May 16, 1933. F. A. FAHRENWALD 1,908,740

CAR WHEEL AND PROCESS OF MAKING SAME

Filed July 6, 1929

Fig. 1

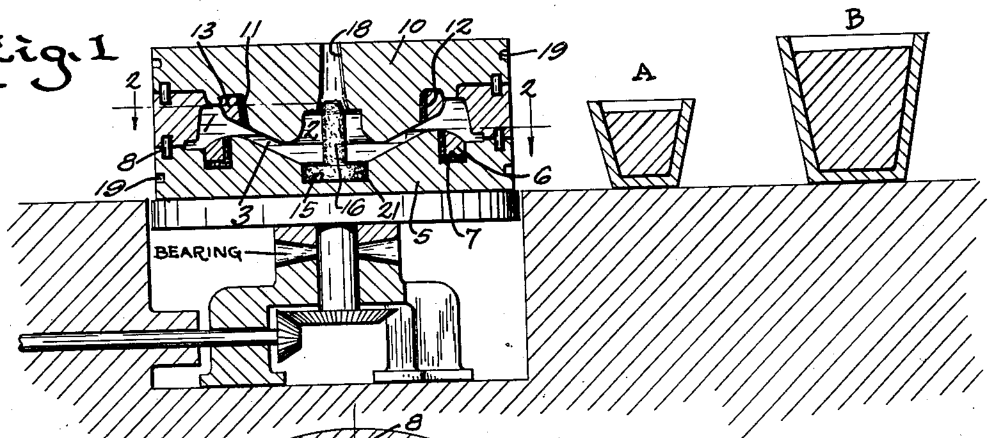


Fig. 2

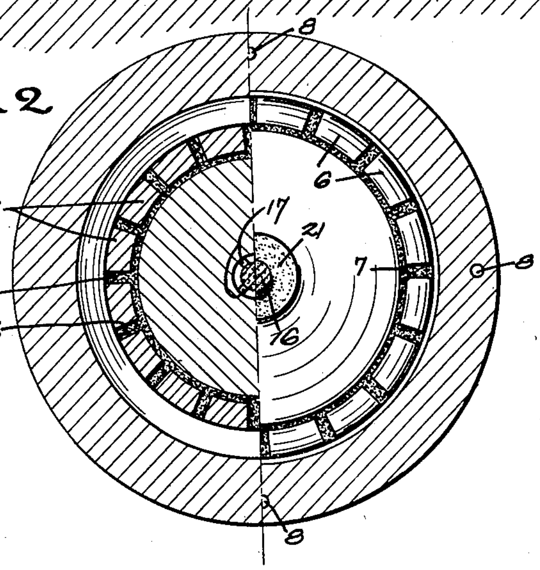


Fig. 3

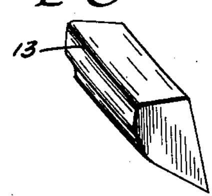


Fig. 4

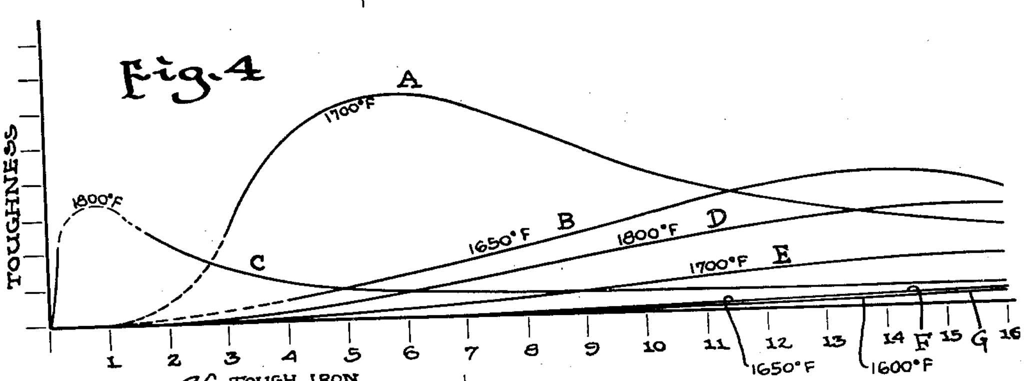
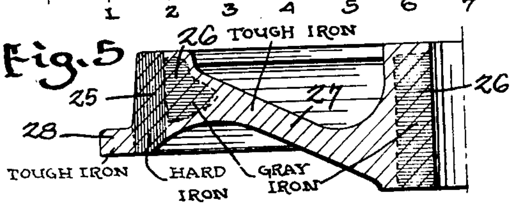


