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FERROUS ALLOY MILL ROLL

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1 Claim. (Cl. 80—58)

This invention is for a ferrous alloy especially useful in the manufacture of rolls for rolling mills used for the rolling of steel and other metals and is also for a roll formed from such alloy. The invention is particularly applicable to an alloy and roll formed of such alloy intended for use in the rolling of hot metal rather than for cold rolling, and is more especially applicable for rolls for rolling bars and shapes as distinguished from flat products or sheets.

In the hot rolling of metal bars and shapes there are two difficulties encountered with the rolls, and this invention overcomes or greatly reduces both of these. The first of these difficulties is caused by the presence of scale on the hot steel or metal to be rolled. With some rolls there is a tendency for the scale to adhere to the rolling mill rolls. This impairs the smooth surface of the roll and produces roughness in the rolled stock. There is also a tendency for scale which adheres to the roll to be rolled or forced into the hot metal instead of being removed from the surface of the stock being rolled. According to the present invention, the character and structure of the metal constituting the roll is such that the scale does not tend to cling or adhere to the surface of the roll and the roll is provided with a peculiar quality of smoothness.

The second difficulty encountered at the present time and which the present invention is designed to eliminate or reduce is due to the non-uniform character of the metal in the roll from the outside toward the center. The molten metal which is cast into a mold for forming a roll must cool from the exterior toward the center. These rolls are often several feet in diameter, and as the metal cools toward the center the rate of cooling decreases. It is recognized in the art at the present time that the crystalline structure of a casting is affected by the rate at which it is cooled. In a large rolling mill casting, the metal forming the outer part of the roll undergoes an initial cooling much more rapidly than the inner portion and therefore the grain structure varies from the outside toward the center, the grain usually being finer in the outer portion than in the inner portions. Also, due to a certain selective action which occurs in the crystallization of the metal, there may be and usually is a definite chemical difference in the composition of the metal constituting the outermost portion of the roll and the metal constituting the inner portions. Certain ingredients of the alloy, for example, may more or less completely crystallize out while other constituents in the metal are still molten. The variation from the exterior toward the center, both as to grain structure and composition, tends to produce in the cross section of the roll more or less definitely defined concentric zones or layers which have different physical or chemical properties or both and each in turn affects the adaptability of the metal for use in rolling.

In the making of rolls for the rolling of flat sheets and strips, this tendency of the metal to stratify is not objectionable because the rolling surface is always the same distance from the center of the roll and the outermost edge has the most desirable properties from a rolling standpoint and extends a sufficient number of inches into the body of the roll to permit of the roll being dressed a great many times before any noticeable variation in the character of the metal is encountered. In the rolling of bars and shapes, however, the surface of the rolls has to be recessed or grooved so that some parts of the stock-engaging surface of the rolls are much closer to the center of the roll than other parts. The metal forming the inner boundaries of the groove in a roll pass, for example, may be several inches closer to the center of the roll than is the periphery of the roll. Consequently where there is considerable variation in the character or composition of the metal between the outer portion and the inner portions and such a roll is grooved for rolling shapes or bars, the metal forming the bottoms of the grooves constituting the roll pass may be much less suited for working on the stock than is the metal closer to the periphery. For these reasons the roll passes wear unevenly and the rolls have to be more frequently dressed than do rolls for hot rolling flat sheets, and because of the non-uniform character of the metal, each re-dressing of the roll, since it comes closer to the center where the metal is softer, aggravates this defect.

According to the present invention this difficulty is substantially eliminated or at least greatly minimized through my discovery that certain alloys may be used for rolls which not only have the peculiar quality of smoothness required for hot rolling operations, but which also are less affected by the variation in the rate of cooling from the outside toward the center. By reason of this fact there is no appreciable variation in the quality of the metal from the periphery of the roll to a depth well in toward the center. Any groove or recess cut in such a roll to form a roll pass will not extend from one zone into another, and the rolling quality of the metal which contacts the stock will be substantially constant even though the roll pass-forming groove is cut quite deeply into the surface of the roll. Such a roll, because of the absence of different zones from the periphery toward the center, does not have to be machined or dressed as frequently, and the useful life of the rolls is greater. The present invention comprises a roll in which there is no sudden change in the grain structure from the

periphery toward the center within the limits of depth to be exposed to the stock being rolled.

