(54) Title: RAILWAY VEHICLE WHEEL WITH ELASTIC RUBBER SUSPENSION

(57) Abstract:
The invention concerns a railway vehicle wheel with elastic rubber suspension designed in particular, but not exclusively, for low railway vehicles. In said railway vehicle, the wheel tyre (2) is connected to the wheel rim (3) via a rubber lining consisting of two flat
(57) Abrégé(suite)/Abstract(continued):
rings (11, 12) substantially vertical relative to the wheel shaft. The rings (11, 12) are highly preloaded axially between an inner circumferential median rib (5) of the wheel tyre and two outer flanges (6, 8) of the rim (3). At least one of the flanges (8) is supported on the rim (3) by an adjusted seat (9) in a conical tight fit. The adjusted seat (9) is configured such that the cone of the flange (8) when free of tension has a tapering smaller than that of the cone of the rim (3) and when compressed, presses its entire surface on the cone of the rim (3) with a compressive surface as uniform as possible over the entire width of the adjusted seat (9). The flange (8) is thus securely maintained. Additional threaded screws (10) are therefor not necessary in the zone of the rings (11, 12) of the rubber lining, such that the space found between the rib (5) and the flanges (6, 8) can be exclusively used for the rubber lining.
The invention relates to a rubber-sprung rail vehicle wheel which is designed in particular, but not exclusively, for rail vehicles with a low design height. In this rail vehicle wheel, the wheel tire (2) is connected to the wheel rim (3) by way of a rubber insert that is formed by two flat rings (11, 12) that are arranged so as to be essentially vertical in relation to the wheel axle. The rings (11, 12) are held, under very considerable axial prestress, between an inner circumferential middle web (5) of the wheel tire (2) and two outer flanges (6, 8) of the wheel rim (3). At least one of the flanges (8) is seated on the wheel rim (3) with an interference fit (9) that is designed as a conical press fit. The interference fit (9) is designed such that the cone of the flange (8) in the stress-free state has a lesser conicity than does the cone of the wheel rim (3), and in the pressed-on state rests on the entire surface against the cone of the wheel rim (3), as far as possible at an even surface pressure across the entire width of the interference fit (9). This provides a secure hold for the flange (8). There is no need to provide additional screw bolts (10) in the region of the rings (11, 12) of the rubber insert, so that the space between the web (5) and the flanges (6, 8) can be utilised entirely for the rubber insert.

Figure 1 has been provided for the abstract.
The invention relates to a rubber-sprung rail wheel in which a wheel tire is connected to a wheel rim by way of a rubber insert that is formed by two flat perforation-free rings that are arranged so as to be inclined to vertical in relation to the wheel axle, wherein the rings are exclusively held, under axial prestress, between supporting surfaces that are arranged so as to be inclined to vertical in relation to the wheel axle and that are formed by a circumferential inner middle web of the wheel tire and two outer flanges of the wheel rim, which rings, when the vehicle wheel is under radial load, are predominantly subjected to shear stress, and wherein at least one of the flanges is held directly to the wheel rim by screw bolts that are arranged outside the rings of the rubber insert.

Such a rail wheel is known from the literature and from practical application. Rubber-sprung rail wheels have been known for considerably more than half a century and have a successful track record in practical application. In a rubber-sprung rail wheel of which hundreds of thousands have been in use, the rubber insert comprises a plurality of radially highly prestressed rubber pads that are seated in facing annular grooves of the wheel tire and of the wheel rim. When compared to such a rail vehicle wheel, the rail vehicle wheel of the type mentioned in the introduction, which rail vehicle wheel comprises the differently oriented and axially prestressed rubber insert, provides the advantage of greater axial rigidity when subjected to lateral loads such as driving along a curved section of track, and of a lower spring constant when subjected to vertical loads. However, this arrangement is associated with a disadvantage in that when
subjected to vertical loads the rubber insert is essentially subjected to shear stress.

In order to be able to cope with such high shear loads, attempts have been made to use the greatest possible volume of rubber and to provide the rubber insert with very considerable axial prestress. In order to generate the very considerable axial prestress, the flanges that rim the rubber insert on the outside are braced to each other by means of screw bolts that lead through the flanges, the rubber insert and the web. While in this way even axial prestress in the rubber insert can be achieved over the diameter, this type of bracing is, however, associated with a loss of rubber volume. However, in various applications, in particular in the case of low-floor carriages, where comparatively small wheel diameters are required, it is not possible to provide a larger radial area in order to accommodate more rubber volume.