Fig. 5



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UNITED STATES PATENT OFFICE

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CAR WHEEL AND PROCESS OF MAKING SAME

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This invention relates to car wheels and has for its object the provision of a new, cheapened and improved wheel for railway rolling stock. Such wheels have long been made by casting iron into a mold of the proper shape, the periphery of the mold consisting of a massive iron ring called a "chiller", which causes this exterior portion of the casting to become solidified very rapidly. The composition employed for the purpose is what I call an unstable iron mixture, namely one which produces grey cast-iron when cast in a sand mold, or white-iron when cast against a chiller. A composition often used for car wheels is carbon 3.25% to 3.50%, silicon .60% to .90% and the balance iron. In such a mixture the carbon is at least largely held in solution when the metal is melted, but the presence of silicon tends to precipitate that carbon in the form of graphite at and immediately below the temperature of solidification. The result is that when such a mixture is poured in a sand mold the resultant slow cooling causes the graphite to become separated out in the form of innumerable minute graphite plates or flakes which almost completely interrupt the metal phase, so that the latter, although it consists of an iron which would ordinarily be tough and ductile, exhibits the well known weakness and brittleness of "cast-iron". The same material when cast in a chilled mold, produces a casting, the fracture of which is white, like silver but very crystalline, the carbon being retained in combination with the iron in the form of a carbide known as "cementite", Fe_3C. Such white-iron consists of a mass of cementite embraced in a continuous phase of rather high-carbon steel. The cementite particles are extremely hard and resistant to wear, and the steel matrix due to the quick chilling is quench-hardened to a glass-like brittleness with the result that this type of metal is ordinarily excessively weak, and brittle. In the making of car wheels, all the mold excepting the tread portion has heretofore customarily been made of sand, but the tread portion has been formed by a massive iron ring known as a "chiller", thus producing a wheel having a body of grey cast-iron and a tread of chilled white-iron, the chilled condition ordinarily extending into the metal a distance of one-half to one inch depending upon the composition of the metal. Due to the sudden cooling and the consequent contraction of the periphery of the wheel during the time that the hub remains not only hot but almost molten, very severe stresses are set up, as a consequence of which it is customary to remove the "chiller" at the earliest possible moment, to lift the wheel from the mold, and to transfer it while still red hot to a slow cooling device where it can be annealed for a period of one or more days. According to contemporary practice no fuel is employed in this annealing operation, the wheels being merely deposited in piles of six or eight in thermally insulated pits where they cool gradually by reason of their mutually high temperature; and care has been taken not to introduce or maintain them at an unduly high temperature lest the treads be softened, while at the same time introducing them into the pits at a temperature above the critical range, which for this composition is about 1325° Fahrenheit. With this in view a technique has been established which will introduce the wheels into the pits at around 1400° to 1600° Fahrenheit.

Due to the extreme hardness of the chilled tread, wheels of this nature possess a high reputation from the standpoint of wearing ability, but due to the deficient tensile strength and the absolute absence of ductility in the grey iron plate of the wheel, the expansion and contraction of the rim due to temperature changes (caused principally by the friction of the brakes) sometimes causes these wheels to fail by breakage of the plates. With the constantly increasing weights and speeds of trains and the consequent vigorous application of the brakes the strain upon the car wheels is constantly increasing and has now reached a point which is upon the borderline of the ability of grey iron wheels to stand.

Even a very small improvement in the wheel as regards toughness would add a valuable factor of safety, but many years of research by metallurgists all over the world have failed to produce any treatment whereby grey iron castings can be rendered tough or ductile. On the other hand the only alternative heretofore known has been to use steel wheels which while sufficiently tough and ductile, are so expensive in the first cost and so subject to tread wear as to produce marked disadvantages of another kind.

The objects of my invention are the provision of a new and improved car-wheel of cast-iron which shall retain the low cost of cast-iron in combination with the hard white-iron tread, while possessing a high degree of toughness and tensile strength in the plate which shall better enable the latter to withstand the necessary operating conditions; the provision of a cast-iron car-wheel having a tough plate and a hard tread; the provision of a method of casting and heat-treating a cast-iron car-wheel which shall render the plate tough and ductile while leaving the tread hard and wear-resistant; while further objects and advantages of the invention will become apparent as the description proceeds.

