This carbon appears to be mostly temper carbon and exists in about the same form as in the primary chill, namely, in microscopic nodules which are individually practically indistinguishable to the naked eye, although they impart a slight grayish cast to the secondary chill, particularly toward the interior of the roll. The nodules are, however, more numerous and somewhat larger, as would be expected in going from the white iron primary chill toward the gray iron core. The carbon in the secondary chill is distinctly different from the carbon in the sub-structure or mottled chill of the ordinary chilled iron rolls in which the carbon exists as flakes or bands of graphite giving the characteristic mottling. While the grain structure of the secondary chill, and particularly its portions adjacent the primary chill, closely approaches the fineness of the primary chill grain structure, it is not quite as fine. However, the secondary chill grain structure is much finer than that of the usual mottled iron chill which forms the sub-structure of the usual primary chill. The closeness of the approach of the fineness of the grain structure of the secondary to the primary chill is shown by the fact that in cutting grooves through the primary chill into the secondary chill of my rolls, it is virtually impossible to distinguish with the eye the secondary from the primary chill. Other characteristics of the secondary chill closely approach those of the primary chill, being modified somewhat, of course, as would be expected by the slower rate of cooling of the metal. The secondary chill is somewhat stronger but not quite as hard as the primary chill. The hardness and wearing qualities of the secondary chill, however, sufficiently closely approach those of the primary chill so that the roll may be turned down in dressing into the secondary chill without destroying its usefulness, a thing which is impossible with the ordinary chilled iron rolls. Moreover, grooves may be cut in the roll through the primary and into the secondary chill. The bottoms of the grooves in the secondary chill will approximate the close grained texture and wearing qualities of the metal in the primary chill and the passes will not roughen up as is the case when the mottled chill is reached in the ordinary chilled roll. Therefore, while the roll may be used for plain work, it is particularly adapted for shape work due to the ability to form grooves in the roll through the primary chill and into its close textured secondary chill.

I have found that the hardness of the metal in the primary chill of my chilled rolls of the preferred carton content is

about 70 to 75 on the Shore scleroscope scale, while the secondary chill on the same roll shows about 60 to 70. These figures show that not only is the primary chill harder than that of the usual chilled roll for hot rolling, but the secondary chill is enormously harder than the sub-structure or mottled chill of the ordinary chilled roll.

When the metal is cast in a mold having less massive chilling rings, the chilling is of course less pronounced, so that the outer surface of the roll, instead of being practically pure white iron, is more like that of the secondary chill which underlies the primary chill when the roll is cast against a heavy chilling ring. Chilled rolls which are cast against the lighter chills are ordinarily known in the trade as condensed grain iron rolls. They are of course chilled rolls in that the metal is cast against a chill which results in a surface hardening, although the hardening is not carried to the full extent usual in the type of roll commonly known to the trade as a "chilled" roll. The term "chilled" cast iron rolls as used herein with reference to my rolls is intended to include the more lightly chilled or condensed grain rolls as well as the heavily chilled rolls. In the ordinary more lightly chilled or condensed grain roll, the metal in the surface layer is a mottled iron characterized by a rather finer mottling or grain than the more slowly cooled metal in the interior of the roll. When my roll metal is cast against a lighter chill mold such as employed for making condensed grain rolls, a grain structure or mottling is produced which is much finer than that of the usual condensed grain rolls. The carbon is much more uniformly distributed and is in a much finer condition, the result being that a gray iron condensed grain roll may be produced having a much closer grain, harder surface and one which will roughen much less in service than that of the usual condensed grain iron roll. In general, it may be stated that the chill of a condensed grain roll made from my metal has substantially the same characteristics as those of the secondary chill, as described above. The degree to which these characteristics are present may be considerably varied by the amount of chilling to which the metal is subjected, so that the condensed grain chill may vary in the degree of its characteristics from those of that part of the secondary chill which is next the primary chill to those of that part of the secondary chill which is next the core of a roll having a white iron primary chill.

The entire structure of my roll, including the core, as well as the chilled portions, has a much greater strength than that of the ordinary iron rolls, so that the average life of my rolls is much greater since they are practically unbreakable under rolling mill conditions in which iron rolls are used. This is of importance, because when a roll breaks the mill must be shut down and production stopped. The remarkable increased strength of my roll over the usual iron rolls is apparently due to the peculiar action of the small amount of molybdenum in conjunction with the fine grain imparted to the roll by the chilling operation on a metal containing the carbon, chromium, low phosphorus and low sulphur, as described herein.

