May 16, 1933. F. A. FAHRENWALD 1,908,741

CAR WHEEL AND METHOD OF MAKING SAME

Filed July 6, 1929

Fig. 1

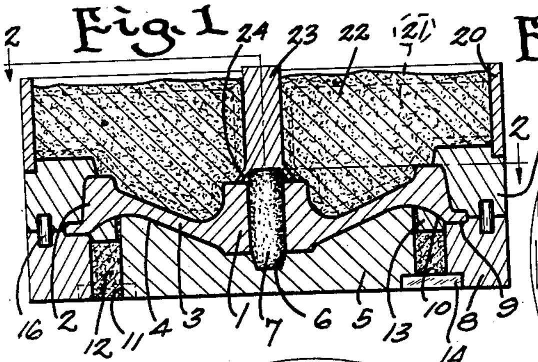


Fig. 2

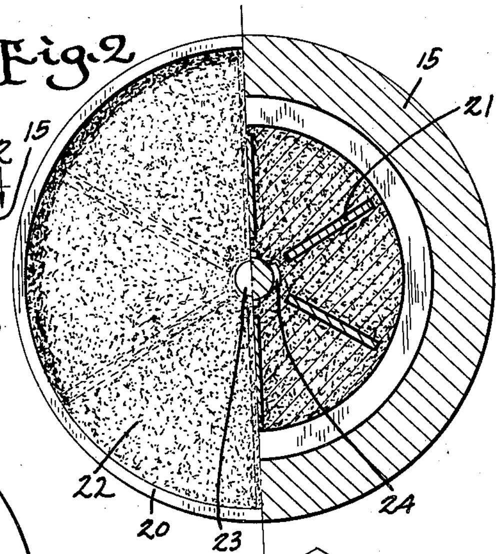


Fig. 3

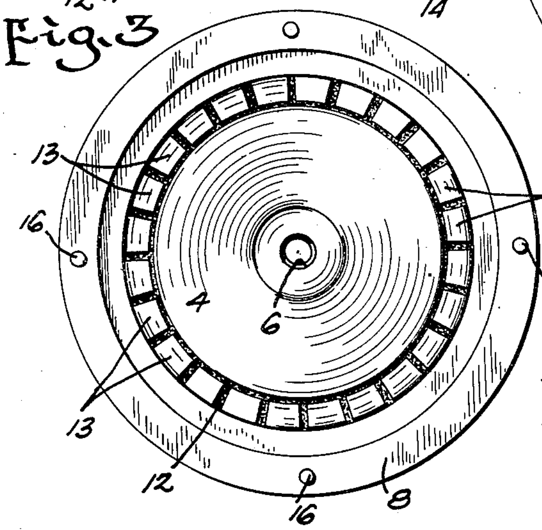


Fig. 3a

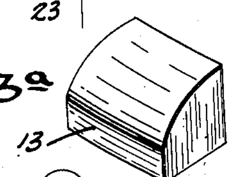


Fig. 5

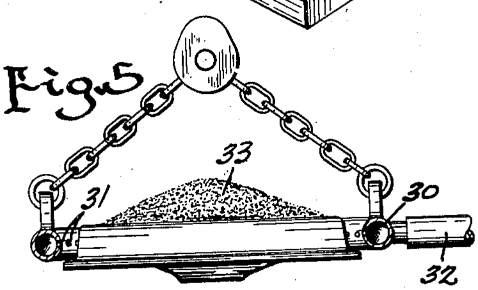


Fig. 4

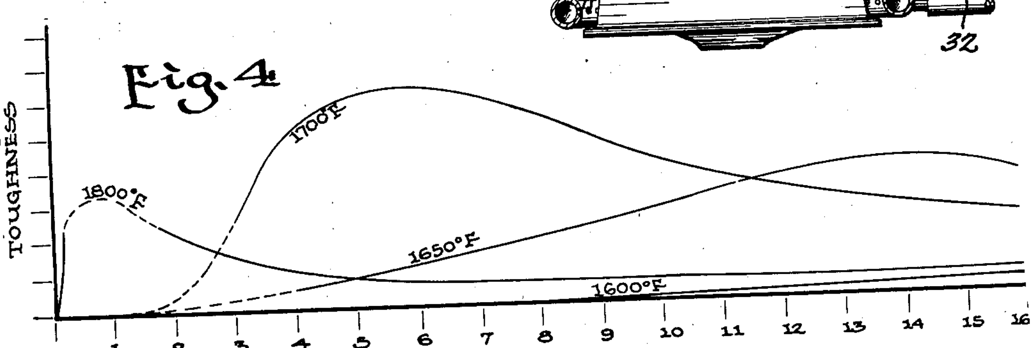
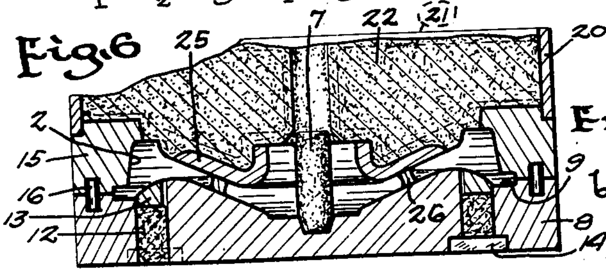


