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(54) PNEUMATIC RADIAL TIRE

(71) We, BRIDGESTONE TIRE KABUSHIKI KAISHA, of No. 1-1, 1-Chome, Kyobashi, Chuo-Ku, Tokyo, Japan, a company organized according to the laws of Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a pneumatic radial tire, and more particularly to an improvement in the tread configuration of such a tire, e.g. a large-sized pneumatic radial tire, i.e. a pneumatic radial tire intended for trucks and buses.

In tires of this type, there is provided a carcass of substantially radial construction (by which is meant that the cords of the carcass are arranged in radial or substantially radial planes of the tire) and a belt superimposed about the carcass, which serve as a reinforcement for the tire. This belt is generally composed of a plurality of rubberized cord layers, at least one layer of which is composed of steel cords and frequently disposed near the tread of the tire.

Such pneumatic radial tires are particularly used in a flat form having an aspect ratio of not more than 0.9 for trucks and buses, monorail vehicles, and electric cars. In these applications, however, it has been observed that a peculiar and abnormal wear occurs which shortens the wear-resistant life of the tire.

That is, when a vehicle provided with such tires is driven straight on a good road, for example a highway paved with concrete or asphalt or a single-purpose track for a monorail vehicle or an electric car, abnormal wear occurs concentrically in shadowed portions along grooves in the tread near both shoulders of the tire, as shown in Fig. 1, of the accompanying drawings, particularly adjacent edges S, S′ at one side of tread grooves *g*, *g′* extending substantially in the widthwise direction of the tire. Fig. 1 is a schematic illustration of the tread configuration of a tire of this type viewed from the rear of the vehicle, the rotating direction of the tire being shown by an arrow. Surprisingly, the abnormal wear is formed at the trailing side or heel side *t* of a tread element *e* in the left half region B viewed with respect to a center line X—X′ of the tire crown and also at the leading side or toe side *h* of a tread element *e* in a right half region A.

According to general experience relating to pneumatic radial tires, it has been confirmed that a stepped wear or so-called "heel and toe" wear is formed at the trailing side *t* due to the following fact; that is, at that portion of the tread element firstly contacting the ground during the rotating of the tire, i.e. the leading side *h*, the ground contact pressure gradually increases as the ground contact area becomes large and then gradually decreases as the leading side *h* leaves the ground, while at the trailing side *t* contacting the ground following the leading side *h*, the increase in the ground contact pressure is small owing to the presence of succeding tread grooves *g*, *g′* and the trailing side *t* is liable to be displaced toward the tread grooves *g*, *g′*, so that a lagging movement of the trailing region accompanied by such displacement is caused against the ground.

In general, the tread pattern of a tire is constructed with groove parts and island parts. The island parts are called ribs, lugs or blocks in accordance with their form and the groove parts are called main grooves, lateral grooves, branch grooves, fine grooves or sipes in accordance with their form. In any island parts, which are divided in the circumferential direction of the tire by two groove parts inclined at an angle α of up to 90° with respect to the circumferential direction of the tire and arranged at a given interval in the circumferential direction, that portion of the island part which first contacts the ground during rotation in a given direction is defined as the leading side *h* and that portion of the island part which subsequently contacts the ground is defined as the trailing side *t*. Of course, the sides *h* and *t* are reversed when the rotating direction of the tire is reversed.

In the aforesaid applications, the phenomenon of such stepped wear has been observed only at the trailing side in the left half region of the tire and only at the leading side in the right half region of the tire as shown in Fig. 1.

The pattern of tread grooves used for the tread configuration of a tire is variously selected in accordance with the characteristics required for the tire, such as braking performance or cornering performance. In general, such a tread pattern is a series of repeated pattern units with respect to the circumferential direction of the tire, provided that the half portions of the pattern unit are symmetrically arranged at the left and right half regions of the tire while shifting these portions by a half pitch with respect to each other in the circumferential direction. In the case of tires for passenger cars, construction vehicles or agricultural vehicles, the half portions of the pattern unit may be non-symmetrically arranged at the left and right half regions of the tire. In the applications aimed at by the present invention as mentioned above, however, such unsymmetrical patterns are not usually adopted. Moreover, the cross-section of each tread groove is usually V-shaped with the walls of the groove being inclined at an angle of approximately 5° with respect to a vertical line from the tread surface.

It will thus be apparent that the different wear behaviours at the left and right half regions of the tire are a phenomenon peculiar to large-sized pneumatic radial tires.

