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Pneumatic tire for a vehicle

Abstract

A pneumatic tire for a vehicle with a tread having at least one profile rib, which is delimited on at least one side thereof by a circumferential groove. The circumferential groove has, when viewed in cross section, a portion running in the radial direction and having a width of up to 3.0 mm and, adjoining it, a radially inner channel region. The radially inner channel region is delimited by two channel walls and a channel base forming the groove base, and has a larger cross-sectional area and is made wider in each case than the portion running in the radial direction. The profile rib is provided over its circumference with sipes, which merge into the circumferential groove, run at an angle of 0° to 50° with respect to the axial direction and have a width of 0.4 mm to 1.2 mm and a maximum depth of 70% to 100% of the profile depth, and have sipe walls. Each sipe is locally widened by at least one channel which is open to the tread periphery and merges into the radially inner channel region of the circumferential groove. The channel is formed by a depression formed in one sipe wall and a depression formed on the other sipe wall, opposite the first depression.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) The present application is a National Stage Application under 35 U.S.C. § 371 of International Patent Application No. PCT/DE2021/200266 filed on Dec. 17, 2021, and claims priority from German Patent Application No. 10 2021 205 792.6 filed on Jun. 8, 2021, in the German Patent and Trademark Office, the disclosures of which are herein incorporated by reference in their entireties.

TECHNICAL FIELD

(2) The invention relates to a pneumatic tire for a vehicle, in particular a utility vehicle tire, with a tread having at least one profile rib, which is delimited on at least one side thereof by a circumferential groove, wherein the circumferential groove has, when viewed in cross section, a portion running in the radial direction and having a width of up to 3.0 mm and, adjoining it, a radially inner channel region, wherein the radially inner channel region is delimited by two channel walls and a channel base forming the groove base, and has a larger cross-sectional area and is made wider in each case than the portion running in the radial direction.

BACKGROUND

(3) Circumferential grooves with sipe-like narrow portions running in the radial direction and channel regions located in the interior of the tread, having the groove base and configured to be substantially wider than the narrow portion are advantageous for a low rolling resistance of the tire, especially in the central or middle tread region. When the tire rolls on the underlying surface, the profile ribs separated by the circumferential groove are supported on one another in the region of the sipe-like narrow portions, contributing to a reduction in the rolling resistance. When the tread has worn down further, the channel ensures good braking characteristics on a wet roadway.

(4) A pneumatic tire of the type mentioned at the outset for a vehicle, which is preferably a utility vehicle tire, is known, for example, from DE 10 2017 208 010 A1. The tread of the tire has at least one circumferential groove, which, when viewed in cross section, is composed of a radially outer portion widening outward in the shape of a funnel, a middle portion running in the radial direction and having a width of 1.0 mm to 3.0 mm, and a radially inner channel region having a larger cross-sectional area than that in the middle portion. The channel region has two channel walls having radially inner wall portions, which run at an angle of 5° to 25° with respect to the radial direction,

with the distance from one another decreasing, and run in a wave shape in the direction of their circumferential extent. After corresponding tread wear, the wave shape leads to the formation at the tread periphery of groove edges with a greater edge length than straight groove edges, as a result of which the grip and braking characteristics on a wet roadway are improved.

SUMMARY

(5) In the case of pneumatic tires for vehicles of the type stated at the outset, the narrow, radially extending portion of the circumferential groove has the effect that the drainage behavior of the tread, particularly in the region of the profile ribs adjacent to the circumferential groove, is in need of improvement when the tire is new or exhibits little wear. This impairs the performance of the tire on a wet roadway, especially the grip and braking characteristics.

(6) It is the underlying object of the invention, in the case of a pneumatic tire of the type stated at the outset for a vehicle, to further improve the drainage behavior of the tread, wherein the advantageous effect of the circumferential grooves on the rolling resistance of the tire is to be retained.