The alloy herein described is of a character which upon cooling produces little change in the physical structure from the outside inward, either in high carbon rolls commonly classed as cast iron rolls or low carbon rolls commonly referred to as steel rolls.

Judged by its carbon content and general physical properties, the alloy of the present invention would usually be called a cast iron, although it contains much less carbon than cast iron generally used in roll making. The carbon content of the alloy is, however, above that normally found in rolls which are classed as steel rolls. As compared with cast iron alloys heretofore generally used for making cast iron rolls, the alloy of the present invention, while containing less carbon, contains more manganese and more silicon than is usual. Iron, carbon, silicon and manganese are the chief ingredients of the alloy of the present invention, but other alloying elements may also be used in lesser amounts or for special purposes as will hereinafter more fully appear. The characteristic physical properties of rolls cast with this alloy are high strength, hardness, durability of the smooth face which may be formed on the roll and which persists when the roll is being used in hot working operations, and the high uniformity of the structure of the metal deep into the casting.

The smoothness of the finished surface of the roll under hot rolling conditions and the uniformity of structure deep into the casting are unique properties of the alloy of the present invention when used for roll construction. The tensile strength of standard test pieces machined from samples as cast is in the neighborhood of 50,000 lbs. which is entirely suitable for roll construction. The hardness of the machined surface of a roll made from the alloy is in the neighborhood of 50 by the Shore scleroscope test, which hardness is also quite satisfactory. There is no recognized standard test for smoothness of roll surface. Rolls made from the present invention, however, have a unique quality of smoothness which is probably due to the finely divided substantially uniform distribution of graphite disseminated through the metal giving any polished section a slipperiness due to the lubricating action of the graphite. This quality of smoothness is produced by the composition of the alloy or rather of the mix used in casting, said mix having the property of crystallizing in this manner when cast and being substantially unaffected in this regard by the rate of cooling. There is little change in either chemical composition or physical structure owing to the cooling taking place from the outside toward the center.

An important effect of this peculiar character of the surface of the roll in the hot rolling of metal is to prevent the adherence of scale to the surface of the rolls formed from an alloy so that the surface of the rolls is kept smooth and clean, whereas with steel rolls commonly used in roughing stands scale from the work adheres to the roll surface so that the original smooth machined surface of the roll is soon destroyed.

The grain structure of the cast metal is fine and is characterized by highly uniform dispersion of minute graphite crystals. The crystals of carbide are predominantly isolated rather than being formed in chains, as is usual in ordinary hard or chill cast rolls. The ferrite or pure iron crystals are finely disseminated in a solid solution of the iron and dissolved carbides and other metallic ingredients. As previously stated, this structure is uniform deep into the roll from the face of the chill or sand mold in which the roll is cast, there being no stratification into layers such as a hard brittle layer close to the chill or a coarse layer containing large fragments of graphite behind the hard exterior, or soft core, as exists in the usual hard chilled roll formed of the alloys now generally used for this purpose. Rolls cast of my alloy therefore, even when machined to a considerable depth below the surface, have uniform qualities of hardness and smoothness.

Typical analyses of my alloy and rolls containing the same are set forth in the following examples:

Examples indicating the range of carbon content

Use	Percent of alloy composed of—									
	Carbon	Silicon	Mang.	S	P	Mo	Ni	Cr	V	Cu
9" roughing mill	1.71	2.13	1.23	.060	.09	.20	1.20	.43	.06	.27
18" billet mill	1.74	2.05	1.06	.072	.11	.17	1.10	.41	.09	.20
Rod mill roughing	1.85	2.23	1.25	.048	.09	.22	1.10	.49	.09	.30
Large rounds	1.86	2.09	1.40	.063	-----	.27	1.07	.49	.15	.29
Roughing mill	1.95	1.87	1.26	.048	.16	.26	1.25	.49	.06	.39
Do	2.19	1.88	1.23	.052	-----	.22	1.08	.55	.12	.67
10" std. channels	2.27	1.95	1.31	.065	-----	.15	1.11	.52	.06	*.21

