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(54) **Title:** VEHICLE WHEELS HAVING NON-CONSTANT THICKNESS RIMS

(57) **Abstract:** The present invention is a vehicle wheel having a non-constant thickness through the outer rim when the outer rim is viewed in a sectional profile wherein the non-constant thickness allows a significant reduction of the mass momen of inertia of the wheel, while adequately addressing the structural requirements of th vehicle wheel.

VEHICLE WHEELS HAVING NON-CONSTANT THICKNESS RIMS

FIELD OF INVENTION

This invention relates to vehicle wheels having non-constant thickness rims

BACKGROUND

The present invention relates to the field of wheels for motorized vehicles, and more particularly to wheels for motorized vehicles using pneumatic tires mounted to an outer rim of such wheel, wherein the wheel utilizes bead seats to engage beads formed on inner walls of such pneumatic tires.

In order to provide acceptable performance characteristics, motor vehicles typically use wheels on which pneumatic tires are mounted. In the interest of maintaining manufacturability, as well as necessary strength, such wheels are typically formed from steel. The weight of such wheels, however, can have an adverse impact on the efficiency of a vehicle to which the wheels have been mounted.

The mass of the wheels controls the mass moment of inertia of the wheels. In particular, the greater the mass of the wheels at their outer extent, the greater the mass moment of inertia of the wheel. The greater the mass moment of inertia of the wheel, the more energy which must be imparted to the wheel as the vehicle accelerates. Additionally, the weight of the wheel can have effects on the suspension dynamics, with attendant adverse affects on the ability of the vehicle suspension to efficiently engage the vehicle to the road surface.

Although lighter wheels obviously have advantages, such wheels additionally have disadvantages, particularly with regard to wheel strength. As the wheels rotate, they are subjected to cyclic loadings, i.e., the weight of the vehicle applied through the rim is always oriented towards the ground, such that the bottom of the rim is loaded. As the rim rotates during travel, this load is successively applied and released from a given arc segment of the wheel, as the wheel rotates. The frequency with which this loading and unloading occurs is a function of the vehicle speed, i.e., the faster the vehicle is moving, the greater the rotational speed of the wheel, and the greater the frequency of the loading/unloading cycle.

Such cyclic loads can induce fatigue failures in the wheels. Fatigue failures are controlled by the magnitude of the load, and the number of times with which the load is applied and removed. Accordingly, fatigue failures may be of more interest with respect to wheels designed for commercial applications, where high loads and long required operational lifetimes are the norm.

While fatigue failures can result from axial stresses, greater concern exists where the fatigue loading induces a bending moment. Wheels for commercial vehicles typically have an outer shape, such at that shown in Figure 1, showing the standardized profile for an ETRTO standard commercial vehicle wheel, as shown in the European Tyre and Rim Technical Organisation Standards Manual (2007), pp R.17-R.19. The profile of the rim may have a well section, an inner bead seat, an outer bead seat, and a cylindrical section joining the well section. A center disc may be attached to the cylindrical section, with the cylindrical section having a mounting flange for engaging the center section to a vehicle axle.

The sidewalls of a tire mounted to the wheel apply loads to the bead seats. As the bead seats are displaced laterally from the junction between the center disc and the rim, the material of the rim experiences a cyclic bending between the load application points at the beads, and the junction between the center disc and the rim. The stresses resultant from this bending moment are greatest adjacent to the junction between the center disc and the rim.

The outer rim of a wheel is typically formed by bending a flat piece of steel into a circular shape and flattening the ends to facilitate a butt welding process. The outer profile of the wheel may be formed prior to welding, such as by forming the profile on the piece of flat stock, then rolling the flat stock to bend it into a circular shape, followed by the ends of the flat stock being but welded together. Alternately, through an operation known as spinning, the wheel may be formed by first rolling and joining the ends of the flat stock, then imparting the profile by forcing the tubular section against an outer mandrel while the tubular section is being rapidly spun, wherein a cylindrical section of metal is formed against a mandrel, allowing more complex profiles to be created.