(7) According to the invention, the stated object is achieved by virtue of the fact that the profile rib is provided over its circumference with sipes, which merge into the circumferential groove, run at an angle of 0° to 50° with respect to the axial direction and have a width of 0.4 mm to 1.2 mm and a maximum depth of 70% to 100% of the profile depth, and have sipe walls, wherein each sipe is locally widened by at least one channel which is open to the tread periphery and merges into the radially inner channel region of the circumferential groove, wherein the channel is formed by a depression formed in one sipe wall and a depression formed in the other sipe wall, opposite the first depression.

(8) By virtue of the channels formed in the sipes, water drainage paths between the outer surface of the profile rib and the radially inner channel region of the circumferential groove are made available when the tire rolls on wet surfaces. When driving on a wet roadway, water that has been taken up is drained off in a particularly effective manner from the outer surface of the profile rib into the radially inner channel region of the circumferential groove via the channels in the sipes. The advantageous effect of the circumferential grooves in respect of the rolling resistance of the tire remains unaffected by this.

(9) According to a preferred embodiment, each sipe has, at the tread periphery, a slot-shaped sipe widening which runs over its entire extent in plan view and has a bottom, a depth, determined in the radial direction, of 10% to 30%, in particular of 15% to 25%, of the depth of the sipe and a width of 250% to 370%, in particular of 290% to 330%, of the width of the sipe, wherein the channel starts from the bottom of the sipe widening. The slot-shaped sipe widening additionally promotes water take up from the outer surface of the profile rib, wherein the water is drained off via the channels as described. The slot-shaped sipe widening therefore contributes to a further improvement in drainage performance.

(10) According to another preferred embodiment, the channel has a circular cross section with a diameter of 250% to 370%, in particular of 290% to 330%, of the width of the sipe. In such channels, the quantities of water which are taken up when driving on a wet roadway are drained off into the circumferential groove in a particularly efficient manner.

(11) A combination of the two abovementioned embodiments in which the diameter of the channel coincides with the width of the sipe widening, is particularly preferred. This improves the interaction between the channel and the sipe widening in respect of the drainage effect.

(12) A turbulence-free or substantially turbulence-free water flow through the channel is ensured if the channel is half U-shaped in a view toward the sipe wall.

(13) According to another preferred embodiment, the width of the radially extending portion of the circumferential groove which delimits the profile rib on one side is 0.5 mm to 2.5 mm, particularly preferably from 0.8 mm to 1.2 mm.

(14) The sipes with channels provided according to the invention are particularly advantageous if

the associated profile rib is likewise delimited on the second side thereof by a circumferential groove. The profile rib is therefore a central or middle profile rib and hence is located completely within the ground contact area, as a result of which the sipes with the channels improve the drainage behavior of the tread particularly clearly.

(15) In the preferred embodiment mentioned immediately above, it is advantageous if the circumferential groove which delimits the at least one profile rib on the second side thereof likewise has, when viewed in cross section, a portion running in the radial direction and having a width of up to 3.0 mm and, adjoining it, a radially inner channel region having two channel walls and a channel base forming the groove base, wherein the channel region has a larger cross-sectional area and is made wider in each case than the portion running in the radial direction, wherein the sipes formed in the profile rib are of symmetrical configuration in relation to a cross section center plane which is aligned in the radial direction and—with reference to the longitudinal extent—runs through the center of the sipe. This embodiment allows a particularly uniform improvement in drainage of the profile rib.

(16) In combination with the abovementioned preferred embodiment, it is of further advantage for drainage if a connecting channel, which, in particular, runs at a constant depth, locally widens the sipe and is at a distance in the radial direction both from the tread periphery and from the sipe base, is formed between the channels. By means of this connecting channel, drainage of the profile rib is further improved, especially when cornering on a wet roadway.

(17) In the case of the last-mentioned embodiments, it is advantageous if the width of the radially extending portion of the circumferential groove which delimits the at least one profile rib on the second side thereof is 0.5 mm to 2.5 mm, particularly preferably from 0.8 mm to 1.2 mm.