Now, the inventors have made various studies with respect to the main cause of such a phenomenon and have found that this phenomenon is closely related to the construction of the tire.

That is, in large-sized pneumatic radial tires it has been found that the regions where the above mentioned peculiar wear occurs are determined by the direction of internal camber thrust acting on the tire (hereinafter referred to as plysteer), which is produced due to the tire construction and to ground contact reaction force acting on steel cords of at least one rubberized layer disposed near the tread and constituting a belt, which comprises a reinforcing member together with the carcass.

Such plysteer is indicated by an arrow T directed towards a reference letter Y as shown in Fig. 2 of the accompanying drawings when the tire is rotated in an upward direction (with respect to the drawing). Fig. 2 shows an arrangement of steel cord layers in a large-sized pneumatic radial tire 1, wherein a carcass (not shown) of the tire 1 is covered by a belt composed of several steel cord layers 2,3 among which a cord layer disposed nearest the tread 4 is constituted of steel cords 3′ each having a high rigidity and inclined at a given angle β with respect to the circumferential direction of the tire.

Further, the inventors have made various observations and examinations with respect to the tire shown in Fig. 2. As a result, it has been found that when the rotation of the tire is set in a given direction, the abnormal wear shown in Fig. 1 occurs only at the left half region B of the tread and hardly occurs at the right half region A. Moreover, it has been confirmed that if the rotation of the tire is reversed, the abnormal wear occurs at the right half region A of the tread because the leading side *h* of the tread is converted into the trailing side *t* due to the reversed rotation of the tire.

As seen from the above, the abnormal wear shown in Fig. 1 is recognized to be apparently a composite phenomenon developed by compounding the wears at the left and right half regions of the tread with each other during each rotating direction of the tire when the tires provided on the vehicle are run with a change of location after a suitable time or when the rotating direction of the tire is altered by for example shuttling an electric car provided with such tires.

Thus, it can be said that the development of abnormal wear at different positions depends upon the rotating direction of the tire. In the embodiment of Fig. 2, when the tire is rotated in an upward direction, the abnormal wear is caused only at the left half region B as shown in Fig. 3*a* of the accompanying drawings while when the tire is rotated in a downward direction, the abnormal wear is caused only at the right half region A as shown in Fig. 3*b* of the accompanying drawings.

Such phenomenon of developing the wear only at each half region of the tread is investigated as follows.

That is, when a plysteer T is produced during the rotating of the tire in an upward direction, the tire 1 is slightly deformed in the direction of plysteer T as shown by a dot-dash-line in Fig. 4*a* of the accompanying drawings. As a result, the shoulder portion at the right half region A of the tread is slightly deformed towards the ground surface and has a ground contact pressure lower than that of the shoulder portion at the left half region B of the tread, as shown in Fig. 4*b* of the accompanying drawings.

Thus, the ground contact reaction force of the tread element *e* becomes large at the left half region of the tread having a high ground contact pressure, so that this tread element is apt to be lagged against the ground surface, and in particular the lagging of the tread element occurs concentrically on an edge of a tread groove at the trailing side as shown in Figure 4*c* of the accompanying drawings. As a result, local wear is formed on the edge of the tread groove at the trailing side of the tread element.

The present invention provides a pneumatic radial tire comprising a tread including grooves having portions inclined at an angle of 30° to 90° with respect to the circumferential direction of the tire, a belt composed of a plurality of rubberized layers each containing steel cords, and a carcass of a substantially radial construction, the tread including two half regions located one to each side of the mid-circumferential plane of the tire, one of the said regions being a first region extending from the mid-circumferential plane in a direction of plysteer, and the other said region being a second region extending from the mid-circumferential plane in a direction opposite to the direction of plysteer, when the tire is rotated in a given direction, wherein in the said second region reinforcements are provided on the leading walls, but not on the trailing walls, with respect to the said direction of rotation of the tire, of at least the said inclined groove portions adjacent the tread edge.

It will be understood, within the context of the present invention, that a reinforcement may be provided on the wall of a groove portion simply by inclining that wall at an angle larger than that of the opposite groove portion wall with respect to the normal to the tread. Alternatively, a reinforcement may be, for example, a step-like protrusion provided on the wall at the side of a groove portion to be reinforced.