SUMMARY OF THE INVENTION

The present invention may be embodied in a wheel for a motor vehicle that is adapted to receive a pneumatic tire. The wheel may have an outer rim and a center disc. The outer rim may have a well section, with the well section having a base and two sidewalls and a well section thickness. The outer rim may also have a first bead seat for receiving a bead on a side wall of a tire and a second bead seat for receiving a second bead on a side wall of a tire. The outer rim may also have a first angled transition section joining the well section and the first bead seat, and a second angled transition section joining the well section and the second bead seat.

The center disc may be joined to the outer rim adjacent to the well section. The first angled transition section may have a thickness less than the thickness of the well section thickness, and the second angled transition section may also have a thickness less than the thickness of said well section thickness.

The present invention may alternately be embodied in a wheel for a motor vehicle having an outer rim and a center disc. The outer rim may have a well section, with the well section having a base and two sidewalls and a well section thickness. The outer rim may also have a first bead seat for receiving a bead on a side wall of a tire and a second bead seat for receiving a second bead on a side wall of a tire. The outer rim may also have a first angled transition section joining the well section and the first bead seat, and a second angled transition section joining the well section and the second bead seat.

The outer rim may additionally have a cylindrical section, wherein the center disc is joined to the outer rim adjacent to the cylindrical section. The first angled transition section may have a thickness less than the thickness of the well section thickness, and the second angled transition section may also have a thickness less than the thickness of said well section thickness.

The present invention may also be embodied in a process for forming wheels for motor vehicles, utilizing the steps of: determining a desired fatigue life for the wheel; determining expected loading characteristics for the rim; determining via finite element analysis optimized thicknesses for sections of the rim, the finite element analysis utilizing material properties based on work hardened materials from a spin forming process; forming an outer rim blank by rolling a flat piece into a tubular shape; forming a well section in the blank, the well section having a base and two sidewalls, the well section further having a well section thickness; forming a first bead seat for receiving a bead on a side wall of a tire; forming a second bead seat for receiving a bead on a side wall of a tire; forming a first angled transition section joining the well section and the first bead seat; forming a second angled transition section joining the well section and the second bead seat; and joining a center disc to the rim adjacent the well section; wherein the first angled transition section has a thickness less than the thickness of the well section, and the second angled transition section has a thickness less than the thickness of the well section thickness wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

DESCRIPTION OF THE FIGURES

Figure 1 illustrates an ETRTO Standard wheel as known in the prior art.

Figures 2A and 2B illustrate an embodiment of a vehicle wheel having a non-constant thickness rim according to the present invention, shown in an isometric view, with Figure 2A showing the rim with the center disc removed, and Figure 2B showing the rim with the center disc installed.

Figure 3 illustrates the rim of the of the vehicle wheel of Figure 2 shown in cross sectional profile.

Figure 4 illustrates a non-constant thickness rim according to the present invention, wherein the center disc is joined to the well region.

Figure 5 illustrates a non-constant thickness rim according to the present invention, wherein the center disc is joined to a cylindrical section.

DETAILED DESCRIPTION OF THE INVENTION

The accompanying drawings are intended to provide further understanding of the invention and are incorporated in and constitute a part of the description of the invention.

The drawings illustrate an embodiment of invention and together with the description illustrate principles of the invention.

The drawings should not be taken as implying any necessary limitation on the essential scope of invention.

The drawings are given by way of non-limitative example to explain the nature of the invention.

For a more complete understanding of the instant invention reference is now made to the following description taken in conjunction with accompanying drawings.

The various feature of novelty which characterize the invention are pointed out specifically in the claims which are a part of this description. For a better understanding of the invention, its operating advantage, specific objects obtained by its use, reference should be made to the drawings and descriptive matter in which there are illustrated and described preferred embodiments of invention.

