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METHOD OF HEAT-TREATING RAILROAD WHEELS

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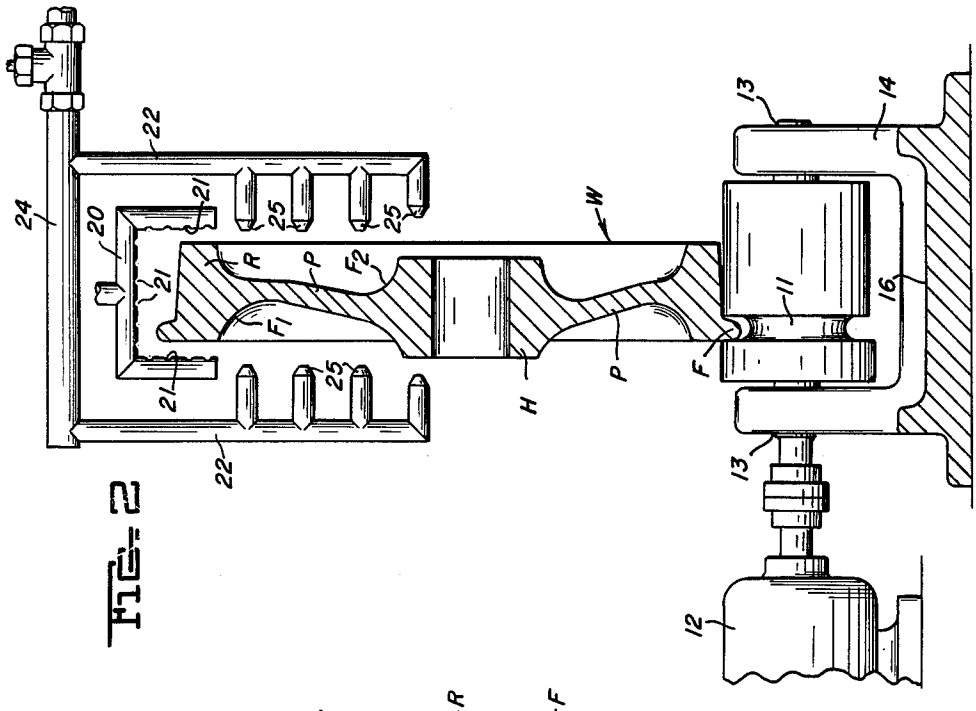