(18) Another preferred embodiment is characterized in that the circumferential groove(s), which has or have the portion running in the radial direction and the radially inner channel region, is provided at the entries of the sipes with recesses having a diameter of 200% to 400%, in particular of 330% to 370%, of the width of the portion running in the radial direction, which recesses are circular in plan view, run in the radial direction, extend as far as the radially inner channel region, and are open to the tread periphery, wherein the recesses are each formed by indentations that lie opposite one another in pairs in the axial direction. The recesses improve the drainage of the respectively adjacent profile ribs. In the context of achieving the object, this means that the channels in the circumferential groove and the channels in the sipes merge into the radially inner channel region of the circumferential groove at substantially coinciding “circumferential positions” on the circumferential groove. This is advantageous especially for the water drainage behavior in the radially inner channel region of the circumferential groove.

(19) According to another preferred embodiment, the channel walls of the radially inner channel region of the circumferential groove(s) are each composed of a radially inner wall portion and a radially outer wall portion, wherein the radially inner wall portions, when viewed in a cross section through the circumferential groove, each run at an angle of 5° to 15°, in particular of up to 10°, with respect to the radial direction, wherein these wall portions are inclined in opposite directions with respect to one another in such a way that the radially inner channel region widens continuously in the axial direction from the radially inner end of the radially inner wall portions to the radially outer end of the radially inner wall portions, wherein the channel or channels, which widens or widen the sipe, merges or merge via the radially inner wall portion into the radially inner channel region of the circumferential groove(s).

(20) For the drainage of the tread, it is furthermore additionally advantageous if the circumferential groove(s), which has or have the portion running in the radial direction and the radially inner channel region, is or are composed of the portion running in the radial direction, the radially inner channel region, and a radially outer portion widening in a V shape toward the tread periphery.

(21) According to another preferred embodiment, the channel has a main axis and a radially outer channel opening, wherein—with reference to the main axis—the radially outer channel opening is

at a distance, projected into the tread periphery and determined in the axial direction, of 10% to 40%, in particular of 15% to 30%, particularly preferably of 20% to 25%, of the width of the profile rib, determined in the axial direction at the tread periphery, from the circumferential groove into which the channel merges.

(22) It is furthermore advantageous for the stabilization of the channel if the sipes each have a sipe base and, for each channel, a base elevation adjacent to said channel and locally raising the sipe base in the radial direction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Further features, advantages and details of the invention will now be described in more detail on the basis of the drawing, which schematically shows exemplary embodiments of the invention. In the drawing:

(2) FIG. 1 shows a simplified plan view of a circumferential portion of a tread of a utility vehicle tire with a first embodiment variant of the invention,

(3) FIG. 2 shows an enlarged plan view of the detail Z.sub.2 in FIG. 1,

(4) FIG. 3 shows a section along the line III-III of FIG. 2,

(5) FIG. 4 shows a further enlarged view of detail Z.sub.4 in FIG. 3,

(6) FIG. 5 shows a visualization of a sipe according to a second embodiment variant,

(7) FIG. 6 shows a visualization of a sipe according to a third embodiment variant, and

(8) FIG. 7 shows a visualization of a sipe according to a fourth embodiment variant.

DETAILED DESCRIPTION

(9) Pneumatic tires for vehicles embodied according to the invention are tires for motor vehicles, in particular for multi-track motor vehicles, and preferably utility vehicle tires of a radial design, in particular for trucks (medium-weight trucks: $7.5 \text{ t} < \text{gross vehicle weight} \leq 18.0 \text{ t}$, heavy trucks: gross vehicle weight $> 18.0 \text{ t}$).

(10) FIG. 1 shows a plan view of a circumferential portion of a tread of a utility vehicle tire. The tire equatorial plane is indicated by a line A-A. The tread has a central profile rib 1, two middle profile ribs 2, and two shoulder-side profile ribs 3, wherein the central profile rib 1 is separated from the middle profile ribs 2 by middle circumferential grooves 4, and the middle profile ribs 2 are separated from the shoulder-side profile ribs 3 by shoulder-side circumferential grooves 5. The shoulder-side profile ribs 3 are illustrated only schematically and can be structured by means of grooves, sipes and the like.

(11) In the exemplary embodiment shown, the circumferential grooves 4, 5 run in a straight line in plan view and are formed to the respectively envisaged profile depth T.sub.P (FIG. 4, shown for a middle circumferential groove 4) in the radial direction, which is generally 12.0 mm to 26.0 mm for the preferred type of tire (utility vehicle tire).