From DE 44 30 342 A1 a rubber-sprung rail wheel is known that comprises a wheel rim, a wheel tire and annular rubber inserts. They are exclusively held on both sides of the mid-plane of the wheel in annular spaces that are formed by a web that protrudes radially inwards from the wheel tire, and by flanges that correspondingly protrude radially outwards from the wheel rim, under essentially axial prestress exclusively between supporting surfaces of the web and of the flanges. While one flange is constructed in one piece with the wheel rim body, the other flange with an integrally formed annular joined-on piece of rectangular cross section is placed in a corresponding annular recess that is provided in the wheel rim body and, by means of a screw connection, is directly connected to the wheel rim body, wherein the annular joined-on piece and the annular recess form a cylindrical seat. In this
arrangement the axial prestress of the rubber inserts is entirely produced by the screw connection. In order to evenly
prestress the rubber inserts across their radial width, a correspondingly rigid construction of flanges and screw
connections is required.

In a different type of rubber-sprung rail wheel, known from DE 24 06 206 C3, the annular rubber inserts are held under axial
and radial prestress between a cylindrical and a radial supporting surface of a wheel rim ring and a radial supporting
surface of a wheel disc on the one hand, and the essentially radial supporting surfaces of a middle web and the flanks of
the wheel tire, which flanks are arranged immediately adjacent to said middle web and are essentially cylindrical, on the
other hand. In this arrangement the radially slotted wheel rim ring with a conical seat surface rests against a corresponding
conical supporting surface of the wheel disc, and is connected to it by way of screw bolts that are arranged outside the
rubber insert. As a result of the inclination of the conical surfaces a self-locking seat of the wheel rim ring on the
wheel disc is achieved, which wheel rim ring due to the radial slit in the diameter is radially expandable. As a result of
this seat, the screw bolts are relieved by the restoring forces of the prestressed rubber insert.

It is the object of the invention to create a rubber-sprung rail wheel that even in the case of small wheel diameters, as
used for example in low-floor carriages, provides good axial rigidity and good radial spring characteristics.

In a rubber-sprung rail vehicle wheel of the type mentioned in the introduction, this object is met in that the flange that
is held by screw bolts is seated in an interference fit on the
wheel rim, wherein the interference fit is a conical press fit in which the cone of the flange in the stress-free state has a lesser conicity than does the cone of the wheel rim, and in the pressed-on state rests with the entire surface against the cone of the wheel rim.

In the rail wheel according to the invention, by selecting the various conicities of the cones of the interference fit, a situation is achieved in which the pressed-on flange, taking into account its elastic deformation, on the one hand is securely held on the cone of the wheel rim, and on the other hand the rubber insert is optimally prestressed over its entire radial width. In this arrangement the screw bolt essentially only assumes the function of holding the flange on the seat. Said screw bolt is practically not subjected to any load as a result of the restoring force of the rubber insert. Because of the new arrangement of the flange on the wheel rim, the entire space between the web and the flanges is available for accommodating the rubber insert. When compared to the known design with the screw bolts that pass through the rubber insert, an additional rubber volume of up to 30% is gained. This has a positive effect on the ability of the rubber insert to withstand shear stress. This also makes it possible to achieve comparatively low design heights.

Accordingly, according to one embodiment of the invention, the conicities of the cones of the flange and of the wheel rim, taking into account the bending strain of the flange due to the restoring force of the prestressed rubber insert, which restoring force acts on said flange, are selected such that the axial static friction of the press fit amounts to 0.2 times to 1 times the restoring force of the prestressed rubber
insert. Thus, with such dimensioning the screw bolts are practically not subjected to any force.

According to an embodiment of the invention, the rail vehicle wheel is designed optimally if the conicities of the cones of the flange and of the wheel rim, taking into account the bending strain of the flange due to the restoring force of the prestressed rubber insert, which restoring force acts on said flange, are selected such that the surface pressure of the press fit is the same across its axial width. In concrete terms this means that in the stress-free state the diameter $D_1$ of the cone of the flange, when compared to the diameter $D_2$ of the cone of the wheel rim, in each case on the inside of the wheel has a lower deviation of dimensions of $\Delta U_1 = 0.0005$ to $0.0035 D_1$, and on the outside of the wheel has a lower deviation of dimensions of $\Delta U_2 = 0.25$ to $0.75 \Delta U_1$ at an axial width of the interference fit of $B = 0.06$ to $0.25D_1$. The angle of inclination of the conical interference fit should be $\alpha = 0.3^\circ$ to $3.0^\circ$.