Fig. 6



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UNITED STATES PATENT OFFICE

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CAR WHEEL AND METHOD OF MAKING SAME

Application filed July 6, 1929. Serial No. 376,353.

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 from 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, with or without a hardened tread, while possessing a degree of toughness and ductility 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 strong plate; 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 an iron car-wheel which shall render the same tough and ductile and capable of withstanding present day requirements without substantial increase in its cost; the provision of a method of hardening the tread of a cast-iron car-wheel at the end of its manufacturing instead of at the start; the provision of a mode of improving the quality and strength of cast-iron car-wheels which shall fit conveniently into the established technique and equipment of car-wheel plants; 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 process steps explanatory of my improvements.

Fig. 1 is a vertical sectional view through the complete mold and pattern; Fig. 2 is a horizontal sectional view corresponding to the broken line 2—2 of Fig. 1; Fig. 3 is a plan view of the drag with cope and chiller removed; Fig. 3a is a perspective view of one of the wedge blocks constituting a part of the drag; Fig. 4 is a graph showing the relation between tensile strength, temperature, and time of treatment for a specimen composition of chilled cast iron; Fig. 5 illustrates a final optional step of local tempering of the tread; and Fig. 6 illustrates a modified mold including an auxiliary web-and-hub chiller.

The pattern may be made of any desired form provided only that it observes the standard relation of hub 1 and tread 2. The contour of the plate 3 which connects the two is relatively unimportant, provided, however, that for purposes of this invention it is preferably made of substantially uniform thickness and is preferably formed, at least on the bottom, with uniform surface configuration as indicated at 4, being at least devoid of abrupt shoulders. Instead of being cast in a mold which is made predominantly of sand and provided only with a tread-chiller, my process contemplates casting practically the entire wheel under chilling conditions, with the possible exception of part of the hub and a part of the tread-interior regarding which it is immaterial whether they be fully chilled or no. In the embodiment herein chosen for illustrative purposes I have shown the drag made almost entirely of metal and the cope made mostly of sand; although obviously this condition can be reversed and it is always possible and sometimes desirable to make both mold elements at least in part of metal and thereby intensify the chilling effect. However it facilitates the casting in some respects to make one of these mold elements crushable to reduce the danger that the casting may be disrupted upon cooling.

I have shown the middle part of the drag as consisting of a massive circular iron block 5 formed at its center with a core-print 6 for the hub-core 7, the outside of the drag consisting of an annular metal member 8 fashioned at 9 to form the rear face of the flange-portion of the tread. It is customary to dish the plate 3 considerably and to merge each face of the same into the tread by sweeping reverse curves 10. Unless carefully handled a rigid one-piece drag will sometimes cause a rupture of the casting at some point while the same is cooling, even though the cope be removed as soon as the entire wheel has solidified. For this reason I have shown an annular space 11 defined between the exterior of the part 5 and interior of the part 8, and rammed with sand 12, preferably reinforced adjacent the casting by wedge-shaped chiller-blocks 13 sufficiently spaced from each other and from the block 5 to permit the interposition of a layer of sand whose cushioning effect reduces the likelihood of fracture. Suitable spacers 14 are shown to hold the two parts of the drag concentric.

Next above the ring 8 is the tread-chiller 15, a massive one-piece iron ring, fashioned to give the desired shape to the working surface of the tread and of its flange, and to chill the same during the casting. This part is identical with the device now used as standard practice in the production of chilled-iron car wheels. Suitable dowel pins 16 are employed to attach the same to the ring 8. Resting on the chiller 15 is the cope portion 20 of the flask, also generally made of cast iron and provided with a large number of radially arranged cast iron plates 21 adapted to help support the sand but terminating short of the surface of the casting. The sand 22 is rammed herein in accordance with the established foundry practice. A header pattern 23 is located over the hub core 7 and terminates in a plurality of sprues 24 by which the casting is fed at several points while permitting ready separation of the header after pouring.