(12) The shoulder-side circumferential grooves 5 have a U-shaped cross section (not visible) and are each delimited by a groove base 5a and two groove flanks 5b.

(13) According to FIG. 4, the middle circumferential grooves 4 are each composed of a radially outer portion 4.sup.I, a middle portion 4.sup.II, and a radially inner channel region 4.sup.III when viewed in cross section and in the radial direction, wherein, in the exemplary embodiment shown, portions 4.sup.I, 4.sup.II are provided with paired local indentations 13 (cf. FIG. 2) running in the radial direction. The configuration of the indentation 13 will be explored in greater detail below.

(14) The radially outer portion 4.sup.I widens in a V shape to the tread periphery, is delimited by two flanks 6 which, when viewed in cross section, run at an angle α of 30° to 50° with respect to the radial direction, and has a width b.sub.1 of 2.5 mm to 6.0 mm in the axial direction and a length of extent I.sub.1 of 10% to 30% of the profile depth T.sub.P in the radial direction at the tread

periphery. The middle portion **4.sup.II** is delimited by two flanks **7** running in the radial direction, and has a width **b.sub.2** of up to 3.0 mm, in particular of 0.5 mm to 2.5 mm, particularly preferably of 0.8 mm to 1.2 mm, in the axial direction, and a length of extent **I.sub.2** of 30% to 60% of the profile depth **T.sub.P** in the radial direction. The radially inner channel region **4.sup.III** has a larger cross-sectional area in the axial direction than the middle portion **4.sup.II**, is made wider in the axial direction than the latter, and has a length of extent **13** of 30% to 60% of the profile depth **T.sub.P** in the radial direction, and is delimited by a channel base **8** running at the profile depth **T.sub.P** and simultaneously forming the groove base of the circumferential groove **4**, and by lateral channel walls **9** arching into the central profile rib **1** and the adjacent middle profile rib **2**. The channel walls **9** are each composed of a radially inner wall portion **9a** and a radially outer wall portion **9b**. When viewed in a cross section through the circumferential groove **4**, the radially inner wall portions **9a** each run at an angle β of 5° to 15° , in particular of up to 10° , with respect to the radial direction, wherein they are inclined in opposite directions with respect to one another in such a way that the channel region **4.sup.III** widens continuously in the axial direction from the radially inner end of the wall portions **9a** to the radially outer end of the wall portions **9a**. The channel region **4.sup.II** has its widest location in the axial direction between the transitions of the radially inner wall portions **9a** to the radially outer wall portions **9b**, wherein this location is at a distance **a.sub.1** from the lowest point of the circumferential groove **4** of 70% to 85%, determined in the radial direction, of the already mentioned length of extent **I.sub.3** belonging to channel region **4.sup.III**. At the widest location, the channel region **4.sup.III** has a width **b.sub.3** of 5.0 mm to 7.0 mm.

(15) According to FIG. 1, the central profile rib **1** and each middle profile rib **2** have a width **b.sub.PR**, determined in the axial direction at the tread periphery, and are provided with a multiplicity of sipes **10**, which are distributed over the circumference of the profile rib **1**, **2**, run parallel to one another within the respective profile rib **1**, **2** in plan view, transect the profile rib **1**, **2** and impart rib blocks **1a** and **2a** to the latter. According to FIG. 2, each sipe **10** is of symmetrical design in relation to a longitudinal-section center plane **E.sub.1**, which is oriented in the radial direction and runs longitudinally through the center of the sipe **10**. Furthermore, each sipe **10** is of symmetrical configuration in relation to a cross-section center plane **E.sub.2** (cf. FIG. 3), which is oriented in the radial direction and which runs orthogonally to the longitudinal-section center plane **E.sub.1** and, in relation to the longitudinal extent, runs through the center of the sipe **10**. When viewed in plan view and in relation to the longitudinal-section center plane **E.sub.1**, the sipes **10** run at an angle γ of 0° to 50° , in particular of 5° to 40° , preferably of 20° to 35° , with respect to the axial direction, wherein the sipes **10** in the middle profile ribs **2** are inclined in the opposite direction to the sipes **10** in the central profile rib **1** in relation to the axial direction (FIG. 1).

