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CAST IRON ROLL

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4 Claims. (Cl. 80—58)

This invention relates to cast iron rolls. It has to do particularly with chilled cast iron rolls suitable for hot and cold forming of strip, sheets, and other articles of ferrous and non-ferrous metals, although it is not necessarily limited to such uses.

This application is a division of my co-pending application Serial No. 206,021, for Alloy cast iron, filed May 4, 1938.

It is customary to employ chilled cast iron rolls in mills for fabricating metals. The chilled portions extend from the surfaces into the rolls for a depth sufficient to give reasonable life with repeated dressings but not so deep as to cause the rolls, as a whole, to be mechanically weak and brittle. For cold rolling of metal, rolls with hard chilled surfaces free from blemishes that take on a good polish and have good mechanical strength are required, while for hot rolling, the rolls may have a somewhat milder chill to more effectively withstand the heat.

The degree of polish on finishing rolls of the type in question and their resistance to roughening while in service are determined not only by the hardness but also by the fineness of grain in the chilled structure. Since the character of the finish on the articles produced by the use of these rolls depends largely on the surface finish on the rolls, both hardness and fineness of grain in the chilled surface are of paramount importance.

To resist roll breakage, the merging of the chill with the core of the roll should be gradual so that there is no distinct line of demarcation between the various zones. The core itself should be strong and tough.

In the prior art of making rolls of the type in question, considerable difficulty has been encountered in producing rolls with very hard, fine-grain chilled zones that grade gradually into strong, tough core materials without a distinct line of demarcation between the various zones. Efforts to raise the hardness of the chill by producing a martensitic matrix have resulted in the use of combinations of molybdenum-manganese, manganese-nickel, nickel-chromium-molybdenum, and nickel-chromium-molybdenum-manganese besides relatively high percentages of either manganese or nickel in the cast irons. As the chill on cast iron is composed essentially of 50 per cent carbide and 50 per cent matrix, the carbide having a Brinell hardness of about 800, the conversion of the matrix from relatively soft pearlite to very hard martensite has increased the hardness of the chill considerably. On alloying, as stated above, surface hardnesses of 675 Brinell have been obtained. The grain structure of the chill, however, is not essentially refined by the use of these combinations of alloying elements.

One of the objects of this invention is the provision of a chilled cast iron roll wherein the chilled zone possesses great hardness, strength and toughness and shades off gradually and without a distinct line of demarcation into a tough, wear-resistant secondary chill and core.

Another object of this invention is the provision of a cast iron roll whose chilled zone has a more refined grain structure than hitherto possible in the prior art so that it may be given a more highly polished surface of greater hardness and toughness than previously possible.

Still another object of this invention is the provision of a fine-grain chilled roll whose matrix is essentially martensite, martensite-sorbite, or austenite, or mixtures of these constituents.

Other objects and advantages of my invention will become apparent from the following description and claims.

I have found that copper in roll compositions having substantial amounts of manganese or manganese and molybdenum very materially aids in the retention of martensitic and austenitic matrices, refines the structure of the chill, and permits the chill to grade off into the core without showing a distinct line of demarcation between the various zones. The composition range in which the specified advantages were found is as follows:

Carbon 1.7 to 4.0 per cent, silicon 0.1 to 1.50 per cent, manganese 1.5 to 10 per cent, copper 1.00 to 5.0 per cent, molybdenum 0.1 to 2.0 per cent, sulphur 0.20 per cent maximum, phosphorus 0.50 per cent maximum, the remainder being chiefly iron which may have associated with it some chromium, nickel, and vanadium either singly or together but in amounts not exceeding a total of 4 per cent.

It is well known that carbon has little effect on the depth of chill, though high carbon contents give chills of greater hardness, and that silicon is the dominating element with respect to control of depth of chill, the chill depth varying inversely with the silicon content. The use of 1 to 5 per cent of copper requires some consideration of its effect on the depth of chill, as it is a mild graphitizing element and is capable of replacing part of the silicon in that capacity. The manganese and molybdenum are mild carbide-forming elements and counteract the graphitizing effect of the copper to some extent. The

depth of chill in various sizes of rolls made according to this invention may, therefore, be controlled by proportioning the silicon to the copper, manganese, and molybdenum contents or by employing small amounts of strong carbide-forming elements, such as chromium and vanadium, when adjustments in silicon contents are impractical as, for example, when the silicon content is so low that it is undesirable to reduce it further.