Referring now to the drawings, wherein like numerals designate identical or corresponding parts throughout the referred views, in Figures 2A and 2B there is shown a wheel according to an embodiment of the present invention. The wheel may include an outer rim 210 and a center disc 240. The center disc 240 may be provided with a central bore 250 and a mounting flange 260 for mounting the wheel onto a vehicle axle. The wheel may have an inner bead seat 230 and an outer bead seat 220. The size of the wheel may be characterized by the diameter of the bead seats, as well as by the distance between the inner bead seat and the outer bead seat.

Figure 3 illustrates a cross-sectional view of the rim of a notional wheel according to the present invention. The rim 300 includes an inner bead seat 310 and an outer bead seat 320. A center well 330 may be provided to assist in the mounting of tires onto the rim. An inner transition section 340 may be provided to connect the center well section 330 with the inner bead seat 310. An outer transition section 350 may be provided to connect the center well section 330 to the outer bead seat 320. An inner flange 360 may be provided outboard of the inner bead seat 310 to assist in retention of a tire mounted to the wheel. An outer flange 370 may be provided outboard of the outer bead seat 320 to assist in retention of a tire mounted to the wheel.

A center disc may be joined to the rim adjacent the well. The center disc may be welded to the rim, or attached utilizing other means commonly used in the wheel manufacturing industry. The center disc may have a bore adjacent the centroid of the center disc, and mounting provisions for engaging the center disc to an axle, such as holes for lug nuts to retain the wheel to an axle.

The center well section 330 may be a u-shaped section, having a diameter at the base of the well that is less than the outer diameter of the legs which form the sides of the well section. A bore for a valve stem may be provided in a sidewall of the center well section, or through the inner or outer transitions sections.
When a tire mounted to the wheel rests on the ground, a contact patch (not shown) is formed by one portion of the tire resting on the ground. The reaction force of the tire on the ground is transferred through the side walls (not shown) of the tire to the bead seats of the rim. This load is transferred through the rim to the center disc. As the loads imparted by the side walls of the tires are offset from the location of the junction between the center disc and the rim, a bending moment is created across the rim. As the wheel rotates, such as when a vehicle to which the wheel is mounted drives, this loading shifts from one section of the tire to the next section. As the wheel completes

a full rotation, the original segment is once again loaded. Accordingly, the loading on a given section of the wheel is cyclic, loading and releasing once each revolution.

This cyclic loading creates issues with respect to fatigue loading, or the failure of the material from which the rim is formed through crack propagation resultant from cyclic loading. The crack propagation is related to the number of loading cycles to which the part is subjected, as well as the bending stresses and material properties. The bending stresses are related to the material thickness. Accordingly, thicker material is required to withstand higher bending stresses, while lower bending stresses can be sustained by thinner materials.

As the weight of a wheel, and the distance of the individual sections of the wheel from the center of rotation, define the mass moment of inertia of the wheel, reducing mass at locations furthest from the center of rotation provides the greatest benefit in reducing the mass moment of inertia of the wheel. As discussed above, reducing the mass moment of inertia of the wheel reduces the amount of energy necessary to accelerate or decelerate the rotational velocity of the wheel, as well as may provide additional benefits.

While fatigue loading is a prime consideration, other stresses which may be generated within the wheel must also be accommodated. For example, the greater the rotational speed of the wheel, the greater the forces generated on the rim of the wheel through centrifugal forces. Vehicle cornering may result in lateral loading of the rim.

Furthermore, loads may be generated on the outer surface of the rim through imposition of pressurized air against the outer surface

As shown in Figure 3, the rim profile is made with varying thickness to reduce the weight at the farther region to reduce the mass moment of inertia for the rim. Appropriate thicknesses are determined through analysis of the loads to be applied to the wheels, such as through finite element analysis, and consideration of the required fatigue life of the rim section. The fabrication process for forming the profile may be selected such that work hardening of the rim material improves the strength of the material, particularly in areas of reduced thickness, to provide improved material characteristics to allow strength and fatigue resistance criteria to be met in spite of reduction in the thickness of the rim.