In the drawing accompanying and forming a part of this application I have illustrated certain apparatus and certain diagrams explanatory of my improvement. Fig. 1 is a vertical sectional view through a mold and rotary support for use in accordance with my present improvements; Fig. 2 is a horizontal sectional view on the broken line 2—2 of Fig. 1; Fig. 3 is a perspective view of a separate chiller block constituting a part of the mold shown in Figs. 1 and 2; Fig. 4 is a diagram showing the relation of time, temperature and tensile strength for certain dissimilar casting compositions; and Fig. 5 is a partial section through a completed wheel.

A car-wheel comprises a circular rim portion 1 termed the "tread", joined to a central massive hub 2 by a comparatively thin web 3 ordinarily called the "plate". This plate is generally dished more or less as shown in Fig. 1 although its specific contour is relatively unimportant provided that the hub and tread preserve their requisite standard relationship. According to my present invention the mold in which the wheel is cast is mounted for rotation about an axis concentric with the wheel axis and rotated during the casting operation at such speed as shall cause the molten metal to stratify circumferentially. The metal is poured from two separate ladles, A and B, the one, A, designed for the casting of the tread, containing a stable iron mixture, that is to say one in which the carbides are difficult to decompose by heat; and the other, B, namely that designed for producing the plate and hub, of what I term an unstable iron mixture, namely one in which the cementite is relatively easily broken down by heat as compared to stable iron. The following are specimens of unstable iron mixtures:

	A	B	C
	(In percent)	*(In percent)*	*(In percent)*
Carbon	2.80 to 3.10	3.00 to 3.25	3.25 to 3.50
Silicon	.90 to 1.20	.80 to 1.00	.60 to .90
Iron	balance	balance	balance
Sulphur	up to .20	up to .20	up to .20
Phosphorus	up to .60	up to .60	up to .60
Manganese	up to 1.00	up to 1.00	up to 1.00

Any one of the foregoing can be converted into a stable white iron by sufficiently reducing the carbon, or by sufficiently reducing the silicon, or both. For example the following are stable white-iron mixtures:

Carbon	2.80% to 3.10%	2.25 to 2.60
Silicon	.25% to .60%	.60 to .80
Iron	balance	balance
Impurities as before		

The mold is preferably made as nearly as possible all of metal, both for the sake of the chilling effect thereby obtained and for the purpose of withstanding the peculiar stress due to the rapid rotation. A convenient way of making such a mold is shown in Figs. 1 and 2, wherein the drag consists of a single massive metal block 5 excepting for an annular portion 6 adjacent to the outwardly and downwardly sloping shoulder presented by the inner rear face of the tread, which is made yielding by the use of said or better still of baked core-composition inset in a groove 7 provided for the purpose. Resting on the marginal portion of this drag in a position fixed by dowel pins 8 is the "tread chiller" usually employed. Resting in turn on this tread-chiller is the cope element 10, here also consisting of a massive piece of cast-iron excepting for a portion immediately inside the forward shoulder of the tread which I have also shown as made yielding by the use of sand or preferably of baked core material 11 received in a groove 12. In each groove I preferably employ a plurality of tapering, metal, chiller-blocks 13 sufficient in size to exert a chilling effect but separated from each other and from the inner wall of the groove by the crushable material 11.

Formed at the center of the drag is a recess 15 for the lower end of the hub-core 16 whose upper end is received between suitable fingers 17 projecting inwardly around the lower end of the pouring hole 18. The spaces between these fingers constitute the sprues. I have shown the peripheries of these mold members as formed with suitable recesses 19 for the reception of crane hooks, since it is important to remove the cope and chiller at the earliest possible moment after pouring to reduce the danger of the wheel drawing apart upon contraction. It is for this reason that the crushable portions 6 and 11 are introduced, namelv to allow a trifle more latitude in the time of opening the mold. Excepting for this I would prefer to make the entire mold of metal. The core 16, however, can be made of ordinary baked core-materials, and I have shown it as formed with an enlarged lower end 21 defining the face of the hub as well as the bore thereof, so that the molten iron entering through the sprues may fall thereon instead of on the metal surface of the mold on which it might have a local eroding influence.