In a preferred embodiment of the invention, reinforcements are provided on the trailing walls, but not on the leading walls, with respect to the said given direction of rotation of the tire, of at least the inclined groove portions adjacent the tread edge in the said first region of the tread, whereby the tire may be preferably used in applications wherein the rotating direction of the tire is alternately reversed. Further, the tire according to the invention preferably has an aspect ratio of not more than 0.9 and/or a tread having a ratio of the tread gauge to the total belt gauge of 0.7—2.5.

The invention will be further described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a partial schematic view of a rubber tire for an electric car illustrating peculiar wear caused at its tread pattern;

Fig. 2 is a partial schematic view of a tire showing steel cords of a belt in an exposed state by partly cutting out tread rubber from the tread surface and illustrating the behaviour of peculiar wear phenomenon as well as means for preventing such wear phenomenon;

Fig. 3*a* is a partial schematic view of the tire shown in Fig. 2 illustrating the abnormal wear phenomenon caused during rotating of the tire in an upward direction;

Fig. 3*b* is a partial schematic view of the tire shown in Fig. 2 illustrating the abnormal wear phenomenon caused during rotating of the tire in a downward direction;

Fig. 4*a* is a schematic sectional view of the tire deformed by plysteer produced during rotation of the tire;

Figs. 4*b* and 4*c* are graphical representations showing distributions of ground contact pressure and circumferential lagging amount of the tread in the tire of Fig. 4*a*, respectively;

Fig. 5 is a partial schematic illustration of a tire for measuring tread gauge and total belt gauge;

Figs. 6 and 7 are cross-sectional view of tread groove portions provided with embodiments of reinforcements and taken along the line C—C of Fig. 2, respectively;

Fig. 8 is a partial schematic illustration of another embodiment of a tire having tread groove portions with reinforcements;

Figs. 9 and 10 are cross-sectional views of a tread groove portion taken along the lines A—A and B—B of Fig. 8, respectively;

Figs. 11*a* and 11*b* are cross-sectional views of another embodiment of a tread groove portion provided with reinforcements and taken along the lines C—C and D—D of Fig. 2, respectively; and

Fig. 12 is a graphical representation illustrating the effect of decreasing the lagging amount of the tread by a tread groove reinforcement.

In the tires of the invention, the tread groove portions are preferably provided with reinforcements by arranging that a wall of the groove portion is inclined, in cross-section, at an angle larger than that of an opposite wall with respect to the normal to the tread surface, particularly at an angle of 10—45°. Alternatively, the tread groove portion may have a step-like protrusion provided on the groove portion wall as the reinforcement. Furthermore, each reinforcement is provided on the wall of a tread groove portion extending at an angle of 30—90° with respect to the circumferential direction of the tire. Moreover, each reinforcement preferably extends over a length corresponding to at least 20% of the length of a substantially straight edge of the groove portion.

In the embodiment of Fig. 2, the tread pattern comprises a center rib 5, a pair of zigzag center grooves 6 defining the center rib, a pair of side ribs 7 disposed outside the respective center grooves 6, and a pair of zigzag side grooves 8 disposed outside the respective side ribs 7. Each side groove 8 comprises portions inclined with respect to the circumferential direction of the tire and portions extending in the circumferential direction and has a plurality of lateral groove portions 9 each extending from the protruded portions of the groove 8 toward a shoulder portion of the tire.

In such a pattern, wear is liable to be concentrically caused along the edges of the inclined portions of the side groove 8 and along the groove portions 9 at the trailing side t in the left half region B of the tread of the tire 1 as is apparent from the above. Therefore, reinforcements 10 are provided on these edges. In this case, the groove edge to be reinforced should be inclined at an angle α of 30—90° with respect to the circumferential direction of tire.

In applications wherein the rotating direction of the tire will be alternately reversed similar reinforcements 10′ may be provided along the edges of the groove portions to be reinforced at the remaining right half region A of the tread.

Such reinforcements are particularly effective for tires having an aspect ratio of not more than 0.9, because in tires of this type the width of the belt is large and therefore the tire is strongly affected by plysteer acting to the outermost cord layer of the belt. Further, the present invention is particularly applicable to large-sized tires having a ratio (GT/GB) of tread gauge (GT) to total belt gauge (GB) of 0.7—2.5, more preferably 0.9—2.0, because the development of abnormal wear is considerably influenced by the cord layer disposed immediately beneath the tread. As shown in Fig. 5, the tread gauge (GT) is the distance between the surface of the tread and the surface of the outermost layer constituting the belt in the crown center and the total belt gauge (GB) is the sum of the thicknesses of the cord layers constituting the belt in the crown center.