There are various options for designing the flange. Preferably, the flange is designed as a flat ring that is supported by a ring that is screwed on with the screw bolts. However, the flange and the ring can also be designed as one part.

Provided the two rings of the rubber insert are arranged so as to be exactly perpendicular in relation to the wheel axle, when subjected to radial wheel loads they are exclusively subjected to shear stress. However, it is advantageous if they face each other at a slight incline, such that in the case of a radial axle load the rubber rings are not only subjected to
shear stress but also to pressure. Their angle of inclination in relation to the wheel axle can be up to 75°. In this arrangement the angles of inclination of the two rings can differ.

In practical application rubber inserts have been proven reliable that have a shore hardness of 60 to 85 and that in the installed state are compressed by 5% to 17% of their thickness. Preferably, the rubber inserts comprise moulded-on rings on their outsides.

If the rail vehicle wheels are braked and/or used as drive wheels, they are not only subjected to loads in axial and radial directions but also in circumferential direction. This load must then also be handled by the rubber insert. In order to prevent the rubber insert from becoming displaced in relation to the web and the flanges, the wheel tire can comprise projections on the outsides of the two rings of the rubber insert as an antirotational device relative to the wheel rim, which projections engage, with positive fit, recesses in the adjacent sides of the flanges and of the web.

In order to, on the one hand, provide sufficient clearance to the web and to the rubber insert during spring deflection, and in order to, on the other hand, prevent stress concentration at the points of transition between the wheel rim and the flanges, on its outer periphery in the region of the rubber insert the wheel rim can comprise a flat circumferential spring deflection bed for the web of the wheel tire and the rubber insert, wherein the radius of curvature of the rim areas of said spring deflection bed becomes increasingly smaller towards the outside.
Below, the invention is explained in more detail with reference to a drawing that shows several exemplary embodiments. The following are shown:

Fig. 1 a radial half section of a rail wheel for low-floor vehicles, comprising conventional wheel sets;

Fig. 2 a half section of a rail wheel for low-floor vehicles, with the design differing from that shown in Fig. 1;

Fig. 3 a radial half section of a rail wheel for low-floor vehicles with loose wheels;

Fig. 4 a radial half section of a rail wheel for low-floor vehicles, with the design differing from that shown in Fig. 1;

Fig. 5 a radial half section of a rail vehicle wheel, with the design differing from that shown in Fig. 1;

Fig. 6 a radial half section of a rail vehicle wheel, with the design differing from that shown in Fig. 1;

Fig. 7 a diagrammatic section view of a conical press fit of the rail vehicle wheels shown in Figures 1 to 6; and

Fig. 8 a radial half section of a wheel rim of the rail vehicle wheel shown in Fig. 3.

The rail vehicle wheel shown in Fig. 1 is designed for low-floor vehicles. It comprises a disc wheel body 1 and a wheel tire 2. The disc wheel body 1 comprises a wheel rim 3 and a wheel hub 4. The wheel tire 2 comprises a circumferential
inside middle web 5. The wheel rim 3 comprises two flanges 7, 8, of which one flange 7 is connected in one piece to the wheel rim 3, while the other flange 8, by means of an interference fit 9, is seated on the wheel rim 3 and is additionally held by screw bolts. The wheel tire 2 is connected to the wheel rim 3 by way of a rubber insert that comprises two flat rings 11, 12, on the outsides of which flat rings 11, 12, rings 11a, 11b, 12a, 12b are moulded on. The rings 11, 12 that form the rubber insert have a shore hardness of 60 to 85 and are loaded with very considerable axial prestress. Their thickness is compressed by 5 to 17%. Due to this very considerable axial prestress that is to be produced by the flange 8 the interference fit 9 is designed in a particular manner.