Finite element analysis allows for the specific geometry of the rim to be modeled, including consideration of static and dynamic loads, and material properties. Typically, when finite element analysis is conducted on a design, an assumption is applied that the material properties are homogenous, i.e., constant throughout the design. In the present case, and in particular where work hardening changes material properties in localized regions, applying non-homogenous material properties in the finite element analysis model allows the improvements in material properties resultant from work hardening to be considered, such that further optimization of the required thicknesses of the material making up the outer rim can be used to minimize the required thicknesses of the outer rim section.

The use of a spinning process to form the rim can provide such enhanced material properties, enhancing the ability to reduce the thickness of the rim, while providing an efficient manufacturing process for forming a non-constant thickness rim section.

In the embodiment shown in Figure 3, and using a wheel having a distance between bead seats of approximately 8 ¼ inches and a bead seat diameter of approximately 22 ½ inches the relationships between the thicknesses can be shown. For an optimized wheel having a joint formed between the center disc and the rim adjacent to the center of the well section, and utilizing the proportions approximated in the Figure, the ratios between the thicknesses of the various sections can be shown as below:

Table 1: Optimized Wheel Thicknesses

Location Description	Figure Ref.	Proportionate Thickness
Inner Transition Section	A	.61t
Well Region	B	.71t
Cylindrical section	C	.96t
Outer Transition Section	D	.61t

Where "t," a notional base thickness, is dependant on the expected loading for the wheel.

For comparison, the thicknesses of an ETRTO standard wheel are as follows, using similar sections as identified in Figure 1:

Table 2: ETRTO Standard Thicknesses

Location Description	Figure Ref.	Proportionate Thickness
Inner Transition Section	A	1.0t
Well Region	B	1.03t
Cylindrical section	C	1.0t
Outer Transition Section	D	1.0t

It can be noted that for the configuration shown, the well section may be made thinner to provide the additional benefit of increasing clearance space for brake equipment, such as disc brakes, mounted within the center of the wheel, while maintaining maximized clearance for mounting wheels as formed by the well section.

Based on the ETRTO Standard rim as shown in Figure 1 formed by a roll and weld process, as compared against the rim of the present invention having been formed by the weld and spin process, the physical properties of the rims at the same positions as described above are comparatively as follows, wherein the differences in the material properties are resultant from the spin forming process:

Table 3: Comparative Physical Properties

Physical Property	ETRTO Rim	Improved Rim	ETRTO Rim	Improved Rim
	Matl. Hardness (BHN)		Matl. Strength (UTS)	
Inner Bead Seat	H1	1.77 H1	S1	1.67 S1
Well Section	H1	1.80 H1	S1	1.52 S1
Cylindrical Sect.	H1	1.74 H1	S1	1.43 S1
Outer Bead Seat	H1	1.78 H1	S1	1.66 S1

As can be seen, the spin forming process imparted significant work hardening of the material, which resulted in significant increases to the ultimate tensile strength at the spin formed region. Furthermore, the weight of the rim section using the non-constant thickness is only approximately 78% of the ETRTO Standard rim, which greatly decreases the mass moment of inertia of the rim. Finally, the fatigue life to failure of the compared rims has been determined to be increased between 17 and 20% by using the spin formed non-constant thickness rim section when cornering force fatigue life and radial fatigue life are compared.

Although Figure 4 illustrates the center disc 410 being joined to the rim at the well section 420, the present invention is not limited to such a configuration. In particular, the center disc 510 may be joined to the rim with the cylindrical section 520, such as is shown in Figure 5. Changing to this location may necessitate matching the thickness of the disc with that of the joining region. Appropriate thicknesses may be determined by analysis of the loads applied to the wheel, such as through using finite element analysis as discussed above.

It is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be regarded as falling within the scope of the invention as defined by the claims that follow.