FIG. 2

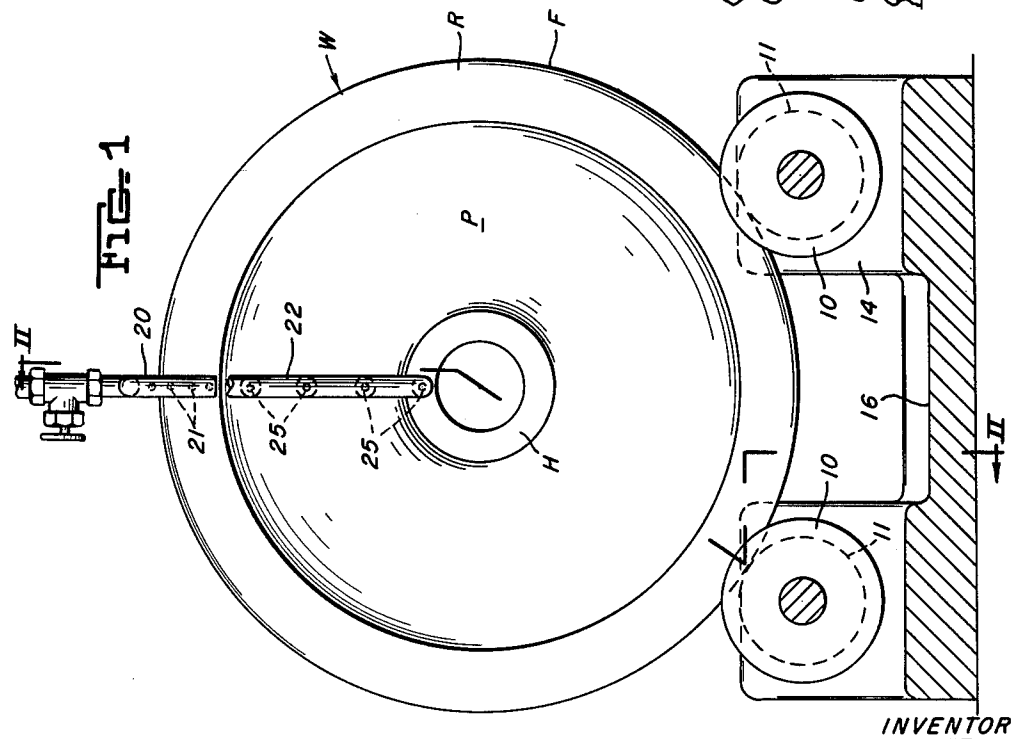


FIG. 1

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METHOD OF HEAT-TREATING RAILROAD WHEELS

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This invention relates to a method for heat-treating metal wheels and, in particular, to a heat-treatment for steel railroad wheels that provides improved resistance to plate-fatigue and explosive failures.

In service, trains are usually stopped by applying brake shoes directly against the tread of the wheel. The frictional heat resulting from this operation produces temperature gradients within the rims of the wheels that cause the formation of circumferential tensile stresses in the rims. Thermal cracks form initially as a result of these stresses. If subsequent tensile stresses are sufficiently high and if thermal cracks are present, a sudden propagation of the thermal cracks occurs, commonly known as explosive failure. The explosive failure may propagate in a radial direction through the rim, plate, and hub or circumferentially in the plate and join other thermal cracks in the rim. Explosive failures often result in train derailments.

Plate fatigue failures usually develop at the back-rim-plate fillet and at the front-hub-plate fillet (known as the critical plate fillets). These failures are caused primarily by repeated tensile stresses that are produced at these critical plate fillets by thermal expansion of the rim during braking. Cyclic stresses produced in the plate by the wheel rolling on the rail contribute to these failures, but these stresses are not sufficient to cause failure in the absence of tensile stresses produced by braking. The plate fatigue failures may propagate circumferentially in the plate or join thermal cracks in the rim. Plate fatigue failures can also result in train derailments.

Industry has in general employed two methods of heat-treating railroad wheels to increase hardness and partially control residual-stress patterns, as a means for obtaining improved resistance to explosive and plate fatigue failures. Both heat-treatments involve first austenitizing the wheels at a suitable temperature for approximately one hour and then quenching. In one method the quenching step comprises a rim-quenching treatment, commonly known as rim toughening, and in the other method the wheel is completely immersed in oil or other quenching medium which is commonly known as oil quenching.

In rim toughening, only the rims are quenched by rotating the wheels while in a vertical position with only the lowest portion of the wheel immersed in water to the rim-plate edge. In oil quenching, the entire wheel is quenched by immersion in an oil bath. Wheels which have been quenched in either manner from the austenitizing temperature are then tempered at a suitable sub-critical temperature for approximately two hours and slow-cooled in pits for about twenty-four hours. In the rim toughening method only the rims of the wheels are hardened; whereas, the rims, plates, and hubs of oil-quenched wheels are hardened.

Both methods of heat-treatment produce over-all hoop compressive stresses in the rim of the wheel, but these compressive stresses are considerably higher in rim-toughened wheels than in oil-quenched wheels. Residual hoop compressive stresses in the rims of railroad wheels are desirable because they offset the thermally developed tensile stresses that produce thermal cracking and explosive failure. Residual radial tensile stresses are present at the critical plate fillets of rim-toughened wheels, but residual radial compressive stresses are present at these

locations in oil-quenched wheels. Residual radial compressive stresses at the critical plate fillets are desirable, because they offset the tensile stresses that cause plate fatigue failure. However, residual radial tensile stresses are undesirable, because they add to the stresses that cause plate fatigue failure.