(16) The further configuration of the sipes **10** is explained below with reference to an individual sipe **10** formed in the middle profile rib **1**.

(17) As FIG. 2 and FIG. 3 show in combination, the sipe **10** has a sipe base **11** (FIG. 3) and two mutually opposite sipe walls **12** (FIG. 2) running in the radial direction, is extended by two tubular channels **14** running to the middle circumferential grooves **4**, and furthermore has a slot-shaped sipe widening **15** at the tread periphery. Between the sipe walls **12**—that is to say in the region outside the channels **14** and the sipe widening **15**—the sipe has a width **be** (FIG. 2) of 0.4 mm to 1.2 mm, in particular of up to 0.8 mm, determined perpendicularly to the longitudinal-section center plane **E.sub.1**, and a depth **t.sub.E** (FIG. 3) at its deepest point in the radial direction of 70% to 10% of the profile depth **T.sub.P** (FIG. 3). The depth **t.sub.E** is preferably no more than the profile depth **T.sub.P** reduced by 1.0 mm. Outside the channels **14** and the slot-shaped sipe widening **15**, the sipe walls **12** are unstructured, flat surfaces.

(18) According to FIG. 2, the sipe widening **15** runs in a straight line and over the entire sipe **10** when viewed in plan view, and—in accordance with the stated symmetrical configuration of the sipe **10**—is of symmetrical design in relation to the longitudinal-section center plane **E.sub.1**, and

is bisected in its longitudinal extent by the cross-section center plane E.sub.2. When viewed in cross section, the sipe widening **15** is of rectangular or U-shaped design, is furthermore delimited by two side surfaces **15b** (FIG. 3), running in particular in the radial direction, and delimited in the radial direction by a bottom **15a** (FIG. 3), and, in the longitudinal-section center plane E.sub.1, has a depth t.sub.N (FIG. 4) in the radial direction of 10% to 30%, in particular of 15% to 25%, of the depth t.sub.E (FIG. 3) of the sipe **10** and a width b.sub.N, determined perpendicularly to the longitudinal-section center plane E.sub.1, of 250% to 370%, in particular of 290% to 330%, of the width be of the sipe **10**.

(19) The two channels **14** are each of symmetrical design in relation to the longitudinal-section center plane E.sub.1, wherein one channel **14** is formed symmetrically with respect to the other channel **14** in relation to the cross-section center plane E.sub.2 (FIG. 3), with the result that one channel **14** is situated in the half of the sipe **10** defined by the cross-section center plane E.sub.2, and the other channel **14** is situated in the other half of the sipe **10**, defined by the cross-section center plane E.sub.2 (FIG. 3). According to FIG. 3, each channel **14** starts from the bottom **15a** of the sipe widening **15**, merges into the radially inner channel region 4.sup.III of the corresponding middle circumferential groove **4**, is formed by a depression **14'** (FIG. 2) formed in one sipe wall **12** and by a depression **14'** (FIG. 2) formed in the other sipe wall **12**, runs in a half U shape and has a circular cross section, a main axis a.sub.K running through its center and a diameter d.sub.K of 250% to 370%, in particular of 290% to 330%, of the width b.sub.E (FIG. 2) of the sipe **10**. The diameter d.sub.K of the channel **14** preferably coincides with the width b.sub.N (FIG. 2) of the sipe widening **15**.

(20) According to FIG. 4, each channel **14** in the exemplary embodiment shown is composed of a radially outer channel portion **14a** starting from the bottom **15a** of the sipe widening **15**, a middle channel portion **14b**, and a channel end portion **14c**, wherein the radially outer channel portion **14a** has a channel opening **14d** situated at the groove base **15a**, and the channel end portion **14c** has a channel opening **14e** situated in the radially inner wall portion **9a** of the corresponding channel wall **9** of the radially inner channel region 4.sup.III. In relation to the main axis a.sub.K, the channel opening **14d** is at a distance a.sub.2 (FIG. 2), determined in the axial direction and projected into the tread periphery, of 10% to 40%, in particular of 15% to 30%, particularly preferably of 20% to 25%, of the width b.sub.PR (FIG. 2) of the middle profile rib **1**, from the middle circumferential groove **4**, into which the channel **14** merges.