WE CLAIM:

1) A wheel for a motor vehicle, said wheel being adapted to receive a pneumatic tire, said wheel comprising a rim and a center disc, wherein said rim comprises:

A well section, said well section having a base and two sidewalls, said well section further having a well section thickness;

A first bead seat for receiving a bead on a side wall of a tire;

A second bead seat for receiving a bead on a side wall of a tire;

A first angled transition section joining said well section and said first bead seat;

A second angled transition section joining said well section and said second bead seat;

Wherein said center disc is joined to said rim adjacent said well section;

Wherein said first angled transition section has a thickness less than the thickness of said well section thickness; and

Wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

2) A wheel for a motor vehicle according to claim 1, wherein said outer rim is formed by a spin forming process.

3) A wheel for a motor vehicle according to claim 2, wherein said wheel has a distance between said first bead seat and said second bead set of between approximately 7 ½" and wherein said first bead seat has a bead seat diameter of between approximately 16 inches and 25 inches, said wheel further comprising a cylindrical section between said first angled section and said first bead seat section, said cylindrical section having a cylindrical section thickness, and wherein said first angled transition section is angled approximately 15 degrees with respect to the axis of rotation of said wheel, and wherein said first transition section thickness is between approximately 50% and 75% of the thickness of said cylindrical section thickness.

4) A wheel for a motor vehicle according to claim 3, wherein said first transition section thickness is between approximately 58% and 68% of said thickness of said cylindrical section.

5) A wheel for a motor vehicle according to claim 4, wherein said well section has a well section thickness, and wherein said well section thickness is between approximately 60% and 90% of said cylindrical section thickness.

6) A wheel for a motor vehicle according to claim 4, wherein said well section has a well section thickness, and wherein said well section thickness is between approximately 70% and 80% of said cylindrical section thickness.

7) A wheel for a motor vehicle according to claim 3, wherein said second angled transition section has a second transition section thickness, and wherein said second section thickness is between approximately 50% and 75% of the thickness of said cylindrical section thickness.

8) A wheel for a motor vehicle according to claim 3, wherein said second angled transition section has a second transition thickness of between approximately 70% and 80% of said cylindrical section thickness.

9) A wheel for a motor vehicle according to claim 7, wherein said second transition section is angled with respect to said center of rotation by between approximately 15 degrees.

10) A wheel for a motor vehicle, said wheel being adapted to receive a pneumatic tire, said wheel comprising a rim and a center disc, wherein said rim comprises:

A well section, said well section having a base and two sidewalls, said well section further having a well section thickness;

a first bead seat for receiving a bead on a side wall of a tire;

a second bead seat for receiving a bead on a side wall of a tire;

a first angled transition section joining said well section and said first bead seat;

a second angled transition section joining said well section and said second bead seat; and

a cylindrical section, said cylindrical section having a cylindrical section thickness; and

a center disc is joined to said rim adjacent said cylindrical section;

wherein said first angled transition section has a thickness less than the thickness of said well section thickness; and

wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

11) A wheel for a motor vehicle according to claim 10, wherein said outer rim is formed by a spin forming process.

12) A method for forming a motor vehicle wheel having a non-constant rim thickness, said wheel comprising an outer rim and a center disc, the method comprising the steps of:

determining a desired fatigue life for said rim;

determining expected loading characteristics for said rim;

determining via finite element analysis optimized thicknesses for sections of said rim, said finite element analysis utilizing material properties based on work hardened materials from a spin forming process;

forming an outer rim blank by rolling a flat piece into a tubular shape;

forming a well section in said blank, said well section having a base and two sidewalls, said well section further having a well section thickness;

forming a first bead seat for receiving a bead on a side wall of a tire;

forming a second bead seat for receiving a bead on a side wall of a tire;

forming a first angled transition section joining said well section and said first bead seat;

forming a second angled transition section joining said well section and said second bead seat; and

joining a center disc is joined to said rim adjacent said well section;

wherein said first angled transition section has a thickness less than the thickness of said well section thickness; and

wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

13) A method for forming a motor vehicle wheel according to claim 12, wherein said well section, said inner and out transition sections, and said inner and outer bead seats are formed on said blank by spin forming.

