

April 26, 1938.

W. J. MERTEN

2,115,465

ROLLING MILL ROLL

Filed March 22, 1937

2 Sheets-Sheet 1

Fig. 9.

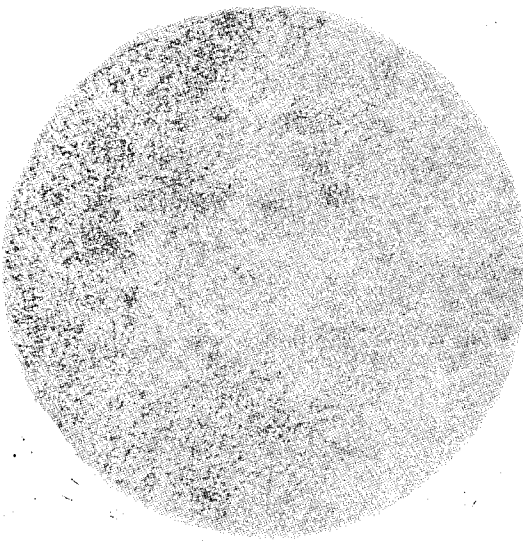


Fig. 11.



Fig. 8.

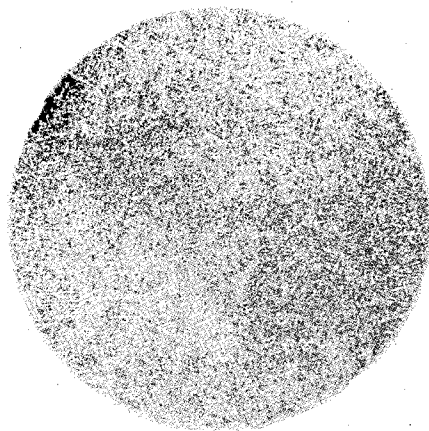
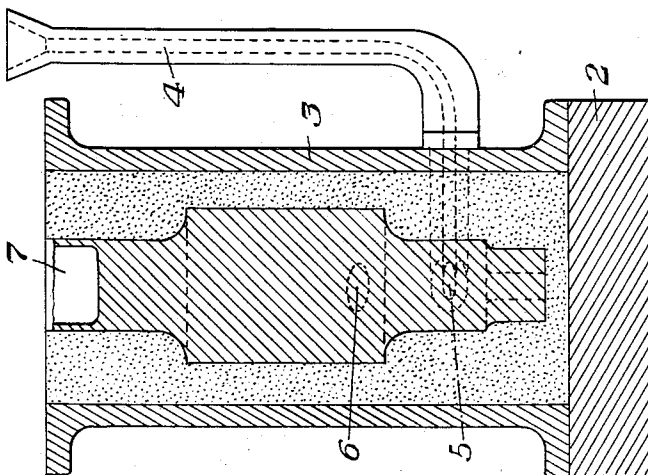


Fig. 10.



Fig. 1.



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Fig. 2.



Fig. 3.

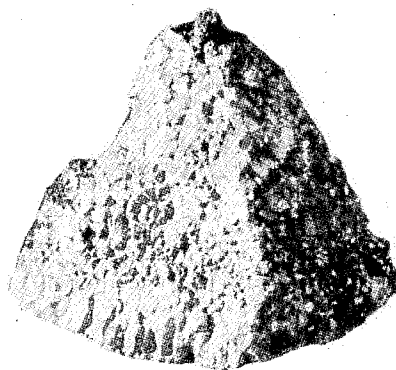


Fig. 4.



Fig. 5.



Fig. 6.

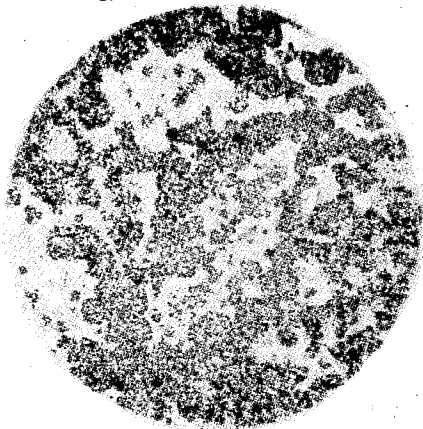


Fig. 7.



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UNITED STATES PATENT OFFICE

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ROLLING MILL ROLL

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Application March 22, 1937, Serial No. 132,257

16 Claims. (Cl. 86-58)

This invention relates to rolling mill rolls and provides a ferrous base roll having outstanding qualities either for hot or cold rolling and for use either as a working roll or as a pressure roll in backed-up mills. While the invention is applicable either to iron or steel rolls, it is herein particularly described as applied to steel rolls.