The mold having been set in rotation at a sufficient speed to deliver the molten metal to the periphery thereof, the contents of the two ladles of proper size are emptied therein in qick succession. I first introduce the entire contents of the smaller ladle A, which contains the stable iron mixture but is only of such capacity as to make about half the tread thickness; then, and with the smallest possible break (or even with some overlapping) sufficient of the unstable mixture from the larger ladle B is introduced to fill the mold completely and stand well up in the pouring hole 18. These different iron mixtures are sufficiently similar in composition so that they fuse readily together, exhibit nearly the same coefficient of thermal expansion at least throughout the herein essential range, and offer little or no tendency to separate along the line of junction when properly poured as I have described. Immediately upon the filling of the mold the rotation is stopped, and the cope and chiller are lifted off just as soon as the iron has become entirely solidified so that the wheel can contract with sufficient freedom to minimize the danger of disruption.

If the wheel were allowed to cool, and then broken, it would be found that all portions of the same were of white iron excepting probably the interior of the hub, and possibly also a slight portion of the interior of the tread where it is thickest. The tread portion would be white because of the nature of the iron and regardless of the use of a tread chiller. The latter is employed for the purpose of affording the desired contour to the tread, and also as a convenient mode of producing a centrifugal mold which will not fly apart. The plate (and also the flange if cast as may be done from the unstable iron mixture) will be white because of chilling. However, it is best not to allow this wheel to assume too low a temperature since it would be very likely to break in pieces because of cooling strains before room temperature was reached, but to transfer it immediately to a heat treating furnace having an atmosphere-temperature of between 1700° and 1750° Fahrenheit, where it is left for a sufficient period of time to enable the cementite content of the unstable-iron-portions to become more or less decomposed. Cuves A, B, and C in Fig. 4 show the relation of toughness to time of treatment at different temperatures for unstable compositions of the type I have described when cast against chillers; curves D, E, F, and G thereof show the relation of toughness to time of treatment at different temperatures for stable iron compositions of the type I have described. With the unstable mixture the liberation of the combined carbon is substantially complete in portions of the casting which are maintained at a temperature of 1800° Fahrenheit for even less than an hour, and maximum toughness is secured in substantially less time. Indeed the rapidity of the decomposition is so great at this high temperature that I have been unable to plot the top of the curve to my entire satisfaction for which reason I have shown this in dotted outline. On the other hand the decomposition of the massive carbide is only partially accomplished after eight hours or more at a temperature of 1650° Fahrenheit, although with most compositions of the unstable type this is ample for the purpose in view and maximum toughness is generally exhibited by portions which are maintained for about four hours at about 1700° Fahrenheit.

The effect of this breaking down of the carbides is to produce a steel-like matrix having nodular masses submerged therein consisting partly of cementite and partly of graphite, the proportions of the last two ingredients depending upon the time and temperature of treatment. If the treatment is continued sufficiently long, the cementite portions are entirely broken down, and the combined carbon is largely driven out of the matrix-metal also, leaving the same substantially in the ferrite condition. With shorter treatment the matrix metal can be made to consist almost wholly of pearlite which is known to exhibit a high degree of strength and toughness. Accordingly the best results in point of strength are obtained at a point short of complete breaking down of the cementite or of total liberation of the combined carbon. Furthermore the operating requirements are not such as to demand the maximum obtainable toughness since a condition which sometimes limits the life of a gray-iron car-wheel is the thermal expansion and contraction of its tread which sets up strains in the plate which the latter being totally devoid of ductility is unable to bear despite the fact that the actual amount of expansion and contraction is very small. Hence even a small accession of ductility is enough to satisfy the essential requirements.

Curves D, E, F, and G of Fig. 4 show, however, that a stable iron mixture, such as that used for the tread of the wheel, is very little decomposed even by several hours exposure to a temperature of 1700° Fahrenheit or even of 1800° Fahrenheit. Accordingly the treatment which serves to break down the unstable chilled portion of the casting, producing a condition of toughness and strength therein, has no noticeable or measurable softening effect upon the tread. The hub will take care of itself. The only practical requirement is that it be sufficiently soft to enable convenient boring and sufficiently strong to withstand the stress of service. If the hub should turn out to consist of gray-iron, it can readily be machined as is well known; whereas if it should turn out to consist of chilled iron, the heat-treatment which affords ductility to the plate also softens the metal to such a degree as to enable ready machining. Ordinarily metal so unstable as that which I prefer to employ for this process will not chill all the way through with a hub of this size wherefore the same will come out partly gray and partly chilled.