(21) In relation to the main axis a.sub.K, the channel portion **14a** runs in a straight line and at an angle δ of 15° to 40°, in particular of 20° to 30°, with respect to the radial direction. In relation to the main axis a.sub.K, the middle channel portion **14b** runs in an arc shape overall and is composed of four channel subsections **14b'**, which, in relation to the main axis a.sub.K, run along circular arcs of various radii. In relation to the main axis a.sub.K, the channel end portion **14c** runs in a straight line and at a depth t.sub.K, determined in the radial direction, of 50% to 100%, in particular of at least 60%, of the depth t.sub.E (FIG. 3) of the sipe **10**, wherein the depth t.sub.K is appropriately matched to the already mentioned length of extent I.sub.3 of the radially inner channel region 4.sup.III.

(22) In the exemplary embodiment shown, as per FIG. 3, the sipe base **11** ends at the channels **14**, wherein furthermore a base elevation **16**, which raises a portion of the sipe base **11** in the radial direction relative to the depth t.sub.E and extends as far as the sipe walls **12**, is formed adjoining each channel **14**.

(23) In the case of the sipes **10** formed in the middle profile rib **2**, as shown in FIG. 1, the channel **14**, which in each case continues on on the outside of the tread, merges via the respective groove flank **5b** into the corresponding shoulder-side circumferential groove **5**.

(24) As FIG. 2 and FIG. 4 show, especially in combination, the already mentioned paired indentations **13** are located at the mouths of the sipes **10**, said mouths being situated at the middle circumferential groove **4**. The indentations **13**, which each belong to a pair, form a recess **13'** (FIG.

2), which is circular in plan view, extends as far as the channel region 4.sup.III (FIG. 4) and has a diameter d.sub.A (FIG. 4) of 200% to 400%, in particular of 330% to 370%, of the width b.sub.2 (FIG. 4) of the middle portion 4.sup.II of the circumferential groove 4.

(25) FIG. 5 to FIG. 7 show visualizations of sipes 10.sup.I (FIG. 5), 10.sup.II (FIG. 6), 10.sup.III (FIG. 7), which are variants of the sipe 10.

(26) The sipe 10.sup.I shown in FIG. 5 differs from the sipe 10 in that each channel 14 is composed of a middle channel portion 14f, which is curved continuously and uniformly and takes up the majority of the channel 14, a channel end portion 14c, and a radially outer channel portion 14g, which extends as far as the tread periphery, is formed exclusively in the region of the sipe widening 15 and runs in the radial direction.

(27) The sipe 10.sup.II shown in FIG. 6 differs from the sipe 10.sup.I in that no base elevations 16 (FIG. 3) and no sipe widening 15 (FIG. 3) are provided.

(28) In the case of the sipe 10.sup.III shown in FIG. 7, each channel 14 is composed of five channel portions—three straight and two curved channel portions—wherein each straight channel portion alternately follows a curved channel portion. Moreover, a connecting channel 17, which locally widens the sipe 10.sup.III, is formed between the two channels 14, said connecting channel running at a constant depth, determined in the radial direction, and being at a distance in the radial direction both from the tread periphery and from the sipe base 11.

(29) The invention is not limited to the exemplary embodiments described.

(30) The profile rib can be provided with transverse grooves made wider than the sipes. The sipes can also be formed in shoulder-side profile ribs and can furthermore each be provided with just a single channel. Moreover, the sipes do not have to run parallel to one another in plan view. The channel or channels can merge into the respective circumferential groove at a distance from the sipe base which is determined in the radial direction. The radially outer circumferential-groove portion 4.sup.I, which widens in a V shape to the tread periphery, is optional.