The hub core 7 is preferably made of crushable material such as the sand-core heretofore used, although a collapsible metal core can be employed in case it be felt desirable to chill the hub also.

The composition which I prefer to employ consists of:

Carbon	2.85 to 3.10%
Silicon	1.30 to .70%
Balance iron	
Sulphur	Not over .20%
Phosphorus	Not over .60%
Manganese	Not over 1. %

This is a slightly lower carbon and higher silicon mixture than is customarily used for cast-iron car-wheels at the present time. However, it is possible to use successfully, when proper care is exercised, the standard car-wheel iron formula which is:

Carbon	3.25 to 3.50%
Silicon	.70 to .90%
Balance iron	
Sulphur	Not over .20%
Phosphorus	Not over .60%
Manganese	Not over 1. %

It is also possible to decrease the carbon, to as low as about 2¼%, with proper increase in the silicon content. All these mixtures will cast grey in a sand-mold and white to a depth of one-half to one inch when chilled. When poured into the mold shown in this drawing the web should preferably become chilled all the way through; if not it may either be made thinner or the percentage of silicon may be decreased or a chiller 25 applied to the cope as shown in Fig. 6. Even though the plate is chilled only part way through the strength of the wheel can be improved, since even a small improvement is important. Ordinarily the hub, which is more massive than any other portion, will turn out grey at least in part, especially if the core be made of sand. The cope and the tread-chiller are lifted off at the earliest possible moment in order to enable the wheel to rise over the drag sufficiently to permit the necessary contraction adjacent the tread. The pouring gate is broken off while white-hot, and the entire wheel carried to a heat-treating furnace while still at least red-hot. Promptness in this is desirable for several reasons, among which are the saving of heat, and the increased danger of cracking due to internal strains if allowed to become unduly cool.

The wheel is immediately introduced into a furnace whereby it is raised to a temperature between 1600° (or better 1650°) and 1800° Fahrenheit and where it is left for a period of time from twenty minutes to several hours depending upon the temperature and the mixture and the extent of the chilling and the result desired. Fig. 4 of my drawing shows the relation of toughness to time of treatment at different temperatures for the preferred composition I have described. The result of this treatment is to decompose the cementite portions of the casting more or less thoroughly into graphite and pearlite. This breaking down is substantially complete when all parts of the wheel are maintained at a temperature of 1800° Fahrenheit for less than one hour with the composition stated, in case the same has been thoroughly chilled in the casting; and how much less than one hour would produce such complete decomposition of the combined carbon depends upon the temperature of the wheel when it is introduced into the furnace and the extent of the chilling and the relation of silicon to carbon in the alloy. At a temperature of 1700° Fahrenheit the complete decomposition of the cementite is not generally accomplished even by eight hours, and at a temperature of 1650° the action is very considerably slower; I do not consider any temperature substantially below this point as at all practical; indeed with some mixtures not effective, within any reasonable time.

However it is not necessary to effect a complete breaking down of the cementite or liberation of combined carbon. In the first place the maximum toughness is attained when at least a part of the carbon is still retained in the combined state, and in the second place increase of toughness much less than the maximum attainable would provide the factor of safety most sought for at this time. One condition which sometimes limits the life of a grey-iron car-wheel is the thermal expansion and contraction of its tread. While this is very small it should be remembered that the ductility of such grey-iron castings is practically nil and no treatment ever found for such castings has increased it. Even a small accession of ductility is enough to satisfy the essential requirement of a car-wheel and after this point added treatment is likely to be injurious. For example, the wheels ought not to be converted into graphite and ferrite as in malleableizing for two reasons, first because the process is long and expensive, and second because a malleableized wheel would not wear well and would be too soft and weak.

The extent to which this heat treatment is carried is a matter largely of choice on the part of the manufacturer. It should be remembered that a very small improvement in the ductility of the plate only of the present cast-iron wheels would overcome the most serious objections; although of course the toughness of the entire wheel is even more desirable. With any of the above compositions cast in the manner described an exposure for from one to four hours to an atmosphere of 1700° Fahrenheit is very satisfactory, though changes in compositions or in casting method require different treatments. The effect of the treatment is to decompose the non-pearlitic cementite with liberation of graphite, this graphite being left in the form of rather compact nodules occupying approximately the positions of the original cementite grains, and surrounded by a continuous phase of pearlite or other steel-like alloy depending upon the composition of the metal and the nature of the heat treatment. Due to the compactness of the graphite inclusions as compared with those of ordinary grey cast-iron, the resulting metal exhibits much greater tensile strength combined with a considerable degree of plastic flow under deformation and a greatly augmented toughness. However, these results are obtained only in those portions of the casting which have been cast white by chill. It has practically no effect on the grey portions of the casting which show primary graphite in flake form, and the effect on stable white-iron mixtures is extremely small. By "primary graphite" I mean that graphite which is deposited in flake or plate form during the original solidification or early cooling stages of the casting; by "secondary graphite" I mean that graphite which is liberated by the decomposition of primary cementite.

