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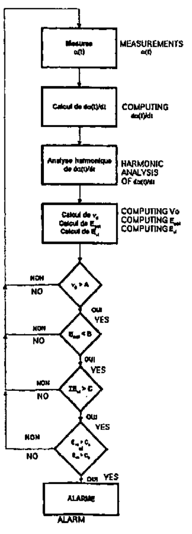
(54) Titre: PROCEDE ET DISPOSITIF DE DETECTION D'UNE CONDITION DE ROULAGE A PLAT D'UN PNEUMATIQUE-INSERTS, ROUES ET PNEUMATIQUES CONÇUS POUR CE PROCEDE

(57) Abstract

The invention concerns a method for detecting a vehicle tyre flat running condition, said tyre being mounted on a wheel, consisting in: sensing a value $f(\alpha,t)$ which varies with the wheel angular displacement in time; elaborating measurement signals which vary with the wheel angular speed $d\alpha(t)/dt$; computing a characteristic measurable quantity of the measurement signals dispersion; triggering an alarm when the characteristic measurable quantity satisfies a predetermined relationship.

(57) Abrégé

Procédé de détection d'une condition de roulage à plat d'un pneumatique d'un véhicule, ledit pneumatique étant monté sur une roue, tel que: on capte une grandeur $f(\alpha,t)$ qui varie avec le déplacement angulaire de la roue dans le temps; on élabore des signaux de mesure qui varient avec la vitesse angulaire de la roue $d\alpha(t)/dt$; on calcule une grandeur caractéristique de la dispersion des signaux de mesure; on déclenche une alarme lorsque ladite grandeur caractéristique satisfait une relation donnée.



ABSTRACT

Method of detection of a run-flat condition of a vehicle tire, said tire being mounted on a wheel, whereby: a quantity $f(\alpha, t)$ is sensed, which varies with the angular displacement of the wheel in time; measuring signals are elaborated, which vary with the angular speed of the wheel $d\alpha(t)/dt$; a quantity characteristic of the dispersion of measuring signals is calculated; an alarm is set off when the characteristic quantity satisfies a given ration.

METHOD AND SYSTEM OF DETECTION OF A RUN-FLAT CONDIDTION OF A TIRE - INSERTS, WHEELS AND TIRES DESIGNED FOR THAT METHOD

The invention concerns a method and a system of detection of a run-flat condition of a vehicle tire as well as tires, wheels and safety inserts designed to facilitate that detection.

When a mounted assembly – tire and wheel assembly – contains means of support of the tire tread in case of running flat, those means of support make it possible to avoid a forced stop of the tire in case of serious loss of air pressure in the tire. Those means of support can be a safety insert placed radially outside the rim of the wheel of the mounted assembly or reinforcing elements placed inside the structure of the tire sidewalls and/or beads. Such tires are called "self-supporting".

The bearing of the tire on those means of support is accompanied by a more or less marked degradation of its performance, which may not be perceptible to the driver through the behavior and comfort of the vehicle. Furthermore, the operating lifetime of those means of support is limited. It is therefore useful for the driver to be alerted as soon as a tire bears on its means of support so that he can follow the manufacturer's instructions.

Patent application WO 94/03338 proposes a system of detection of the bearing of a tire on a safety insert. That system comprises one accelerometer per wheel, placed on one of the suspension elements of the wheel and measuring the vertical accelerations linked to a central processing unit. The analysis is based on detection of the appearance, upon bearing, of a resonance mode of the system consisting of the tire bearing on the safety insert, of the unsuspended weights and of the suspension springs. That resonance mode is characteristic of running flat and is situated beyond 100 hertz.

However, for some safety supports, made, for example of elastomeric material, the sensitivity of the aforesaid analysis may prove insufficient.

In the case of mounted assemblies not containing the aforesaid means of support, on a run-flat condition, the tread bears on the beads and the rim hooks. That can result in a rapid deterioration of the tire and a fall of the beads into the rim mounting groove, not to mention degradation of behavior of the vehicle. As soon as such a support comes into play, it is also very useful to alert the driver.

In what follows, the "run-flat condition" of a tire means running when the air pressure in the tire is no longer sufficient to guarantee that the tire will carry the load of the tire. The tire tread then bears on the support elements. Those support elements can be provided for that purposes (such as safety inserts arranged around the rim) or not (rim hooks, etc.).