To form a reinforcement, that wall of a groove portion having a tendency to undergo wear along its edge is inclined at an angle larger than that of the opposite wall with respect to the normal to the tread or a step-like protrusion is provided along such a groove portion wall. However, when the tread groove portion extends at an angle α of less than 30° with respect to the circumferential direction of the tire, there is no problem relating to the development of abnormal wear, so that the provision of such a reinforcement is unnecessary. Further, the reinforcement is not necessarily provided on the tread groove portion over the whole length of its substantially straight edge but may be provided on the groove portion over a length corresponding to at least 20% of the length of such groove portion edge.

As shown in Fig. 6, the reinforcement 10 is so constructed that the angle θ_1 of the groove portion wall 11 to be reinforced with respect to the normal v to the tread 1 is larger than the angle θ_2 of the opposite groove portion wall 12 with respect to the same normal v, i.e. $\theta_1 > \theta_2 \geqq 0$. The angle θ_1 is preferably within a range of 10—45°. Alternatively, as shown in Fig. 7, a step-like protrusion 13 is provided as the reinforcement 10 on the groove portion wall 11 to be reinforced so as to make the two walls of the tread groove portion unsymmetrical with each other with respect to the normal v. In the latter case, the protruded width b of the protrusion 13 is preferably 20 to 40% of the width w of the tread groove portion.

The reinforcement 10 is not necessarily provided along the overall length of the groove portion edge. As shown in Fig. 8, the reinforcement 10 only extends over a length corresponding to at least 20% of the length l of the substantially straight edge of the groove portion.

The cross-section of the groove portion provided with the reinforcement 10 is not necessarily the same over its length. As shown in Figs. 9 and 10, the cross-section of the groove portion may be changed continuously or stepwise in accordance with the degree of abnormal wear. In these figures, a broken line represents the fundamental cross-section of the tread groove portion commonly used.

The provision of reinforcements 10 is particularly effective for tires having a flat cross-section wherein the width of the tread is large and the thickness of the tread is small. However, the invention is applicable to and effective in respect of tires for buses and trucks.

The invention will be further described with reference to the following illustrative example.

In a pneumatic radial tire for an electric car having a size of 1400R 16, reinforcements 10 were provided at the trailing positions 18, 19 of the tread elements in the tread pattern of Fig. 2 wherein the groove portion walls 11 at these positions taken along the lines C—C and D—D of Fig. 2 were inclined at an angle of 40° with respect to the normal to the tread as shown in Figs. 11a and 11b, respectively.

When the tire provided with such reinforcements was rotated in a given direction, the circumferential lagging amount of tread was measured at the trailing positions 18, 19 to obtain results as shown in Fig. 12. For comparison, the circumferential lagging amount of tread in a tire having no reinforcements is also shown in Fig. 12. As seen from Fig. 12, the circumferential lagging amount of tread can be decreased to about 80% by the provision of the reinforcements 10, whereby the wear-resistant life of the tread can be more than doubled.

WHAT WE CLAIM IS:—

1. A pneumatic radial tire comprising a tread including grooves having portions inclined at an angle of 30° to 90° with respect to the circumferential direction of the tire, a belt composed of a plurality of rubberized layers each containing steel cords, and a carcass of a substantially radial construction, the tread including two half regions located one to each side of the mid-circumferential

plane of the tire, one of the said regions being a first region extending from the mid-circumferential plane in a direction of plysteer, and the other said region being a second region extending from the mid-circumferential plane in a direction opposite to the direction of plysteer, when the tire is rotated in a given direction, wherein in the said second region reinforcements are provided on the leading walls, but not on the trailing walls, with respect to the said direction of rotation of the tire, of at least the said inclined groove portions adjacent the tread edge.

2. A pneumatic radial tire as claimed in Claim 1, wherein in the said first region reinforcements are provided on the trailing walls, but not on the leading walls, with respect to the said direction of rotation of the tire, of at least the said inclined groove portions adjacent the tread edge.

3. A pneumatic radial tire as claimed in Claim 1 or 2, having an aspect ratio of not more than 0.9.

4. A pneumatic radial tire as claimed in any of claims 1 to 3, having a ratio of tread gauge to total belt gauge of 0.7—2.5.

5. A pneumatic radial tire as claimed in any of claims 1 to 4, wherein each said reinforcement is so constructed that a wall of a said groove portion to be reinforced is inclined at an angle larger than that of the opposite groove portion wall with respect to the normal to the tread.