Certain problems and conditions of use peculiar to rolling mill rolls have long been known in the art and a number of schemes, some metallurgical in their nature and others having to do with processes of manufacture, have been proposed. Despite the large amount of study which has been given to the problem the life of rolls in use has been distressingly short and has been reflected in higher manufacturing costs. The problem has become one of increasing importance as the rolling art has progressed in operations which, because of their nature, impose particularly great hardships on the rolls. Examples are alloy sheets and high speed wide strip mills.

Rolls of this sort should have great physical strength and toughness, should be relatively free from fire cracking, spalling and roughening, and should be susceptible of taking and retaining a high surface finish. As heretofore made, however, such rolls have suffered from the limitations indicated to a greater or less degree and with increases in mill loads have shown an increasing tendency to fracture under the alternating stresses to which rolls are inevitably subjected.

By the present invention I provide a roll which in practice has been conclusively shown to have a much longer life than rolls as heretofore made, to be substantially or entirely free of the defects which result in fractures, and to be vastly superior to ordinary rolls in respect of the features above enumerated. I cast my improved roll from an alloy containing carbon, manganese, chromium, molybdenum and a killing agent, preferably silicon, although titanium or aluminum may be used. These several elements are so proportioned as to give the qualities above referred to. Preferably their proportions are such that the alloy has a very short period of primary crystallization resulting in freedom from coarse dendritic freezing or segregation. I believe my alloy to be a eutectic or of quasi-eutectic composition. Despite the fact that the alloy contains an unusually large amount of manganese much beyond the figure generally regarded as the limit for steel rolls, my composition is such that the coarsening effect of the manganese is limited. In fact, the alloy is markedly responsive to structural modification

by thermal treatment in the solid state, and after the proper thermal treatment has been effected the roll is remarkably fine grained and uniform.

In the accompanying drawings illustrating a present preferred embodiment of the invention,

Figure 1 is a vertical section, largely diagrammatic, showing a mold with my improved roll cast therein;

Figure 2 is a photomicrograph showing the steel in the cast state;

Figure 3 is a view showing a fracture of the steel in the cast state;

Figure 4 is a view corresponding to Figure 2 but showing the steel after it has been homogenized;

Figure 5 is a view corresponding to Figure 3 but showing a fractured section of the homogenized steel;

Figure 6 is a view corresponding to Figure 2 but showing the fracture after annealing;

Figure 7 is a view corresponding to Figure 6 but showing the steel after annealing;

Figure 8 is a view corresponding to Figure 2 but showing the steel after air quenching and tempering and in condition to be used.

Figure 9 is a photomicrograph corresponding to Figure 8 but to a higher degree of magnification;

Figure 10 is a view corresponding to Figure 3 but showing a fracture of the material after air quenching; and

Figure 11 is a corresponding view showing a fracture of the material after tempering.

In the illustrated embodiment of the invention the roll is a steel casting within the following composition range:

	Percent.	
Carbon	0.3 to 0.9	35
Manganese	2 to 3.5	
Chromium	2.5 to 5	
Molybdenum	0.4 to 0.75	

The balance is substantially iron except for metallic elements or their compounds added for deoxidizing and degasifying the melt such as an element of the group silicon, titanium, aluminum. I prefer to add silicon in an amount sufficient to obtain in the solid metal a silicon content of 0.2 to 0.35 percent. A more specific range which may be conveniently followed and which I have found particularly desirable is as follows

	Percent.	
Carbon	.5 to .7	50
Manganese	2 to 2.5	
Chromium	3 to 3.5	
Molybdenum	.4 to .5	
Silicon	.3 to .35	
Balance	principally iron	55

A specific analysis which I have employed with great success is as follows:

	Percent.
Carbon	.58
5 Manganese.....	2.5
Chromium.....	3.31
Molybdenum.....	.44
Silicon	.35
Phosphorus	.039
10 Sulphur	.023
Balance Iron	

The phosphorus and sulphur are undesirable impurities and should be kept as low as is practical in open hearth or electric furnace practice.

15 The relationship between the manganese and the chromium content is of importance and should be carefully maintained if the best results are to be secured. I prefer to keep the chromium content in excess of the manganese content, preferably by 0.5 percent or more. It will be found that if this relationship is observed the carbon content of the roll can be varied over quite wide limits. The chrome-manganese relationship is also of importance in that it makes the roll soften more readily during the heat treatment.

Figure 1 illustrates a conventional mold comprising a base 2 and a flask 3 for the casting of the roll R. The mold is in accordance with customary foundry practice in the manufacture of cast rolls and is bottom poured through a spout 4. The gate 5 is tangentially arranged so as to impart a swirling motion to the steel. A melt of the specific analysis above given may be successfully poured at a temperature of 2650-2750° F. I endeavor to have the metal at a temperature of 2700° F.

As is usual in the casting of rolling mill rolls, the mold is several feet higher than the desired roll length, thus insuring sound metal in the roll itself. After the pour has been completed, the top of the mold is covered as with kieselguhr to prevent heat loss.