The object of the invention is a method of detection of a run-flat condition of a vehicle tire, the tire being mounted on a wheel, the sensitivity and reliability of which are improved.

SUMMARY OF THE INVENTION

The method of detection according to the invention is such that:

- a quantity $f(\alpha, t)$ is sensed, which varies with the angular displacement of the wheel in time;
- measuring signals are derived from that quantity, which vary with the angular speed of the wheel $d\alpha(t)/dt$;
- a quantity characteristic of the dispersion of measuring signals is calculated;
- an alarm is set off when the characteristic quantity satisfies a given threshold value.

The characteristic quantity can simply be the value of the standard deviation of the measuring signals.

According to the invention, there is provided a method of detection of a run-flat condition of a vehicle tire, said tire being mounted on a wheel, whereby:

- a quantity $f(\alpha, t)$ is sensed, which varies with the angular displacement (α) of the wheel in time (t);
- a measuring signal is derived from said quantity, which varies with the angular velocity of the wheel $d\alpha(t)/dt$;
- the rotation frequency of the wheel is determined;
- the energy of the measuring signals is calculated in at least one narrow frequency band centered on one of the first harmonics of said rotation frequency over said rotation frequency or first harmonic; and
- an alarm is set off when said energy exceeds a predetermined threshold value.

Preferably, the rotation frequency of the wheel can be determined from the measuring signals.

The applicant, in fact, very surprisingly observed that analysis of a measure of the dispersion of the rotation speeds of the wheels reveals notable changes on a run-flat condition of a tire, that is, when the tread bears on any support element. The method has the advantage of not necessitating, as in previously known methods, specific sensors such as accelerometers, but can rather use simple measurement of angular rotation of the wheels. Those measurements are often already available, as in the case of vehicles equipped with antilock devices on the wheels. The method may then include deriving the measuring signals from sensors of the wheel antilock device.

Furthermore, upon bearing of the tread of a tire in run-flat condition on any support element, the method of detection may be very sensitive and very reliable, because the applicant observed that the energy of the measuring signals varies preferentially in the frequency bands centered on the different harmonics of the turn of a wheel.

The method of detection preferably analyzes the development of energy of the spectrum of speeds in at least two narrow frequency bands centered on harmonics of the turn of a wheel, with the exception of harmonic 1.

Preferably, the energy of the measuring signals is calculated in at least two narrow frequency bands each centered on one of the first harmonics of the rotation frequency of the wheel over said rotation frequency or first harmonic.

Advantageously, after having detected that the sum of the energies of the measuring signals in at least two narrow frequency bands centered on one of the first harmonics exceeds a predetermined value thereof, the energy of the measuring signals in each of those frequency bands is compared to a given corresponding threshold and an alarm is set off when, for at least two of said frequency bands, the energy of the signals is higher than said corresponding threshold.

This supplementary test has the advantage of limiting the influence of possible disturbances, such as those due to engine vibrations. In fact, such disturbances are usually limited to a single frequency band.

The analysis can be conducted wheel by wheel or by comparing the wheels with each other. Wheel by wheel comparison has the advantage of making it possible to identify the tire in run-flat condition. Preferably, the location of the tire in run-flat condition is identified and transmitted to the driver of the vehicle. In the case of comparison among several tires, the energy or energies of the measuring signals of the wheel of said tire may be compared with the energy or energies of the measuring signals of at least one of the other tires of the vehicle, an alarm being set off when the result of the comparison satisfies a given ratio.

The analysis can also use measuring signals which vary with angular acceleration of the wheels $d^2\alpha(t)/dt^2$.

The narrow frequency band or bands may have a width less than or equal to 10hz.

Preferably, to avoid false alarms, the energy of said measuring signals is also calculated in at least one further frequency band, where the measuring signals are substantially independent of the run-flat condition of said tire and no alarm is set off when the measuring energy in said further frequency band or bands exceeds a given threshold.

Said further frequency bands are preferably situated outside frequencies that are multiples of the rotation frequency of said wheel.

It is also preferable that no alarm can be set off when the speed of the vehicle is below a given threshold.