6. A pneumatic radial tire as claimed in Claim 5, wherein the said wall of the groove portion to be reinforced is inclined at an angle of 10—45° with respect to the said normal.

7. A pneumatic radial tire as claimed in any of claims 1 to 4, wherein each said reinforcement is a step-like protrusion provided on the wall of a said groove portion to be reinforced.

8. A pneumatic radial tire as claimed in any of claims 1 to 7, wherein each said reinforcement extends over a length corresponding to at least 20% of the length of the substantially straight edge of a said groove portion.

9. A pneumatic radial tire according to claim 1, substantially as herein described with reference to, and as shown in, Figs. 2 and 6 or Figs. 2 and 7 of the accompanying drawings.

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1592065 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

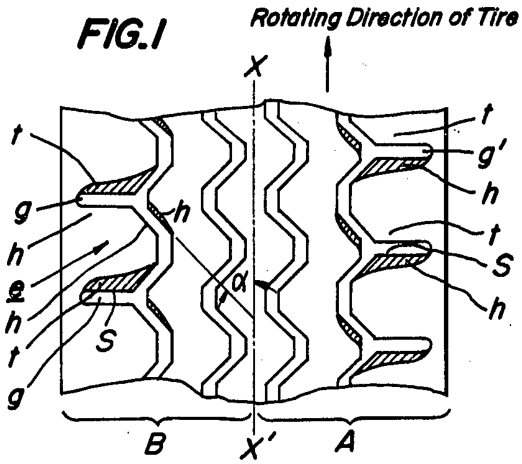


FIG. 2

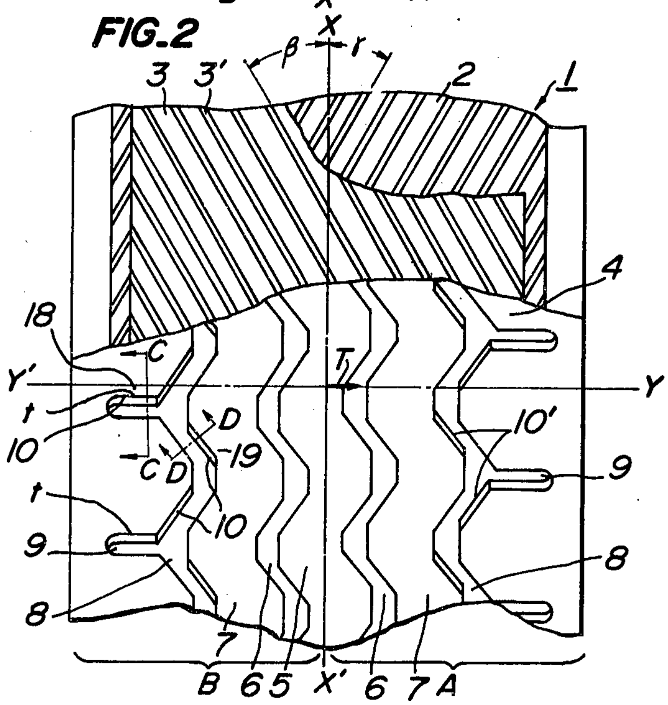


FIG_3a

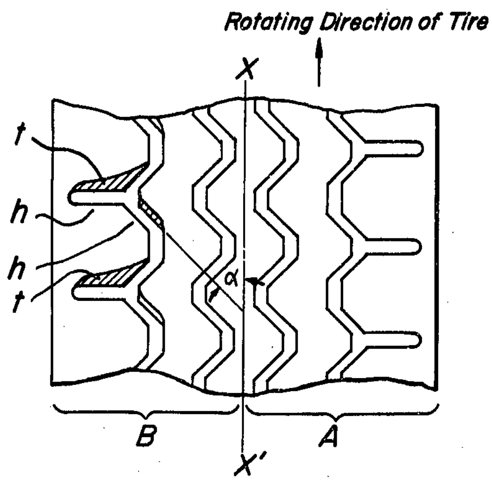
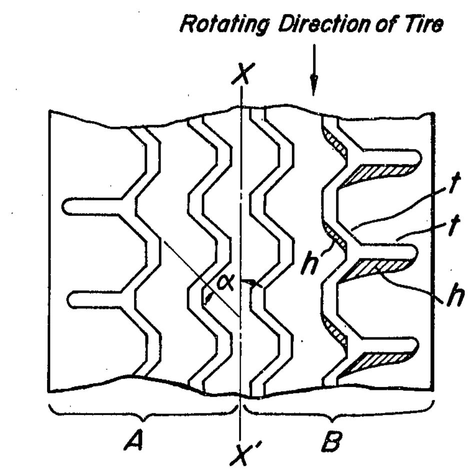