In the alloys which I preferably use, the elements phosphorus and sulphur occur within the usual percentage ranges for chilled cast iron rolls. While sulphur is sometimes used to control chill depth in some roll compositions, in this case the high manganese contents tend to destroy the chilling tendencies of sulphur. It is, therefore, unnecessary to maintain sulphur contents so closely within narrow limits for chill control. They should, however, be within limits consistent with good roll making practice, as sulphur is detrimental to strength. Phosphorus adds fluidity to the molten metal, but as it increases the brittleness of the castings, it should not be used in excess. However, sulphur, up to .25 per cent and phosphorus, up to .75 per cent may be used without departing from my invention.

The important alloying elements in my cast iron roll are copper, manganese, and molybdenum, for it is upon these elements that the development of fine-grained, extremely hard chill surfaces and strong, tough cores depend. Copper is used essentially to refine the grain, but as it has the capacity of stabilizing martensite and austenite, it is also useful in producing extreme hardness in the chill and toughness and strength in the core. With the alloys I have made, I have found that 2 per cent copper or more is required to substantially refine the grain. Grain refinement continues with increased copper content, and the use of high percentages of copper is limited only by the fact that the solubility of copper in the alloy cast iron is readily exceeded, causing particles of nearly pure copper to form. These particles are soft and my experiments to date indicate that they become of sufficient size at 5 per cent copper to be noticeable to the extent of interfering with the smoothness of the ground and polished chilled surfaces and with the uniformity of surface hardness.

The effect of copper on grain refinement and chill hardness was demonstrated on an iron whose composition was 3.60 per cent carbon, 3.0 per cent manganese, 0.60 per cent silicon, 0.10 per cent phosphorus, 0.05 per cent sulphur, 0.50 per cent molybdenum, and 0.50 per cent chromium, the latter being used to increase the depth of chill. To this cast iron was added 1.0, 2.0, 3.0 and 4.0 per cent copper with results as follows:

Casting	Copper	Type of crystals in chilled surface	Brinell hardness of chill
	Percent		
3348	0	Coarse columnar	529
3347	1	do	553
3346	2	do	608
3345	3	Moderately columnar	613
3344	4	Fine columnar	616

The increase in Brinell hardness of the chill with copper content is evidence of the tendency for copper to form martensitic structures.

The above tests also demonstrated that copper does not tend to sharpen the boundary between the chill and the grain of the core, the composition of the iron being one in which the transition from the chill to the grain is gradual.

The advantages of fine-grained, chill surfaces on rolls are obviously reflected in the quality and smoothness of the polished roll surface and in the improved surface appearance of materials finished on the rolls. Because of its effect on grain structure, smoothness of polish, and strength, I have found copper to be an important element in my alloyed cast iron roll.

The stabilizing of sorbitic-martensitic, martensitic, or austenitic matrices in the chill and grain of the roll is accomplished by employing manganese and molybdenum, which are augmented to some extent by the copper. The following table lists a number of irons cast into a given size chilled mold for the purpose of showing the stabilizing effects of manganese and molybdenum. These effects were observed from the trend in hardness of the chill with variations in manganese and molybdenum contents and from micrographs.

Casting	Composition, percent							Brinell hardness of chill
	Carbon	Silicon	Manganese	Molybdenum	Copper	Chromium	Vanadium	
3030	3.20	0.60	2.0	0.30	4.0	------	------	467
3034	3.20	0.60	1.5	1.0	4.0	------	------	562
3031	3.20	0.60	2.5	0.3	4.0	------	------	463
3110	3.60	0.60	3.0	0.3	4.0	------	------	524
3111	3.60	0.60	3.0	0.5	4.0	------	------	584
3113	3.60	0.60	3.0	1.0	4.0	------	------	619
3115	3.60	0.60	3.0	0.5	4.0	0.5	------	642
3116	3.60	0.60	2.5	1.0	4.0	0.5	------	642
3354	3.60	0.60	4.0	0.5	4.0	0.5	------	616
3355	3.60	0.60	5.0	0.5	4.0	0.5	------	617
3352	2.80	0.60	3.0	0.5	4.0	0.5	------	587
3350	3.60	0.20	3.0	0.5	4.0	0.5	------	617
3353	3.60	0.60	3.0	0.5	4.0	0.5	0.25	599
3678	3.60	0.60	10.0	1.0	5.0	------	------	518
3679	3.60	0.60	7.0	1.0	4.0	------	------	523
3680	3.60	0.60	7.0	2.0	4.0	------	------	527
3681	1.80	1.25	10.0	1.0	3.0	------	------	313
3682	2.50	0.60	7.0	1.0	4.0	------	------	378

The matrix of the chills in the lower-hardness, lower-alloy range was sorbitic, but with increased hardness and alloy content it changed to a mixture of sorbite and martensite, and finally became full martensitic at hardnesses in the vicinity of 600 Brinell and above. The matrix of the chill in alloys containing 7 per cent or more of manganese was austenitic, causing the Brinell hardness to again decrease. Thus the whole range of structures from sorbitic to martensitic, and finally to austenitic, may be obtained within the composition limits of my invention.