The interference fit 9 is a conical press fit. As shown in Fig. 7 in an exaggerated manner for the sake of clarity, the angle of inclination $\alpha$ of the cone N of the wheel rim 3 is larger than the angle of inclination $\alpha'$ of the cone N' of the flange 8. The angles of inclination $\alpha$, $\alpha'$ are between 0.3° and 3°. In the stress-free state the diameter $D_1$ of the cone N' of the flange 8, when compared to the diameter $D_2$ of the cone N of the wheel rim 3, in each case the inside of the wheel has an upper deviation of dimensions of $\Delta U_1 = 0.0005$ to 0.0035 $D_1$, and on the outside of the wheel the corresponding diameters $D_3$, $D_4$ have an upper deviation of dimensions of $\Delta U_2 = 0.25$ to 0.75 $\Delta U_1$. With these dimensions of the involved components in the initial state, i.e. prior to installation, in the installed state a firm seat of the press fit results with the desired very considerable axial prestress of the rings 11, 12 of the rubber insert. In this arrangement the expansion effect of the flange 8 is taken into account, which expansion effect occurs
due to the restoring force of the rings 11, 12 of the prestressed rubber insert, which restoring force acts on said flange 8. Consequently, this expansion effect, in conjunction with the special conical design of the interference fit 9, ensures that the surface pressure is even across the entire width of the interference fit 9. Because the flange 8 is held by said interference fit 9, the screw bolts 10 are relieved. In an ideal case said screw bolts 10 only assume securing functions.

In order to, on the one hand, provide sufficient clearance for radial spring deflection to the wheel tire 2 with the rings 11, 12 of the rubber insert, and in order to, on the other hand, prevent stress concentration in the transition region from the wheel rim 3 to the integrally formed flange 6, the wheel rim 3, on its outer periphery in the region of the rings 11, 12, comprises a spring deflection bed 13 for the web 5 of the wheel tire 2 and of the rings 11, 12, wherein the radius of curvature of rim areas of said spring deflection bed 13 becomes increasingly smaller towards the outside. With the use of the designations shown in Fig. 8 the curve of the spring deflection bed 13 meets the following function: \[ y = f(x) = 0.07045 - 0.30105x + 0.18546x^2 - 0.03849x^3 + 0.003756x^4 - 0.000169x^5 + 2.854 \cdot 10^{-6} x^6 \], wherein the starting point at \( L = 0.3 \) is up to 0.5 B of the width of the spring deflection bed. The radius of curvature ends at \( H = 0.1 \) to 0.3 L.

While in the exemplary embodiment shown in Fig. 1 the flange 8 is held by the screw bolts 10 by way of an integrally formed retaining ring 14, in the exemplary embodiment shown in Fig. 2 it is held by an independent retaining ring 15, which reaches slightly over the flange 8 only at the inner rim.
While in the exemplary embodiment shown in Fig. 2 the wheel rim 3 forms part of a wheel body 1, in the exemplary embodiment shown in Fig. 3 a mounting flange 16 is integrally formed on the wheel rim 3, which mounting flange 16 can be affixed to a corresponding counter flange of a drive or the like.

In the vehicle wheel according to the exemplary embodiment 4, in a manner that is different to the exemplary embodiments described so far, the rings 11, 12 of the rubber insert are placed at a slight inclination against the wheel axle, namely such that in the case of a radial wheel load the rubber inserts 11, 12 are not only subjected to shear stress but also to pressure. The inclined position of the rings 11, 12 of the rubber insert results in a conical shape of the web 5. The angles of inclination $\beta_1$, $\beta_2$ of the rubber inserts are between 75° and 90°. It can vary. Moreover, the inclination of the respective outsides of a ring 11, 12 can be different. For example, the difference of the angles $\beta_1$, $\beta_1'$, or $\beta_2$, $\beta_2'$ can be in the region of 15°. Preferably, the angles $\beta_1$, $\beta_1'$, $\beta_2$, $\beta_2'$ of the outsides of a ring 11, 12 are selected such that the rings 11, 12 are somewhat thicker in the radially outer region than in the radially inner region.