The invention also concerns a system of detection of a run-flat condition of a vehicle tire, the tire being mounted on a wheel, including:

- first means for sensing a quantity $f(\alpha,t)$ which varies with the angular displacement of the wheel in time,
- second means for operating the method of detection according to any one of the forms disclosed above;
- third means for transmitting said alarm to the driver of the vehicle; and
- fourth means arranged in the mounted tire/wheel assembly to generate vibrating warning signals generating at least one sinusoidal function, the period of which is a submultiple of a turn of the wheel, on a run-flat condition of the tire.

The fourth means for generating vibrating warning signals advantageously generate one sinusoidal function only, the period of which is a submultiple of a turn of the wheel.

Such signals are easily detected by the system according to the invention, even in the case where the fourth means appreciably generate only a single sinusoidal function, the period of which is a submultiple of a turn of the wheel.

The fourth means can belong to the tire, to the wheel or to a safety insert placed radially outside a rim of the wheel.

The invention also provides a safety insert intended to cooperate with the aforesaid detection method in order to offer a reliable detection of any run-flat condition of the tire. There is also provided the system of detection including the safety insert.

The safety insert, intended to be radially mounted outside the rim of said wheel, may contain on its radially outer surface axially oriented bars, those bars having sides whose inclination from normal to the tread in the longitudinal (i.e. circumferential) direction varies as a function of azimuth in order to generate vibrating warning signals on running in a run-flat condition. Those warning signals reinforce, on running flat, rotation speed fluctuations of the wheel.

Preferably, the circumferential inclination according to the azimuth is at least a sinusoidal function, the period of which is a submultiple of a turn of the insert. That has the advantage of generating running speed variations specifically at harmonic frequencies of a turn of the wheel of the insert and, therefore, of being very easily detected by the aforesaid detection method with great reliability.

The invention also provides a tire intended to equip a wheel, the tire containing a tread, two sidewalls and two beads as well as support elements intended to support the tread in case of run-flat condition. That tire is characterized in that the support elements contain means for generating vibrating warning signals on a run-flat condition.

The means for generating those vibrating warning signals preferably entail a variation as a function of azimuth of the radius under load of the tire on running on camber above a given threshold. That variation as a function of azimuth of the radius under load of the tire is advantageously a sinusoidal function, the period of which is a submultiple of a turn of the insert.

There is also provided the system for detection including such a tire.

The invention provides, further, a wheel intended to receive a tire, characterized in that it contains means for generating vibrating warning signals of a run-flat condition of the tire. Those means can be a variation as a function of the azimuth of the radial height of least one of its hooks. That variation can be obtained by the addition of an extra part at least partially covering the radial end of the hook.

As previously, the variation of radial height as a function of azimuth is preferably at least a sinusoidal function, the period of which is a submultiple of a turn of the insert.

There is also provided the detection system including such a wheel.

Several embodiments are now described nonlimitatively by means of the attached drawing in which:

- Figure 1 represents, in axial section, a mounted assembly equipped with a safety insert;
- Figure 2a and 2b schematically represent, in side view, a first embodiment of a safety insert according to the invention;
- Figure 3 represents the course of the longitudinal inclination of axial bars of the insert of Figure 2b as a function of the azimuth;
- Figure 4 represents, in meridian section, a diagram of a second insert with an outer radius variation;
- Figure 5 represents, in meridian section, a diagram of a third insert with a radial stiffness variation;
- Figure 6 represents, in meridian section, a diagram of a fourth insert with a combination of radial stiffness and outer radius variations;
- Figure 7 schematically represents a detection system according to the invention;
- Figure 8 represents a general diagram of the method of detection according to the invention;
- Figure 9 represents two spectra of measuring signals as a function of frequency in inflated and run-flat condition on an ordinary road;
- Figure 10 represents, in axial half-section, a tire according to the invention;

- Figure 11 represents the course as a function of azimuth of the radial height of a tire reinforcement;
- Figure 12 represents, in axial section, a wheel according to the invention;
- Figure 13 represents, in interior side view, the wheel of Figure 9; and
- Figure 14 represents the course as a function of azimuth of the radial height of the interior hook of the wheel of Figures 12 and 13.

Figure 1 shows a wheel rim 10 equipped with an annular safety insert 13 resting on the bearing 11 of the rim 10. The particular geometry of that wheel rim 10 is, notably, described in French patent application No. 2,713,558. It represents two bead seats of different diameters and is particularly adapted for easy placement of that safety insert 13. This assembly makes running possible in spite of a considerable pressure drop in the tire 12. In the case of such running, the interior of the deformed tire rubs on the outer surface of the insert, producing a heating which limits the radius of action available; it is therefore important for the driver to be informed as soon as a tire bears on its insert 13.