Results of service tests and full-scale laboratory tests have demonstrated that rim-toughened wheels have better resistance to explosive failure than oil-quenched wheels. However, the service tests have demonstrated that the oil-quenched wheels have better resistance to plate fatigue failures than do rim-toughened wheels. Because plate fatigue failures occur less often than explosive failures, the use of rim-toughened wheels has generally been more satisfactory than the use of oil-quenched wheels. However, wheels are needed with better resistance, both to explosive failure and to plate fatigue failure, than the conventional rim-toughened wheels.

It is therefore a principal object of this invention to provide a method of heat-treating steel wheels to impart improved residual-stress patterns.

A related object of this invention is the provision of a method of treating steel wheels which permits control of the residual-stress patterns developed.

A further more specific object of this invention is the provision of a method of differentially quenching steel wheels from sub-critical tempering temperatures to produce desired stress patterns.

Yet another object of this invention is to provide a method of improving the stress patterns in the plate portion of a steel wheel without sacrificing beneficial stress patterns in the rim portion of the wheel.

Other objects and advantages of the invention will become apparent from the following description and accompanying drawings, in which:

FIGURE 1 is an elevational view partially in section somewhat schematic of a wheel supported and positioned to be quenched according to this invention;

FIGURE 2 is a sectional view taken substantially along the plane of line II—II of FIGURE 1 showing the wheel positioned to be quenched.

I have found that by differentially quenching the rim, plate and hub of a steel wheel from the tempering temperature, preferably with water spray, after the wheel has been previously quenched in a conventional manner from the austenitizing temperature, desirable controlled residual-stress patterns are produced. Further, because the quenching is from below the critical temperature, the quenching rate can be varied without affecting the microstructure or other physical properties of the steel wheel developed at the tempering temperature.

Referring now to FIGURES 1 and 2, an apparatus suitable for quenching wheels according to this invention is shown supporting a wheel W in position for quenching. The wheel W includes a rim portion R, a plate P and a hub H. The rim portion R conventionally has a flange F, and for convenience, the plate P and hub H will hereafter be referred to collectively as the plate-hub portion. The wheel W is supported in upright position by a pair of rollers **10** each having a groove **11** adapted to engage the flange F of the wheel. One of the rollers **10** is driven by a motor **12** and the other roller is freely rotatable. The rollers **10** are journalled by bearings **13** in a frame **14** which defines a water catching trough **16**.

A first U-shaped spray head pipe **20** is provided which partially surrounds the rim of the wheel and has a plurality of openings **21** arranged to spray liquid onto the rim portion R of the wheel. A pair of lateral spray heads **22** are arranged on opposite sides of the wheel and are connected to a central header **24**. Each of the spray heads **22** has a plurality of nozzles **25** adapted to direct liquid spray onto the plate and hub of the wheel.

The wheel to be heat-treated is heated to the tempering temperature which must be at least 600° F. in order to provide the necessary physical properties but must be less than the lower critical temperature of the steel, the preferable temperature being between 850° F. and 950° F. When the wheel has been heated to this tempering temperature it is placed on the rollers **10** and the motor **12** is started and regulated to rotate the wheel W at about 60 r.p.m. The rim R and the plate-hub portion are then spray quenched as the wheel is rotated. Two wheels which had previously been rim-toughtened by rim-quenching from above the austenitizing temperature were differentially quenched from between 850° F. and 950° F. according to this invention. The quenching of the first wheel was initiated on the rim portion with water being sprayed from the U-shaped pipe **20** onto the rim at a rate of about 10 gallons per minute as the wheel was rotated. Five seconds after the quenching of the rim had started water was sprayed from the nozzles **25** onto the plate-hub portion. Water was also fed from these nozzles at a total rate of 10 gallons per minute. The quenching of the rim from the U-shaped nozzle **20** was discontinued two minutes after it started with the rim thereafter air cooling; and the plate-hub portion was quenched for five minutes. In this way the plate-hub portion was quenched to ambient temperature before the rim portion reached ambient temperature. The stresses developed by this quench are shown in Table I below. The other wheel was similarly treated except that the quenching of the plate-hub portion was delayed for fifteen seconds instead of five seconds, the other times and rates being the same. This also resulted in the plate-hub portion reaching ambient temperature before the rim portion. The results of this test are also shown in Table I below. For comparison, Table I also shows stresses developed in a conventionally rim-toughtened wheel and a conventionally oil-quenched wheel. The stresses in the rim are measured by the radial saw-cut-strain test. In this test 2 inch gauge lengths are marked tangentially on both rim faces. The rim is then machined as a concentric section from the wheel and a radial section is sawed from between the gauge lengths. The change in gauge length is a measure of the overall hoop strain in the rim. Compression or rim closure stress is indicated by a minus sign and tension or rim opening stress is indicated by a plus sign. The radial stresses at the back rim-plate fillet F1 and front hub-plate fillet F2 are determined by cementing 45° rectangular rosette electrical-resistance strain gauges at these locations. The principal radial residual stresses are calculated from stress relaxation measurements that are made after sections containing the gauges are machined from the wheel.