14) A method for forming a motor vehicle wheel having a non-constant rim thickness, said wheel comprising an outer rim and a center disc, the method comprising the steps of:

determining a desired fatigue life for said rim;

determining expected loading characteristics for said rim;

determining via finite element analysis optimized thicknesses for sections of said rim, said finite element analysis utilizing material properties based on work hardened materials from a spin forming process;

forming an outer rim blank by rolling a flat piece into a tubular shape;

forming a well section in said blank, said well section having a base and two sidewalls, said well section further having a well section thickness;

forming a first bead seat for receiving a bead on a side wall of a tire;

forming a second bead seat for receiving a bead on a side wall of a tire;

forming a first angled transition section joining said well section and said first bead seat;

forming a second angled transition section joining said well section and said second bead seat;

forming a cylindrical section, said cylindrical section joining said well section and said first transition section, said cylindrical section having a cylindrical section thickness; and

joining a center disc to said outer rim adjacent said cylindrical section;

wherein said first angled transition section has a thickness less than the thickness of said well section thickness; and wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

a center disc is joined to said rim adjacent said cylindrical section;

wherein said first angled transition section has a thickness less than the thickness of said well section thickness; and

wherein said second angled transition section has a thickness less than the thickness of said well section thickness.

14) A method for forming a motor vehicle wheel according to claim 13, wherein said well section, said inner and out transition sections, said inner and outer bead seats, and said cylindrical section are formed on said blank by spin forming.

16) A method for forming a motor vehicle wheel having a non-constant rim thickness, the method comprising the steps of:

determining a desired fatigue life for said rim;

determining expected loading characteristics for said rim;

determining via finite element analysis optimized thicknesses for sections of said rim, said finite element analysis utilizing material properties based on work hardened materials from a spin forming process;

spin forming an outer rim for said wheel, said outer rim having a non-constant rim thickness wherein said non-constant thickness is in accordance with the optimized thicknesses for said rim determined via finite element analysis;

joining a center disc to said outer rim to form said motor vehicle wheel.

17) The method for forming a motor vehicle wheel according to claim 16, wherein said step of spin forming an outer rim further comprises the steps of forming an inner bead seat and an outer bead seat and a well.

18) The method for forming a motor vehicle wheel according to claim 16, wherein the step of joining a center disc to said rim comprises welding an outer edge of said center disc to said outer rim at an inner extent of said well.

19) The method for forming a motor vehicle wheel according to claim 18, wherein the step of spin forming an outer rim further comprises the step of forming an inner transition section between said inner bead seat and said well.

20) The method of forming a motor vehicle wheel according to claim 18, wherein the step of spin forming an outer rim further comprises the step of forming an outer transition section between said well and said outer bead seat.