Different proportions of manganese and molybdenum may be used to produce equivalent stabilizing effects as it is shown. The lower manganese content irons require more molybdenum to obtain martensite than the higher manganese content irons. I prefer, however, to use manganese contents above 3.0 per cent, for at lower manganese contents the irons are more susceptible to grinding cracks and are not as tough. In that case the molybdenum content may be under 1 per cent to obtain martensite in the matrix of the chill. The increase in toughness of the chill with manganese content appears to result from the retention of increased amounts of austenite in the matrix. Substantial amounts of austenite are obtained in both the chill and the gray iron core with manganese contents above 5 per cent. Austenite in the core of the

rolls makes them more resistant to breakage. The hardness of the chill decreases as the amount of austenite increases. However, the austenite transforms to martensite on slight deformation as a result of the well known work-hardening effect.

Molybdenum contents from 1 to 2 per cent in the higher manganese containing irons are helpful but appear to be of no material advantage, and I prefer to maintain the molybdenum content below 1 per cent in these irons.

Since the speed of cooling and cast thickness affect the formation of martensite and the retention of austenite, these factors must be taken into account in proportioning the manganese and molybdenum and to some extent the copper. Nickel may be used as a supplementary element, particularly in very large rolls or to retain austenite, as it has a powerful influence on the stability of martensite and on the retention of austenite. The combined content of nickel, chromium and vanadium which may be found in the rolls is limited, however, to 4 per cent.

Neither manganese nor molybdenum was found to influence the grain structure of the chilled surface to any extent, and essentially all refinement was obtained through the use of copper.

It should be understood that my invention contemplates the production of a chilled cast iron roll by the use of copper in an alloy which contains no molybdenum or with an alloy which contains little or no manganese as, for example, from 0.1 to 1.0 per cent manganese. The sulphur content and the phosphorus content in the alloy may be as low as 0.01 per cent of each. It should also be understood that it is within the scope of my invention to provide a chilled cast iron roll wherein the matrix of the chill is either essentially martensitic or essentially austenitic. Various combinations may be produced by alteration of the percentages of the elements in the alloy within the ranges set forth in the appended claims, or variations of both the combinations and the rate of chill. Thus, the matrix of the chill may be partially martensitic and partially austenitic if desired, while the core may be either austenitic, martensitic or sorbitic or a mixture of austenite and martensite or sorbite-martensite.

It will be seen from the above that I have provided a novel type of chilled cast iron roll which, because of the use of copper in the alloy of which the roll is formed has a greater grain refinement than hitherto possible. As a result of this, I am able to obtain a chilled cast iron roll in which the surface on the chilled zone has a higher degree of polish and has a greater resistance to roughening. Likewise, my use of copper as one component of an alloy containing manganese and molybdenum permits of the use of less manganese or less molybdenum to obtain martensitic or austenitic structures. Moreover, by proper regulation of the various factors, as indicated above, I am able to obtain a chill wherein the matrix is at least partially martensitic with consequent hardness and toughness and a core which is either partially austenitic or partially sorbitic with consequent toughness and strength.

Having thus described my invention, what I claim is:

1. A chilled cast iron roll fabricated from an alloy containing more than 2 per cent and up to 5 per cent copper, 1.7 to 4.0 per cent carbon, 0.1 to 1.5 per cent silicon, 0.1 to 10 per cent manganese, up to 2.0 per cent molybdenum, 0.01 to 0.25 per cent sulfur, 0.01 to 0.75 per cent phosphorus, from a trace to a total of 4.0 per cent of at least one element from the group consisting of chromium, nickel and vanadium, and the balance iron with incidental impurities, said alloy having a fine grain structure due essentially to the presence of the said copper, and said roll having a hard white iron chill comprising a matrix which is essentially martensite or austenite grading without sharp demarcation into a tough strong core.

2. The roll of claim 1, wherein the said alloy contains 3 to 7 per cent manganese, 0.1 to 1 per cent molybdenum, and 3 to 4 per cent copper, and wherein the said chill has a matrix which is essentially martensite.

3. The roll of claim 1, wherein the said chill has a matrix which is essentially martensite, and wherein the said core has a matrix which is essentially austenite.

4. The roll of claim 1, wherein the said alloy contains 5 to 10.0 per cent manganese and the said chill has a matrix which is essentially austenite.

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