For that purpose, a safety insert containing means for generating harmonic vibrating warning signals of the turn of the wheel (that is, of the rotation frequency of the tire) is advantageously used as insert.

The insert presented on Figure 2 is made of pliable elastomeric material. It contains a generally ring-shaped base 14, reinforced by a ply (not represented) longitudinally oriented roughly at 0°, a roughly ring-shaped crown 15 with axial bars 19 on its radially outer wall (Figure 2b) and arched walls 16. Between walls 16 there are recesses 17 which can axially cross the insert 13 completely or not. The base can contain an abutment 18 to be placed on the outer side next to the tire bead.

The axial orientation bars 19 present sides 191 whose inclination from normal to the tread in the longitudinal direction varies as a function of azimuth, as represented on Figure 3. That inclination follows a roughly sinusoidal course submultiple of order 2 of the turn of the insert. On running flat on the insert, the bars supporting the tire are going to be crushed with a slight longitudinal displacement of amplitude and direction variable with the inclination of those bars. That displacement is going to be transmitted to the tire by adherence between the insert and the inner surface of the tire and is going to result in the appearance of instantaneous rotation speed fluctuations of the mounted assembly and, therefore, of the wheel. Those fluctuations will, in the present case, preferably be centered on harmonic 2 of the spectrum of wheel rotation speeds. Such an insert therefore comprises an example of means for generating rotation speed variations of the wheel it equips on running flat.

A similar result can be obtained by varying the radial stiffness of the insert as a function of the azimuth or its radius.

Figure 4 represents a diagram of an insert 20 having a variation of outer radius among three values R1, R2 and R3 such that R1>R2>R3 with a progressive variation of that radius between maxima and minima. The two zones of outer radii R1 are at 180° from one another and so are the two zones of radii R2; the four minima of radii R3 are each between two maxima R1 and R2. This result, on running flat, in a variation of that radius as a function of α with two fundamental harmonics, the first of frequency 2, due to the first two maxima of radius R1 and the second of frequency 4 due to the presence of the four maxima of radius R1 and R2 and of the four minima of radius R3. In that example, the R1 – R3 difference is equal to 5 mm and the R2 – R1 difference is equal to 3 mm.

Figure 5 represents a diagram of an insert 30 which has a variation of radial stiffness among three values K1, K2 and K3, such that K1>K2>K3, with a progressive variation of that stiffness between the maxima and the minima. As previously, the two zones of stiffness K1 are at 180° from one another and so are the two zones of stiffness K2; the four minima of stiffness K3 are each between two maxima K1 and K2. This results, on running flat, in a variation of that stiffness as a function of α with two fundamental harmonics, the first of frequency 2, due to the first two maxima of stiffness K1 and the second of frequency 4 due to the presence of the four maxima of stiffness K1 and K2 and of the four minima of stiffness K3.

Figure 6 represents a diagram of an insert 40 presenting a combination of a variation of outer radius and a variation of radial thickness. Each characteristic presents two maxima (R1, K2 respectively) and two minima (R2, K1 respectively), shifted angularly by 90° from one another. The radial thickness maxima are sufficiently localized to produce on the insert 40 assembly a crushed radius variation on bearing with four maxima.

Consequently, that insert also produces an harmonic excitation concentrated on harmonics 2 and 4, but presents the advantage of having a weighting variable as a function of speed. The applicant observed, in fact, that the radial variations of stiffness were more perceptible at low speed and that the outer radius variations were more perceptible at high speed.

Figure 7 represents a vehicle equipped with a system of detection of a run-flat condition according to the invention. The vehicle contains four wheels 1a, 1b, 1c and 1d equipped with tires. Each mounted assembly (tire and wheel) contains means for generating vibrating warning signals on running-flat of the tire, for example, one of the safety inserts presented in Figures 2 to 6. Close to each tire there is a sensor of angular displacement 2a, 2b, 2c and 2d of the wheel concerned. Each sensor is coupled to a notched disk 21a, 21b, 21c and 21d respectively, as well known. The notched disks 21a, 21b, 21c and 21d are made of magnetic disks attached coaxially with the corresponding wheels. The sensors 2a, 2b, 2c and 2d are placed close to the notched disks 21a, 21b, 21c and 21d at such distance that rotation of the notched disk near the sensor creates a signal variable with the angular displacement of the notched disk. The average frequency of that signal gives the angular rotation speed of the wheel. The variable signal of each sensor 21, 2b, 2c and 2d is entered in a central unit 3. The central unit 3 comprises a signal analyzer which analyzes those signals. The result of the analysis is transmitted to a display 4 in order to inform the driver of the vehicle when a roll-flat condition of a tire is detected.