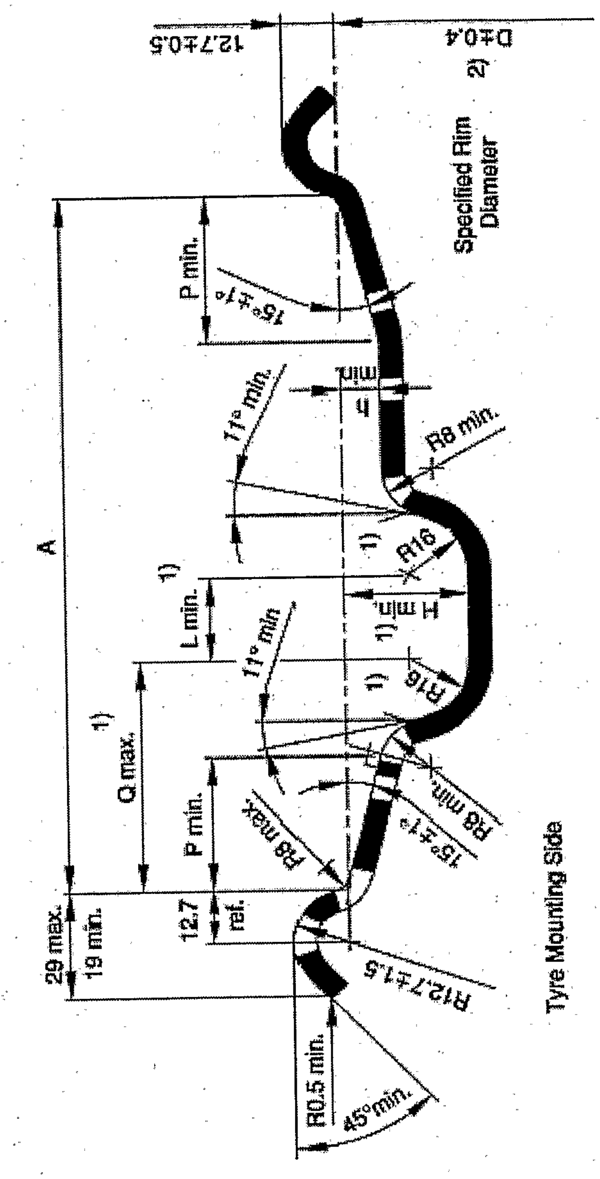
12.7±0.5
D±0.4
2)
Specified Rim Diameter
P min.
15°±1°
h min.
11° min.
R8 min.
A
L min.
1)
R16
H min.
Q max.
P min.
R8 max.
12.7
ref.
29 max.
19 min.
R12.7±1.5
R0.5 min.
45°min.
Tyre Mounting Side