LIST OF REFERENCE SIGNS

(31) 1 . . . Central profile rib 1a . . . Rib block 2 . . . Middle profile rib 2a . . . Rib block 3 . . . Shoulder-side profile rib 4 . . . Middle circumferential groove 4.sup.I . . . Radially outer portion 4.sup.II . . . Middle portion 4.sup.III . . . Radially inner channel region 5 . . . Shoulder-side circumferential groove 5a . . . Groove base 5b . . . Groove flank 6 . . . Flank 7 . . . Flank 8 . . . Channel base 9 . . . Channel wall 9a . . . Radially inner wall portion 9b . . . Radially outer wall portion 10, 10.sup.I, 10.sup.II, 10.sup.III . . . Sipe 11 . . . Sipe base 12 . . . Sipe wall 13 . . . Indentation 13' . . . Recess 14 . . . Channel 14a . . . Radially outer channel portion 14b . . . Middle channel portion 14b . . . Channel subsection 14c . . . Channel end portion 14d . . . Channel opening 14e . . . Channel opening 14f . . . Middle channel portion 14g . . . Radially outer channel portion 14' . . . Depression 15 . . . Sipe widening 15a . . . Bottom 15b Side surface 16 . . . Base elevation 17 . . . Connecting channel A-A . . . Line (tire equatorial plane) a.sub.1, a.sub.2 . . . Distance a.sub.K . . . Main axis b.sub.1, b.sub.2, b.sub.3 . . . Width b.sub.E, b.sub.N . . . Width b.sub.PR . . . Width d.sub.A, d.sub.K . . . Diameter E.sub.1 . . . Longitudinal-section center plane E.sub.2 . . . Cross-section center plane I.sub.1, I.sub.2, I.sub.3 . . . Length of extent t.sub.E, t.sub.N, t.sub.K . . . Depth T.sub.P . . . Profile depth Z.sub.2, Z.sub.A . . . Detail α , β , γ , δ . . . Angle

Claims

1. A pneumatic tire for a vehicle, comprising a tread having at least one profile rib, which is delimited on at least one side by a circumferential groove, wherein the circumferential groove has, when viewed in cross section, a portion running in the radial direction and having a width of up to 3.0 mm and, adjoining it, a radially inner channel region, wherein the radially inner channel region is delimited by two channel walls and a channel base forming the groove base, and has a larger cross-sectional area and is made wider in each case than the portion running in the radial direction,

wherein the profile rib is provided over its circumference with sipes, which merge into the circumferential groove, run at an angle of 0° to 50° with respect to the axial direction and have a width of 0.4 mm to 1.2 mm and a maximum depth of 70% to 100% of the profile depth, and have sipe walls, wherein each sipe is locally widened by at least one channel which is open to the tread periphery and merges into the radially inner channel region of the circumferential groove, wherein the channel is formed by a depression formed in one sipe wall and a depression formed in the other sipe wall, opposite the first depression, and each sipe has, at the tread periphery, a slot-shaped sipe widening which runs over its entire extent in plan view and has a bottom, a depth, determined in the radial direction, of 10% to 30%, of the depth of the sipe and a width of 250% to 370%, of the width of the sipe, wherein the channel starts from the bottom of the sipe widening.