TABLE I

Wheel Treatment

	Rim Stresses	Back Rim-Plate Fillet Stresses	Front Hub Plate Fillet Stresses
Rim-Toughened: 2 Min. Rim-Quench, 5 Min. Plate-Hub Quench, 5 Sec. Delay	−0.490	−23.3	−18.9
Rim-Toughened: 2 Min. Rim-Quenched, 5 Min. Plate-Quench, 15 Sec. Delay	−0.636	−1.3	+20.9
Rim-Toughened: Slow-Cooled from Tempering Temp.	−0.520	+31.5	+35.5
Oil-Quenched: Slow-Cooled from Tempering Temp	−0.300	−24.0	−12.5

The most desired stress patterns in the rim, i.e. stress patterns which are least susceptible to explosive failure, are high compressive stresses in the rim. The more negative the value for the rim stresses the more desirable as far as explosive failure is concerned. Also, the higher the compressive stresses at the back rim-plate fillet and the front hub-plate fillet the more resistant the wheel will be to plate fatigue failure. These are also designated

by minus figures and hence, the more negative this value the more desirable it is. It can be seen from Table I above that the differential quenching with a fifteen seconds delay yields greater compressive hoop stresses in the rim than are obtained with rim-roughened wheels subjected to conventional slow-cooling from tempering temperature. Also, substantial improvements in the stress values at the back rim-plate fillet and front hub-plate fillet are obtained. With the five seconds delay the hoop compressive stresses are not quite as favorable as those developed by conventionally rim-toughening and slow-cooling but an extraordinary increase is obtained in the desirable stresses at the two critical fillets. Also, the wheel quenched with a five seconds delay has better hoop compressive stresses in the rim than the conventionally oil-quenched wheel slow-cooled from the tempering temperature and about the same or slightly better stresses at the critical fillets. Thus, it can be seen that by differentially quenching the rim and the plate-hub portion of the wheel from the tempering temperature a substantial increase can be obtained in the desirable stress patterns developed.

Another indication of the improved results of quenching according to this invention is shown in the increased resistance of the wheels to explosive failure during drag-brake testing. In drag-brake testing a notch is machined in the rim of the wheel to simulate a thermal-crack. The wheel is then subjected to drag-braking cycles until the wheel fails explosively or until excessive tread wear precludes further testing. Each drag-braking test is conducted at a constant speed of 45 m.p.h. with diametrically opposed cast-iron brake shoes being applied for fifty seconds out of each minute for a tolal of thirty-five minutes. The wheel is then cooled for a period of thirty minutes. Table II below compares test results obtained on a Class B and Class C composition rim-toughened railroad wheels each of which had a two minute rim-quench and a five minute plate-hub portion quench having a fifteen seconds delay after tempering with conventionally rim-toughened railroad wheels of Class B and Class C compositions slow-cooled after tempering. The number of tests needed to produce explosive failure for the conventional wheels is the average of several tests on several wheels with the maximum number of tests for the Class B composition being about forty-five and for the Class C composition about twenty-five.