When the vehicle is equipped with a wheel antilock device, the aforesaid sensors 2 and the central unit 3 can be those of this antilock device. Under these conditions, all of the stages of the method according to the invention can be ensured by specific software incorporated in the computer of the antilock device. It is advisable to provide a suitable display 4.

Figure 8 represents a general diagram of the method of detection according to the invention. From the measurements $f(\alpha,t)$ of the sensors 2a, 2b, 2c and 2d, the central unit 3 performs the following operations for each wheel:

- calculating $d\alpha(t)/dt$ corresponding to the angular rotation speed of the wheel;

- performing an harmonic analysis of $d\alpha(t)/dt$ by known means, for example, with a Fourier transform, in order to obtain $d\alpha(v)/dv$ (see Figure 9) where v is frequency;
- determining the angular rotation speed of the wheel v_0, corresponding to the frequency of harmonic 1;
- determining the energy E_{sol} of the spectrum of speeds $d\alpha(v)/dv$ in a frequency band not including an harmonic of the turn of the wheel, for example, between harmonics 5 and 6;
- determining the energies of the spectrum of speeds $d\alpha(v)/dv$ in two narrow bands of width in the order of 2 to 10 Hz centered on harmonics 2 to 4, namely, energies E_{v2} and E_{v4}, and adding them in order to obtain ΣE_{vi};
- comparing v_0 to a threshold A, and if v_0 is lower than A, resuming the cycle of measurements;
- if v_0 is higher than A, comparing E_{sol} to a threshold B, and if E_{sol} is higher than B, resuming the cycle of measurements;
- if E_{sol} is lower than B, comparing ΣE_{vi} to a threshold C; and
- if ΣE_{vi} is higher than C, setting off an alarm, unless resuming the cycle.

For each harmonic analyzed, a suitably programmed microprocessor calculates the energy of the harmonic by the integral of the peak emerging from the background noise, the background noise being determined from a frequency band encompassing the narrow band analyzed.

Value ΣE_{vi} is a function of the speed of the vehicle and of the energy level of the spectrum of speeds linked to the unevenness of the road. Several values of threshold C can thus advantageously be used as a function of speed of the vehicle and of the value of E_{sol}.

The first test using v_0 entails not setting off any alarm when the rotation speed of the wheel and, therefore, the speed of the vehicle is less than a given threshold, in the order of 20 to 30 km/h.

The second test also entails neutralizing the alarms when the energy E_{sol} is higher than threshold B, that is, when the unevenness of the road is very great and thus likely to disturb the measurements markedly.

Those two tests make it possible to limit the number of false alarms very appreciably.

As it is always possible for one or more peaks to be disturbed by other sources, for example, by engine vibrations, it is useful to complete that overall energy analysis by verifying that at least two of the harmonics analyzed have had a significant energy evolution. That additional step appreciably improves the reliability of detection.

Figure 9 represents an example of a spectrum of speeds of the wheels on running at normal inflation pressure (white curve) and in run-flat condition bearing on a safety insert (black curve). The vehicle is a Peugeot 405, running at 70 km/h on a standard course. The tire 12, considered in run-flat condition, is supported on the radially outer wall of a standard safety insert not containing means generating warning signals arranged around the rim of the wheel. Such an insert is described in patent application EP 0 796 747.

The white curve (running at normal inflation pressure) presents a notable maximum centered on harmonic 1. That explains why it is preferable to exclude that harmonic in analysis of the spectrum of wheel vibrations.

The black curve (running flat) presents substantially higher energy levels for each harmonic starting from harmonic 2. That well illustrates the effectiveness of analysis of harmonic 2 and 4 in order to detect a run-flat condition of the tire.