On cooling, several important facts will be noted. The transition from the liquid phase to the solid phase is of quite short duration. The metal, while perfectly fluid and free-running at the pouring temperature, has the important property of changing promptly to the solid stage with but little temperature drop. This is of special importance in the casting of rolling mill rolls. Such rolls, as cast, are frequently of very large size, for example, up to 12 feet or more in length and 4 feet or more in diameter. Such a mass of metal in cooling undergoes considerable shrinkage and in most steel alloys gives rise to fissures, cracks or cavities in the body of the casting. In the casting of ordinary rolls the last zone or portion of the metal to freeze is located approximately as indicated at 6 in Figure 1, and the consequence almost invariably is that the metal is discontinuous thereabouts. Since a roll is always flexed to some degree in use, the rotation of the roll brings about an alternating stress therein and in practice it is quite common for rolls of ordinary composition to break at a place corresponding to the location of the point 6. Rolls made of my improved alloy appear to be free of this defect. Certainly experience with the same up to the present time indicates no such weakness. I attribute this important advantage to the uniform solidification or non-dendritic freezing of the alloy or substantially perfect liquid solution practically down to the solidus

temperature. As stated, I believe the alloy to be a eutectic or of quasi-eutectic composition.

A second important point to be noted in the casting of my improved alloy is the characteristic shape of the sinkhead. This is indicated at 7 in Figure 1. In ordinary roll casting practice, the sinkhead cavity is of steeply tapering conical form, the point of the cone extending deep into the riser. The sinkhead cavity formed after casting my alloy is more generally cylindrical in form, being of almost the same diameter at the bottom as at the top and the bottom being much in the form of a shallow dish. My studies indicate that the alloy possesses the property of retaining its fluidity to a marked degree in the initial cooling and of shrinking uniformly and without severe dendritic segregation during the change from the liquid to the solid state, being in these respects far superior to the alloys generally used in making rolls. In consequence a sound casting is insured and the possibility of imperfections in the working portion of the roll is greatly reduced. This is a matter of large commercial importance because of the fact that rolls of this sort are periodically dressed down and any imperfection in the metal for a considerable distance below the cylindrical surface of the roll must be eliminated.

After the casting has solidified, it is removed from the mold, the gate and the riser are cut off, and the roll is then heat treated. In the following description of the heat treatment reference will be made to Figures 2 to 11 as illustrative of the structure at different stages. These views were made from a disc cut from the top of a casting of approximately the analysis above set forth and subjected to the same heat treatment as the roll from which it was cut.

Figures 2 and 3 represent the cast structure. As shown by the photomicrograph Figure 2, the steel is martensitic. As shown by the fracture specimen Figure 3, the steel is coarse grained. There is some difference in grain size of the metal from the outside toward the center, although this difference is not as much as in steels ordinarily used for rolls. The cast metal is substantially free from streaks and ghost lines which, of course, are optical evidence of segregation. This uniformity of cast structure is one reason for the unique and ready response of the structure to thermal treatment for the formation of a desired structure which is substantially uniform throughout the entire casting.

The steel is homogenized by holding it at elevated temperature for a considerable period of time. The roll now under discussion had a body 53 inches in diameter and necks 40 inches in diameter. It was heated to 1975° F., held at that temperature for sixty hours, then cooled slowly in the furnace to a temperature of 800° F. The heat was then cut off, the doors were opened, and air was allowed to circulate freely through the furnace until the metal was brought down to normal temperature. Figures 4 and 5 illustrate the resulting structure. It will be noted from Figure 5 that the grains have been greatly refined and instead of the coarse crystal structure of Figure 3 the structure shows a smooth and silky appearance.

Following the homogenizing treatment, the roll is annealed by heating it to 1450° F., followed by slow cooling. This annealing was given to make the cast roll machinable for the rough turning operation. The grain structure is shown in Figure 6 and the fracture is illustrated in Figure 7.

It will be noted that there is a slight coarsening of the crystal structure.

After the rough turning the roll is heated to approximately 1500° F., is air quenched, and then tempered at 1000° F. Figure 10 illustrates the fracture after the air quench. While there is little change in the grain size or in the silky character of the structure, the character of the break indicates considerably greater toughness. Figure 11 shows a fracture after the tempering. The roll is now extremely tough and the release of strain hardening by the tempering operation results in higher physical properties.

Figures 8 and 9 show the micro structure of the finished roll. Figure 8 is to the same degree of magnification as Figures 2, 4, and 6 (100 diameters in the original drawing, not reduced for reproduction), while Figure 9 is to a greater degree of magnification (1000 diameters in the original drawing, not reduced for reproduction). As will be particularly apparent from Figure 9, there has been considerable spheroidizing.