2. The pneumatic tire as claimed in claim 1, wherein the channel has a circular cross section with a diameter of 250% to 370%, of the width of the sipe.
3. The pneumatic tire as claimed in claim 1, wherein the diameter of the channel coincides with the width of the sipe widening.
4. The pneumatic tire as claimed in claim 1, wherein the channel is half U-shaped in a view toward the sipe wall.
5. The pneumatic tire as claimed in claim 1, wherein the width of the radially extending portion of the circumferential groove which delimits the profile rib on one side thereof is 0.5 mm to 2.5 mm.
6. The pneumatic tire as claimed in claim 1, wherein the circumferential groove(s), which has or have the portion running in the radial direction and the radially inner channel region, is or are provided at the entries of the sipes with recesses having a diameter of 200% to 400%, of the width of the portion running in the radial direction, which recesses are circular in plan view, run in the radial direction, extend as far as the radially inner channel region, and are open to the tread periphery, wherein the recesses are each formed by indentations that lie opposite one another in pairs in the axial direction.
7. The pneumatic tire as claimed in claim 1, wherein the channel walls of the radially inner channel region of the circumferential groove(s) are each composed of a radially inner wall portion and a radially outer wall portion, wherein the radially inner wall portions, when viewed in a cross section through the circumferential groove, each run at an angle of 5° to 15° , with respect to the radial direction, wherein they are inclined in opposite directions with respect to one another in such a way that the radially inner channel region widens continuously in the axial direction from the radially inner end of the radially inner wall portions to the radially outer end of the radially inner wall portions, wherein the channel or channels, which widens or widen the sipe, merges or merge via the radially inner wall portion into the radially inner channel region of the circumferential groove(s).
8. The pneumatic tire as claimed in claim 1, wherein the circumferential groove(s), which has or have the portion running in the radial direction and the radially inner channel region, is or are composed of the portion running in the radial direction, the radially inner channel region, and a radially outer portion widening in a V shape toward the tread periphery.
9. The pneumatic tire as claimed in claim 1, wherein the channel has a main axis and a radially outer channel opening, wherein—with reference to the main axis—the radially outer channel opening is at a distance, projected into the tread periphery and determined in the axial direction, of 10% to 40%, of the width of the profile rib, determined in the axial direction at the tread periphery, from the circumferential groove into which the channel merges.
10. The pneumatic tire as claimed in claim 1, wherein the slot-shaped sipe widening has its depth, determined in the radial direction, of 15% to 25%, of the depth of the sipe and its width of 290% to 330%, of the width of the sipe.
11. The pneumatic tire as claimed in claim 1, wherein the channel has a circular cross section with a diameter of 290% to 330%, of the width of the sipe.
12. The pneumatic tire as claimed in claim 1, wherein the width of the radially extending portion of the circumferential groove which delimits the profile rib on one side thereof is 0.8 mm to 1.2 mm.

13. The pneumatic tire as claimed in claim 1, wherein the circumferential groove(s), which has or have the portion running in the radial direction and the radially inner channel region, is or are provided at the entries of the sipes with recesses having a diameter of 330% to 370%, of the width of the portion running in the radial direction, which recesses are circular in plan view, run in the radial direction, extend as far as the radially inner channel region, and are open to the tread periphery, wherein the recesses are each formed by indentations that lie opposite one another in pairs in the axial direction.

14. The pneumatic tire as claimed in claim 1, wherein the channel walls of the radially inner channel region of the circumferential groove(s) are each composed of a radially inner wall portion and a radially outer wall portion, wherein the radially inner wall portions, when viewed in a cross section through the circumferential groove, each run at an angle of 5° to 10° , with respect to the radial direction, wherein they are inclined in opposite directions with respect to one another in such a way that the radially inner channel region widens continuously in the axial direction from the radially inner end of the radially inner wall portions to the radially outer end of the radially inner wall portions, wherein the channel or channels, which widens or widen the sipe, merges or merge via the radially inner wall portion into the radially inner channel region of the circumferential groove(s).

15. The pneumatic tire as claimed in claim 1, wherein the at least one profile rib is likewise delimited on the second side thereof by a circumferential groove.

16. The pneumatic tire as claimed in claim 15, wherein the circumferential groove which delimits the at least one profile rib on the second side thereof likewise has, when viewed in cross section, a portion running in the radial direction and having a width of up to 3.0 mm and, adjoining it, a radially inner channel region having two channel walls and a channel base forming the groove base, wherein the channel region has a larger cross-sectional area and is made wider—in each case than the portion running in the radial direction—wherein the sipes formed in the profile rib are of symmetrical configuration in relation to a cross-section center plane which is aligned in the radial direction and—with reference to the longitudinal extent—runs through the center of the sipe.

17. The pneumatic tire as claimed in claim 16, wherein a connecting channel, which, locally widens the sipe and is at a distance in the radial direction both from the tread periphery and from the sipe base, is formed between the channels.

18. The pneumatic tire as claimed in claim 16, wherein the width of the radially extending portion of the circumferential groove which delimits the at least one profile rib on the second side thereof is 0.5 mm to 2.5 mm.

19. The pneumatic tire as claimed in claim 16, wherein the width of the radially extending portion of the circumferential groove which delimits the at least one profile rib on the second side thereof is from 0.8 mm to 1.2 mm.