While in the exemplary embodiment of Fig. 1 the outsides of the rings 11, 12, which comprise the moulded-on rings 11a, 11b, 12a, 12b, of the rubber insert are smooth, in the exemplary embodiment shown in Fig. 5 they comprise humps. Instead, with projections 11c, 11d, 12c, 12d they engage, having positive fit, corresponding recesses in the flanges 6, 8 and in the web 5. In this way an antirotational device between the wheel tire 2 and the wheel body 1 is achieved. In
the exemplary embodiment of Fig. 6 such an antirotational device is achieved in a somewhat different way. In this exemplary embodiment the annular metal sheets comprise pin-shaped projections 11e, 11f, 12e, 12f, by means of which they engage corresponding recesses in the flanges 6, 8 and in the web 4.
1. A rubber-sprung rail wheel in which a wheel tire (2) is connected to a wheel rim (3) by way of a rubber insert that is formed by two flat perforation-free rings (11, 12) that are arranged so as to be inclined to vertical in relation to the wheel axle, wherein the rings (11, 12) are exclusively held, under axial prestress, between supporting surfaces that are arranged so as to be inclined to vertical in relation to the wheel axle and that are formed by a circumferential inner middle web (5) of the wheel tire (2) and two outer flanges (6, 8) of the wheel rim (3), which rings, when the vehicle wheel is under radial load, are predominantly subjected to shear stress, and wherein at least one of the flanges (8) is held directly to the wheel rim (3) by screw bolts (10) that are arranged outside the rings (11, 12) of the rubber insert, characterised in that the flange (8) that is held by screw bolts is seated in an interference fit (9) on the wheel rim (3), wherein the interference fit (9) is a conical press fit in which the cone (N') of the flange (8) in the stress-free state has a lesser conicity (α') than does the cone (N) of the wheel rim (3), and in the pressed-on state rests with the entire surface against the cone (N) of the wheel rim (3).
2. The rail vehicle wheel according to claim 1, characterised in that the conicities (α, α') of the cones (N, N') of the wheel rim (3) and of the flange (8), taking into account the bending strain of the flange (8) due to the restoring force of the rings (11, 12) of the prestressed rubber insert, which restoring force acts on said flange (8), are selected such that the axial static friction of the press fit amounts to 0.2 times to 1 times the restoring force of the prestressed rubber insert.

3. The rail vehicle wheel according to claim 1 or 2, characterised in that the conicities (α, α') of the cones (N, N') of the wheel rim (3) and of the flange (8), taking into account the bending strain of the flange (8) due to the restoring force of the rings (11, 12) of the prestressed rubber insert, which restoring force acts on said flange (8), are selected such that the surface pressure of the press fit is the same across its axial width.

4. The rail vehicle wheel according to any one of claims 1 to 3, characterised in that in the stress-free state the diameter (D₁) of the cone (N') of the flange (8), when compared to the diameter (D₂) of the cone (N) of the wheel rim (3), in each case on the inside of the wheel has an upper deviation of dimensions of ΔU₁ = 0.0005 to 0.0035 D₁, and on the outside of the wheel has an upper deviation of dimensions of ΔU₂ = 0.25 to 0.75 ΔU₁ at an axial width of the interference fit (9) of B = 0.006 to 0.25D₁.
5. The rail vehicle wheel according to any one of claims 1 to 4, characterised in that the angle of inclination of the conical press fit is $\alpha, \alpha' = 0.3^\circ$ to $3.0^\circ$.

6. The rail vehicle wheel according to any one of claims 1 to 5, characterised in that the flange (8) of the interference fit (9) is designed as a flat ring that is supported by a ring (14) that is screwed on with the screw bolts (10).

7. The rail vehicle wheel according to any one of claims 1 to 6, characterised in that the two rings (11, 12) of the rubber insert are oppositely inclined.

8. The rail vehicle wheel according to claim 7, characterised in that the angles of inclination ($\beta_1, \beta_2, \beta_1', \beta_2'$) of the rings (11, 12) in relation to the wheel axle are between $75^\circ$ and $90^\circ$.

9. The rail vehicle wheel according to claim 8, characterised in that the angles of inclination ($\beta_1, \beta_2, \beta_1', \beta_2'$) of the two rings (11, 12) differ.

10. The rail vehicle wheel according to any one of claims 1 to 9, characterised in that the two rings (11, 12) of the rubber insert have a shore hardness of 60 to 85 and in the installed state are compressed by 5% to 17% of their thickness.
11. The rail vehicle wheel according to any one of claims 1 to 10, characterised in that the wheel tire (2) comprises projections (11c, 11d, 12c, 12d, 11e, 11f, 12e, 12f) on the outsides of the two rings (11, 12) of the rubber insert as an antirotational device relative to the wheel rim (3), which projections (11c, 11d, 12c, 12d, 11e, 11f, 12e, 12f) engage, with positive fit, recesses in the adjacent sides of the flanges (6, 8) and of the web (5).

12. The rail vehicle wheel according to any one of claims 1 to 11, characterised in that on its outer periphery in the region of the rubber insert, the wheel rim (3) comprises a flat circumferential spring deflection bed (13) for the web (5) of the wheel tire (2) and the rings of the rubber insert (11, 12), wherein the radius of curvature of the rim areas of said spring deflection bed (13) becomes increasingly smaller towards the outside.
Fig. 8