Examples indicating range in silicon content

18" mill—4½" rounds	1.90	1.65	1.00	.048	.15	.25	.93	.48	.15	*.21
Roughing mill	2.00	1.72	1.13	.054	-----	.21	.98	.47	.06	.32
Large rounds	2.02	1.90	1.09	.048	.10	.21	1.05	.54	.15	.34
Rod mill	2.00	2.08	1.21	.055	.13	.30	1.05	.52	.06	.28
10" roughing mill	1.90	2.34	1.44	.061	-----	.27	1.40	.50	.09	.34
10" rod mill	1.98	2.39	1.49	.054	.08	.30	1.25	.50	.09	.26

Examples indicating range in manganese content

3½"–4" rounds	1.90	1.92	0.83	.050	-----	.12	1.08	.55	.09	.34
Tube sizing	2.01	2.08	1.01	.054	.11	.15	1.00	.44	.09	.26
Roughing mill	2.13	1.95	1.22	.058	.14	.21	1.08	.50	.09	*.30
Large rounds	2.25	1.88	1.28	.060	-----	.10	.91	.47	.06	.30
24" billet mill	2.12	2.07	1.35	.066	.10	.42	1.07	.51	.09	*.33
Billet finishing	1.98	1.69	1.49	.068	.11	.22	.98	.53	.09	.33

Examples marked * also contain a trace of boron added in some form to the heat.

The ranges in percentage of the elements composing the alloy of which the above rolls were made is as follows:

Element	Minimum percentage	Maximum percentage
Carbon	1.71	2.27
Silicon	1.65	2.39
Manganese	0.83	1.49
Phosphorus		0.16
Sulphur	.048	.072
Molybdenum	0.10	0.42
Nickel	0.91	1.40
Chromium	0.41	0.55
Vanadium	0.06	0.15
Copper	0.20	0.34
Boron		0.10

The effects produced by increasing the content of any ingredient, within the ranges shown, is approximately as follows:

Ingredient	Effect of increase in amount
Carbon	Increase in dispersed graphite. Increase in dispersed hard carbides of iron, manganese, and chromium. General increase in hardness and strength.
Silicon	Increase in dispersed graphite. Improves tensile strength somewhat.
Manganese	Decrease in dispersed graphite. Increase in dispersed carbides, producing greater hardness.
Molybdenum	Improved tensile strength of alloy.
Nickel	Produce no determining effect on structure.
Copper	
Chromium	Increases hardness by producing carbides.
Vanadium	Increases strength (used principally as a scavenger to cleanse melt of oxygen).
Boron	Improves hardness somewhat.

The composition of my alloy is chiefly characterized by the balance of the components carbon, silicon, and manganese, so as to produce a finely disseminated dispersion of both graphite and metallic carbides in a high strength alloy iron matrix. Other elements used to increase the strength of the matrix, improve the hardness somewhat, or for any other purpose, are not determinants of the characteristic structure of my alloy, and may be omitted, replaced by suitable substitutes or other elements added, according to the experience and judgment of the foundryman. Therefore, when I speak of the remainder of the roll composition aside from the carbon, silicon and manganese as being substantially all iron, I do not mean thereby to exclude other alloying metals in the small amounts above indicated and which may be used to increase the strength, hardness, etc., of the roll but which do not deleteriously affect the novel characteristics imparted by the combination of the essential characterizing elements, carbon, silicon and manganese.

While the examples given of analyses of the melts used in rolls actually cast represent what I deem good commercial practice, these examples do not indicate the complete range of variation permissible in applying the invention, it being understood that the cost of certain ingredients per pound is much greater than that of others, and it is not desirable to introduce expensive ingredients in excess of amounts required to secure satisfactory results, while an excess of cheaper ingredients is not objectionable as long as it is not detrimental to the physical properties of the product.

I claim:

A rolling mill roll formed of a cast ferrous alloy having high strength and hardness and in which the structure and composition of the metal in the roll is substantially uniform from the surface of the roll deep into the center and which is devoid of zones in which the physical properties of the metal change suddenly from one zone to another whereby deep passes may be cut into the surface of the roll without encountering strata of distinctly different physical properties and wherein carbon in the form of minute graphite crystals is substantially uniformly dispersed throughout the mass of the roll in such a manner as to impart a distinctive quality of smoothness to the machined surfaces of the roll, said alloy containing carbon in the range substantially 1.70 to 2.25%, silicon in the range substantially 1.65 to 2.40% and manganese in the range substantially .80 to 1.50%, the remainder being substantially all iron.

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