The length of time actually necessary for the heat-treatment depends upon the temperature of the furnace, the promptness with which the casting is introduced therein, the composition of the metal, and the amount of decomposition and toughening desired. I have found a treatment of four hours at a temperature of 1725° Fahrenheit to be very satisfactory, but considerable changes in time and temperature can be made even with the same mixture, and even greater changes with other mixtures. At the end of this treatment the matrix metal of the plate portion should consist substantially of steel, partly severed of course by the rounded inclusions of graphite, and sometimes mixed with some cementite. The only remaining problem is accordingly that of so cooling the article as to obtain the best condition of this steel and at the same time of setting up a minimum of strain between the hardened tread portion and the adjacent portions of the article. The simplest mode is, after removing these articles from the heat-treating furnace, to introduce them into thermally insulated pits exactly as is done at the present time, and allow them to soak therein for two days or more as at present. The exposure to the air in conveying the articles from the furnace to the pit will ordinarily depress its temperature sufficiently to arrest undue grain-growth, while the effect of the pit is to delay the cooling through the critical range so as to give a controlled degree of toughness to the plate highly desirable to the end in view.

Additional alloying constituents, such as are customarily called "hardeners" and "softeners" can be employed if desired. If used at all I consider it preferable to use the hardeners such as chromium or manganese in the tread portion in order to decrease the likelihood of liberating the combined carbon therein; whereas such softeners as e. g. copper or aluminum might better be employed in the plate portion in order to reduce the time and temperature of treatment.

The process herein described results in a car-wheel which exhibits at different points the structures indicated in Fig. 5 hereof, namely: a hard circumferential portion 25 around the periphery of the tread, a gray-iron core 26 inside the tread and also inside the hub, and a plate of tough iron indicated at 27, which tough iron also overlies the grey-iron of the tread and hub. When the mold is first supplied with a small amount of unstable iron mixture the flange will also be converted to tough iron as shown at 28; in case this refinement be omitted the flange is similar in composition and physical properties to the tread. It may be noted here that one of the best ways of producing this hard tread is to employ chromium or manganese in the small ladle, since the increased stability of the cementite produced thereby is not gained at the expense of brittleness. Of course this hard iron mixture can obviously be melted in a special furnace, but it is often more convenient to stir merely into the small ladle the amount of material necessary to the end in view.

It should be remenbered, however, that in any part where it is desired to obtain toughness, primary graphite should not be allowed to appear; that is to say the cooling rate and the composition employed should be so chosen as to produce unstable white-iron in the portion which may be modified by the heat-treatment. Otherwise stated, after flake graphite has once been deposited throughout the metal there is no known heat-treatment whereby the metal can be rendered tough or ductile. Also when the stability of the iron mixture is such as to render it possible to produce white-iron castings even in a sand-mold, it is likewise very difficult to precipitate graphite therein by the employment of artificial heat; but an unstable iron mixture, when cast under chilling conditions which prevent segregation of graphite, can be altered into a tough and ductile condition with comparative ease, and by making only the parts out of this material wherein toughness and strength are necessary, and by making the other portions of the article of other compositions better specifically suited to their several natures and not susceptible of easy alteration, I am enabled to produce car-wheels of cast-iron combining the tread-hardness of chilled-iron, the plate-toughness of steel and the manufacturing-cost of cast-iron. It will be understood, however, that many changes in detail can be made without departing from the scope of my inventive idea and that I do not limit myself in any wise except as specifically recited in my several claims which I desire may be construed broadly each independently of limitations contained in other claims.

Having thus described my invention what I claim is:

1. A car-wheel having the wearing-surface of its tread portion made of white-iron containing carbides which are relatively stable as concerns decomposition by heat and its plate-portion made of white-iron containing carbides which are relatively unstable as regards decomposition by heat.

2. A one-piece integral cast-iron car-wheel having its hub made principally of gray-iron, its plate made of a white-iron which is comparatively easily decomposed by heating and the wearing-portion of its tread consisting of a white-iron which is comparatively resistant to decomposition by heat.

3. A blank for a car-wheel made of a one-piece integral iron casting, the plate being composed of chilled white-iron and the wearing-surface of the tread of an iron-composition capable of casting white in a sand mold.

4. A one-piece cast-iron blank for a car-wheel having its tread composed of white iron of a composition able to withstand without decomposition a heat-treatment which will decompose the white iron of the plate portion and having its plate portion composed of white iron of a composition which can be decomposed into graphite and pearlite by a heat-treatment which will not soften the tread.

In testimony whereof I hereunto affix my signature.

FRANK A. FAHRENWALD.