Rotating Direction of Tire
X
t
h
h
t
α
B
A
X'

FIG_3b


Rotating Direction of Tire
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t
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h
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α
A
B
X'

FIG.4a

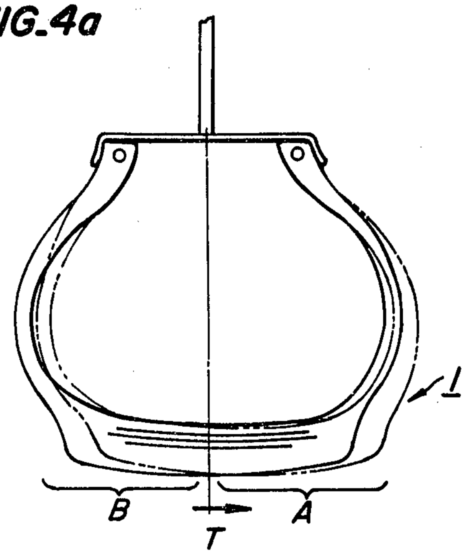

FIG.4c Distribution of Circumferential Lagging Amount of Tread

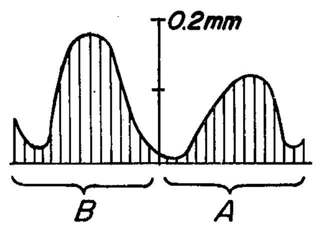

FIG.4b

Distribution of Ground Contact Pressure

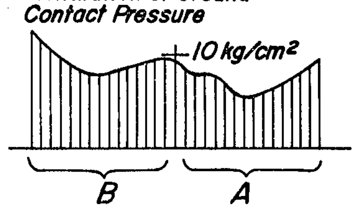

FIG_5

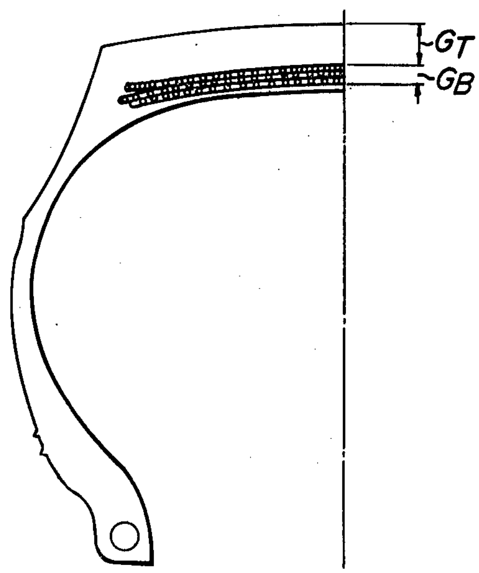

FIG_6

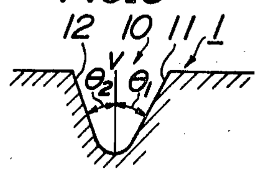

FIG_7

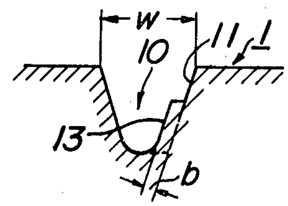

FIG_8

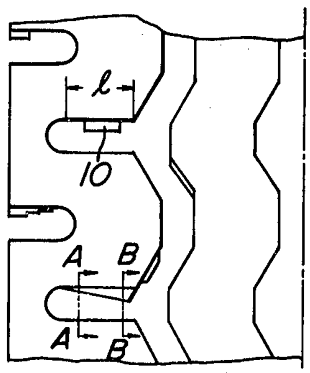

FIG_9

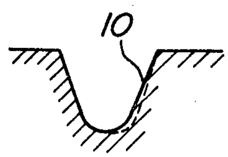

FIG_10

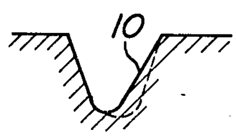

FIG_11a

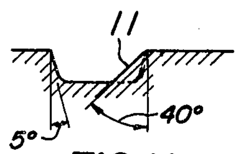

FIG_11b

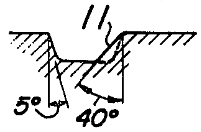

FIG_12