TABLE II

Heat Treatment	Composition	No. of Drag-Braking Tests to Produce an Explosive Failure
Rim-Toughened: Slow-Cooled after Tempering	[1] B	40 (Average)
Do	[1] C	15 (Average)
Rim Toughened: Quenched after Tempering, 5 Min. Plate-Hub Quench, 2 Min. Rim-Quench, 15 Sec. Delay	[1] B	[2] 70+
Do	[1] C	[2] 70+

[1] Class B composition: C, 0.57–0.67%; Mn, 0.60–0.85% P, 0.05% Max.; S, 0.05% Max.; Si, 0.15% Min. Class C composition: C, 0.67–0.77%; Mn, 0.60–0.85%; P, 0.05% Max.; S, 0.05% Max.; Si, 0.15% Min.
[2] Did not fail after 70 tests; testing discontinued due to tread wear.

The results shown in Table II above clearly indicate the enhanced resistance to explosive failure of wheels treated according to this invention.

It has been determined that when quenching according to this invention it is critical that the quench of the rim portion start at least as soon as the quench of the plate-hub portion. It is also critical that the plate-hub portion be quenched with sufficient rapidity to reach ambient temperature before the rim portion reaches ambient temperature. When these two critical conditions exist there will be inherently developed desirable stress patterns in both the rim and the plate-hub portions. However, by varying the rates of flow of the quenching media, the

delay times, and the total time of quenching of the rim the actual stress pattern can be varied to give the most desirable combination of hoop compressive stresses in the rim portion and compressive stress patterns in the plate portion. It is even possible by selecting proper flow rates to start quenching both the rim portion and the plate-hub portion together but of course the plate-hub portion must reach ambient temperature before the rim portion does, as was indicated above. It will be apparent that by varying the variables listed above different stress combinations and patterns can be obtained depending upon the balance required between rim stresses and critical fillet stresses.

One of the outstanding advantages of this method of differential quenching resides in the fact that the quenching is used solely to produce desirable stress patterns. The variation of the quenching rates and delays will not result in any material change in the micro-structure of the wheel developed at the selected tempering temperature. Thus, there need be no consideration given to any possibility of obtaining undesirable physical properties if the quenching rates and times are varied. This is in contra-distinction to the prior art practices of quenching from above the austenitizing temperature and attempting to control the stress patterns by this quenching. Since rate of quenching and delays in quenching from above the austenitizing temperature affect the micro-structure developed upon quenching from any given temperature above the critical temperature this quenching in the prior art from above the austenitizing temperature must be designed to produce a desirable, or at least an acceptable, micro-structure; and, any quenching method which does not produce an acceptable micro-structure is not acceptable irrespective of how beneficial the resulting stress pattern may be. Thus, with prior art methods very real limits were imposed upon the quenching methods with the result that they could not be changed if such a change resulted in an undesirable micro-structure; and even if changes could be made the result was a less than satisfactory compromise between the micro-structure and stress patterns. However, micro-structure need be given no consideration when working within the limits defined in this invention.

It has further been determined that the desirable stress patterns of this invention are achieved irrespective of the previous hardening treatment. The desirable stress patterns are produced if the wheel has been rim-toughened or oil-quenched from the austenitizing temperature.

While one embodiment of my invention has been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A method of heat-treating after hardening a steel railroad wheel having a rim portion and a plate-hub portion, which method comprises the steps of heating the wheel to a temperature between 600° F. and the lower critical temperature of the steel, differentially quenching both the rim portion and the plate-hub portion from said temperature, said quenching being characterized by the quench of the rim portion commencing at least as soon as the quench of the plate-hub portion, and the quench of the plate-hub portion being sufficiently rapid to bring the plate-hub portion to ambient temperature before the rim portion reaches ambient temperature.

2. The method of claim 1 wherein the quenching of the rim portion is ceased before the rim reaches ambient temperature and thereafter the rim is air-cooled to ambient temperature.

3. A method of heat-treating after hardening a steel railroad wheel having a rim portion and a plate-hub portion, which method comprises the steps of heating the wheel to a temperature between 850° F. and 950° F., water spray quenching the rim portion from said temperature at the rate of about 10 gallons per minute and continuing said quench of the rim for about two minutes, commencing to water spray quench the plate-hub portion between five and fifteen seconds after the start of the quench of the rim portion, and continuing the quenching of the plate-hub portion for about five minutes at the rate of about 10 gallons per minute.

4. The method of claim 1 wherein quenching comprises water spray application.

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