The following tabulation gives the physical properties of the roll in the cast condition and after the above described heat treatment:

	As homogenized	Heat treated
Yield point.....	90,000#/sq. in.	125,000#/sq. in.
Ultimate tensile strength.....	120,000#/sq. in.	162,000#/sq. in.
Elongation.....	12%	9%
Reduction of area.....	21%	17%
Hardness-Brinell.....	248	302
Hardness-scleroscope B.....	38	47

Due to the relatively high percentages of chromium, manganese and molybdenum, the alloy is quite resistant to oxidation or heavy scaling at temperatures considerably above those employed in the heat treatment. In consequence, only a very thin scale is produced, the heat penetration is considerably better than in an ordinary heavy-scale-forming alloy. Since scale is a poor conductor of heat, the time period required for raising the temperature of the roll to the temperatures required in heat treatment is consequently shortened and the phenomena of heat treatment proceed more uniformly.

In use, the roll exhibits remarkable properties. It has high physical strength, is very tough and indicates no tendency to fracture from alternating stresses. The use of the roll in hot rolling demonstrates it to be surprisingly free of fire cracking. Fire cracking has heretofore been a limiting factor on the length of time that a roll might be used without redressing, and fire cracks frequently progress to such a point as to cause failure of the roll or to show tears and bad marking on the surface of the work. In any event, deep fire cracking requires heavy dressing of the rolls, thus reducing the tonnage obtainable from them. My improved rolls have a much reduced tendency toward fire cracking and surface marking and such of it as does take place is shallow. Experience proves that it can be eliminated by comparatively light dressing.

In either hot or cold work spalling of rolls has also been a factor. It takes place either in working rolls or in backing rolls due to deep cold work occasioned either by contact with the work itself in the case of a working roll, or by contact with the working roll in the case of a backing roll. My improved roll is remarkably free of this defect. It is also quite free from any tendency to roughen in service, thus indicating an unusually high intergranular or cohesive strength.

I have illustrated and described the present preferred embodiment of my invention. It will be understood, however, that this is by way of example only and that the invention may be otherwise embodied within the scope of the following claims:

I claim:

1. A steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron.

2. A steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, silicon 0.2 to 0.35 percent, the balance being principally iron.

3. A steel roll for rolling mills comprising carbon .5 to .7 percent, manganese 2. to 2.5 percent, chromium 3. to 3.5 percent, molybdenum .4 to .5 percent, silicon .3 to .35 percent, the balance being principally iron.

4. A steel roll for rolling mills comprising carbon .5 to .7 percent, manganese 2. to 2.5 percent, chromium 3. to 3.5 percent, molybdenum .4 to .5 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron.

5. A steel roll for rolling mills having approximately the composition carbon .58 percent, manganese 2.5 percent, chromium 3.31 percent, molybdenum .44 percent, silicon .35 percent, the balance being principally iron.

6. A steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron, the several elements being so proportioned that the alloy is a eutectic or quasi-eutectic.

7. A cast steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron, and characterized by a generally cylindrical sinkhead cavity on casting.

8. A homogenized, annealed and tempered cast steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron, characterized by relative freedom from fire cracking and spalling.

9. An annealed and tempered cast steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group, silicon, titanium, aluminum, the balance being principally iron, characterized by relative freedom from fire cracking and spalling.

10. A steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 4.5 percent, chromium 2.5 to 5 percent, the balance being principally iron, characterized by substantially uniform grain structure throughout.

11. A heat treated cast steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 4.5 percent, chromium 2.5 to 5. percent, the balance being principally iron, characterized by having a substantially uniform fine-grained structure throughout.
12. A steel roll for rolling mills comprising carbon 0.3 to 0.9 percent, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, the chromium content exceeding the manganese content by at least about 0.5 percent, molybdenum 0.4 to .75 percent, the balance being principally iron.
13. A ferrous base roll for rolling mills comprising carbon in essential amount, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, the chromium content exceeding the manganese content by at least about 0.5 percent, molybdenum 0.4 to .75 percent, the balance being principally iron.
14. A ferrous base roll for rolling mills comprising carbon in essential amount, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, the chromium being in excess of the manganese, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron.
15. A ferrous base roll for rolling mills comprising carbon in essential amount, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, the chromium being in excess of the manganese, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron, the several elements being so proportioned that the alloy is a eutectic or quasi-eutectic.
16. A ferrous base roll for rolling mills comprising carbon in essential amount, manganese 2. to 3.5 percent, chromium 2.5 to 5. percent, the chromium being in excess of the manganese, molybdenum 0.4 to 0.75 percent, a small quantity of a degasifying and deoxidizing element of the group silicon, titanium, aluminum, the balance being principally iron, and characterized by a generally cylindrical sinkhead cavity on casting.

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