While the extraordinary strong and tough fine grained roll structure, as above described, is apparently due to the combination of the molybdenum in the metal, a somewhat similar but weaker grain structure may apparently be produced under some conditions by chilling a high carbon chromium iron alloy having low phosphorus and sulphur limits. A roll having the alloying metal and the metalloid contents as described above but without molybdenum is a weaker and inferior roll, although its appearance may approach that of my preferred rolls. If the molybdenum be omitted, it is preferable that little, if any, nickel be present, because the presence of nickel necessitates cutting down silicon which makes the metal more difficult to cast and control. If molybdenum is present, a small amount of nickel is not particularly objectionable, since the molybdenum apparently helps in the control of the metal. If molybdenum is not present, the nickel should preferably be not over about .25 per cent.

While I have specifically described the preferred embodiment of my invention, it is to be understood that the invention is not limited to the herein described details, but may be otherwise embodied within the scope of the following claims.

I claim:

1. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.25 per cent, molybdenum about .15 to .50 per cent, phosphorus not over about .06 per cent, sulphur not over about .08 per cent, silicon about .75 to 2.50 per cent, and manganese about .20 to .80 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill.

2. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.50 per cent, molybdenum about .15 to .80 per cent, phosphorus not over .15 per cent, sulphur not over about .15 per cent, silicon about .50 to 2.50 per cent, and manganese about .15 to 1.50 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of de-

marcation between it and the primary chill and having a grain structure resembling that of the primary chill.

3. As a new article of manufacture, a chilled cast iron roll containing total carbon about 2.75 to 4.00 per cent, chromium about .50 to 1.75 per cent, molybdenum about .05 to 2.00 per cent, phosphorus not over about .15 per cent and sulphur not over about .15 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill.

4. As a new article of manufacture, a chilled cast iron roll containing total carbon about 2.75 to 4.00 per cent, chromium about .50 to 1.75 per cent, molybdenum about .05 to 2.00 per cent, phosphorus not over about .20 per cent, and sulphur not over about .20 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill.

5. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.25 per cent, molybdenum about .15 to .50 per cent, phosphorus not over about .06 per cent, sulphur not over about .08 per cent, silicon about .75 to 2.50 per cent, and manganese about .20 to .80 per cent.

6. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.50 per cent, molybdenum about .15 to .80 per cent, phosphorus not over about .15 per cent, sulphur not over about .15 per cent, silicon about .50 to 2.50 per cent, and manganese about .15 to 1.50 per cent.

7. As a new article of manufacture, an unannealed chilled cast iron roll containing total carbon about 2.75 to 4.00 per cent, chromium about .50 to 1.75 per cent, molybdenum about .15 to .80 per cent, phosphorus not over about .15 per cent, and sulphur not over about .15 per cent, together with sufficient silicon to produce a gray or mottled iron structure in the unchilled portions of the roll.

8. As a new article of manufacture, an unannealed chilled cast iron roll containing total carbon about 2.75 to 4.00 per cent, chromium about .50 to 1.75 per cent, molybdenum about .05 to 2.00 per cent, phosphorus not over about .20 per cent, and sulphur not over about .20 per cent, together with sufficient silicon to produce a gray or mottled iron structure in the unchilled portions of the roll.

9. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.25 per cent, phosphorus not over about .10 per cent, sulphur not over about .10 per cent, silicon about .50 to 2.50 per cent, manganese about .15 to 1.50 per cent, and nickel not over about .25 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill and a gray or mottled iron core underlying the secondary chill.

10. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.25 per cent, phosphorus not over about .10 per cent, sulphur not over about .10 per cent, silicon about .50 to 2.50 per cent, and manganese about .15 to 1.50 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill and a gray or mottled iron core underlying the secondary chill.

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HARRY E. WALTERS.

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6. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.50 per cent, molybdenum about .15 to .80 per cent, phosphorus not over about .15 per cent, sulphur not over about .15 per cent, silicon about .50 to 2.50 per cent, and manganese about .15 to 1.50 per cent.

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10. As a new article of manufacture, a chilled cast iron roll containing total carbon about 3.00 to 3.75 per cent, chromium about .70 to 1.25 per cent, phosphorus not over about .10 per cent, sulphur not over about .10 per cent, silicon about .50 to 2.50 per cent, and manganese about .15 to 1.50 per cent, and having a close grained white iron primary chill and a secondary chill having no distinct line of demarcation between it and the primary chill and having a grain structure resembling that of the primary chill and a gray or mottled iron core underlying the secondary chill.

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Certificate of Correction.

Patent No. 1,627,626. Granted May 10, 1927, to HARRY E. WALTERS.

It is hereby certified that error appears in the printed specification of the above-numbered patent requiring correction as follows: Page 1, line 72, for the word "prefer" read *preferably;* page 3, line 130, for the word "carton" read *carbon;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of June, A. D. 1927.

[L. S.]

M. J. MOORE,
Acting Commissioner of Patents.

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