If the heat treatment should be continued sufficiently far the white iron portions would be converted wholly to graphite and ferrite as in malleableizing; but this is excessive. If arrested at an earlier stage the matrix metal consists of a steel composition resembling pearlite and by suitably controlling the cooling rate an increased hardness and wear-resistance can be secured. Modes of doing this will occur to anyone versed in working with steel. One good way is, after removing the wheel from the furnace to surround it with an annular fluid pipe 30 provided with jet orifices 31 on its interior and supplied with cooling fluid by a hose 32. I preferably use cold air for this purpose, but water or oil can be used if the holes 31 are sufficiently small. In this way the tread can be hardened locally while leaving the plate tough and strong. Owing to the considerable presence of combined carbon in the matrix metal which results when chilled white iron castings are heat treated in this manner it is necessary to control the rate of cooling in such a way as to prevent the plate from becoming brittle. If necessary dry sand can be piled thereon as shown at 33. Any desired succession of temperatures can be employed to produce, restrain or regulate grain-growth. It is also within my invention to allow the wheel to cool at such a rate as to leave all the matrix portions in a pearlitic or other steel-like condition. This means that the tread is soft and requires occasional dressing the same as a soft steel wheel, but the metal produced by this process machines readily and the wheels are so inexpensive as to render this a feasible course.

I have also used other alloying constituents, such as are customarily called "hardeners" and "softeners", and while I do not advocate them, I desire to point out that if one desires or if they be found accidentally in the scrap iron portion of the metal, they can be used if any one desires with the same manner and with the same limitations as in other cast-iron work. Such hardness as chromium, vanadium, manganese, or molybdenum render the cementite more difficult to break down and increase the time and temperature required. They also tend to neutralize the effect of the silicon and to enable more silicon to be used (and also more carbon) without producing initial grey iron. Such softeners as nickel, copper, or aluminum may reduce the amount of silicon (or carbon) permissible or reduce the time or temperature of treatment.

It will be understood that I do not limit myself to any of the details herein described except as the same are 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 cast-iron car-wheel having a chilled tread and also having other portions integral therewith which contain both combined carbon and a substantial amount of free graphite of which not more than a substantially negligible portion occurs in flake form.

2. A car-wheel having a chilled tread and an integral plate connecting its hub and tread, at least one face of said plate consisting of cast-iron which is substantially devoid of primary graphite but contains both combined carbon and secondary graphite, the latter in nodular form.

3. A car-wheel having a chilled tread and an integral plate connecting its hub and tread, at least one face of said plate consisting of cast-iron containing both combined carbon and a substantial amount of free graphite of which not more than a substantially negligible portion occurs in primary form.

4. A car-wheel having a chilled tread and an integral plate connecting its hub and tread, at least one face of said plate consisting of a steel-like matrix having nodular masses of secondary graphite submerged therein.

5. A car-wheel having a chilled tread and an integral plate connecting its hub and tread, said plate consisting of a metal having the average chemical composition of cast-iron and exhibiting a microscopic structure characterized by a continuous pearlitic

metal phase in which are submerged rounded masses consisting partly of cementite and partly of graphite.

6. A cast-iron car-wheel having a chilled tread and an integral plate connecting its hub and tread, said plate consisting of partially decomposed cementite masses embraced by a steel-like matrix.

7. A car-wheel having a chilled tread and an integral plate connecting its hub and tread, said plate consisting of a metal having the average chemical composition of cast-iron and exhibiting an internal structure characterized by the presence of cementite and free secondary graphite confined within nodular or rounded regions.

8. A one-piece car-wheel made of a metal having at each point the average chemical composition of cast iron, the matrix metal of the tread portion having the physical characteristics of hardened steel and the matrix metal of the plate portion having the physical characteristics of annealed steel, the graphite content of both portions being substantially all of secondary origin.

9. A cast-iron car-wheel characterized by the absence at least from some portion of the plate of primary graphite and the presence in said plate of secondary graphite and primary cementite.

10. A cast-iron car-wheel having portions which are substantially devoid of primary graphite but contain both combined carbon and secondary graphite, the latter in nodular form.

In testimony whereof I hereunto affix my signature.

FRANK A. FAHRENWALD.