FIG. 1

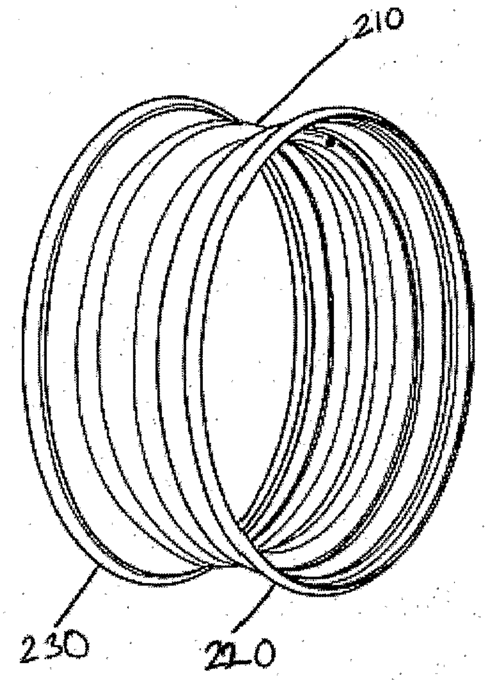

FIG. 2A

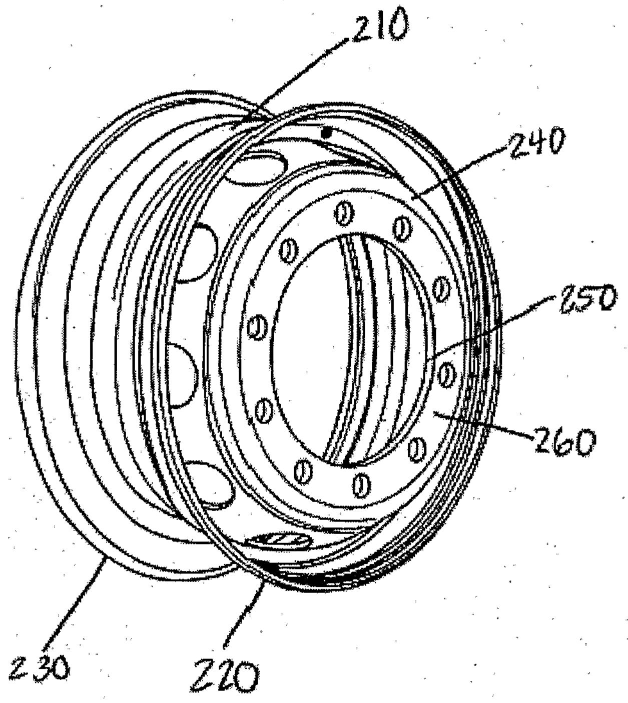

FIG. 2B

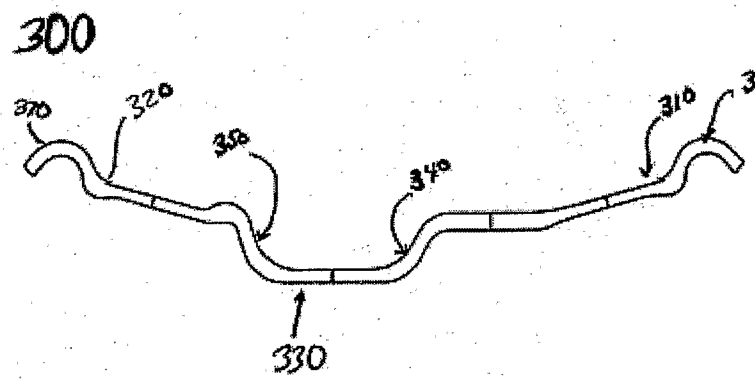

FIG. 3

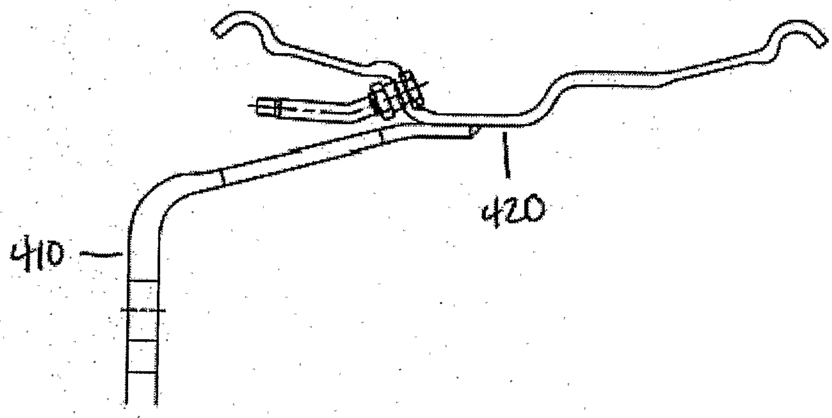

FIG. 4

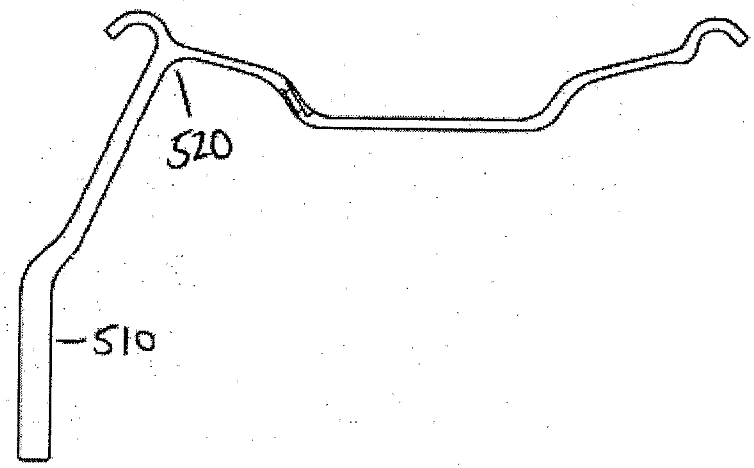

FIG. 5