The method of detection according to the invention is already effective when the tire is supported on a safety insert not generating vibrating warning signals. But that method is particularly well suited for detecting a support on inserts containing such warning means and, notably, means generating harmonic signals of the turn of the wheel.

The invention also concerns a tire 50 equipped with means 60 generating vibrating warning signals on running at camber higher than a given threshold.

That tire 50 contains a crown 51, a sidewall 52 and a bead 53. The sidewall 52 and the bead 53 are equipped with inserts 54, 55, 56 enabling that tire to support its load on running at zero inflation pressure.

The insert 54 contains a reinforcement 60 in the bead and sidewall, the radial height of which varies according to an harmonic function of the azimuth, as presented on Figure 11. That reinforcement 60 is going to result, on running at a camber higher than a given threshold, in a variation of radius under load of the tire and in the appearance of a multiple harmonic signal of the turn of the wheel detectable by the system and method previously described. The reinforcement 60 can be placed on both sides of the tire or on only one. In the latter case, it is preferable for it to be the inner side in order not to degrade the behavior of the tire on turning. That also has the advantage of not setting off an untimely alarm on turns taken at high speed.

Figures 12 and 13 represent a wheel 70 containing a disk 71 and a rim 72 equipped with means for generating vibrating warning signals on running flat.

The rim 72 contains, notably, an interior hook 73. The radial height of that interior hook 73 varies as a function of its azimuth according to a law presented on Figure 14. The variation involves less than half the circumference.

The variation of radial height of the rim hook can also be obtained by fastening a complementary part.

Consequently, when the wheel 70 is equipped with an ordinary tire under a load or with an inflation pressure such that the camber taken by the tire is notably higher than in normal conditions of use, the radial variation of height of the interior hook is going to result in the appearance of vibrating warning signals. Those signals can be detected by the system or method previously described.

On running under normal load and inflation pressure conditions of the tire and, therefore, of camber, modification of the rim hook of Figures 12 and 13 only results in a minimal modification of the bearing conditions of the bead on the interior hook.

As previously, it is important to arrange that variation of radial height of the hook on the interior hook in order not to disturb performance of the tire on a turn and to favor detection on running in a straight line.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method of detection of a run-flat condition of a vehicle tire, said tire being mounted on a wheel, whereby:

- a quantity f(α, t) is sensed, which varies with the angular displacement (α) of the wheel in time (t);
- a measuring signal is derived from said quantity, which varies with the angular velocity of the wheel dα(t)/dt;
- the rotation frequency of the wheel is determined;
- the energy of the measuring signals is calculated in at least one narrow frequency band centered on one of the first harmonics of said rotation frequency over said rotation frequency or first harmonic; and
- an alarm is set off when said energy exceeds a predetermined threshold value.

2. Method of detection according to Claim 1, in which the rotation frequency of the wheel can be determined from said measuring signals.

3. Method of detection according to one of Claims 1 or 2, in which the energy of said measuring signals is calculated in at least two narrow frequency bands, each centered on one of the first harmonics of the rotation frequency of said wheel, over said rotation frequency or first harmonic.

4. Method of detection according to one of Claims 1 to 3, in which, after having detected that the sum of the energies of the measuring signals in at least two narrow frequency bands centered on one of the first harmonics exceeds a predetermined value thereof, the energy of the measuring signals is compared in each of said frequency bands to a given corresponding threshold and an alarm is set off when, for at least two of said frequency bands, the energy of the signals is higher than said corresponding threshold.

5. Method according to Claims 1 to 4, in which the energy or energies of the measuring signals of the wheel of said tire is compared with the energy or

energies of the measuring signals of at least one of the other tires of the vehicle and an alarm is set off when the result of the comparison satisfies a given ratio.

6. Method of detection according to one of Claims 1 to 5, in which measuring signals are derived which vary with the angular acceleration of the wheel $d^2\alpha(t)/dt^2$.

7. Method of detection according to one of Claims 1 to 6, in which said narrow frequency band or bands have a width less than or equal to 10 hertz.

8. Method of detection according to one of Claims 1 to 7, in which the energy of said measuring signals is further calculated in at least a further frequency band, where the measuring signals are substantially independent of the run-flat condition of said tire and no alarm is set off when the measuring energy in said further frequency bands exceeds a given threshold value.

9. Method of detection according to Claim 8, in which said further frequency bands are situated outside frequencies that are multiples of the rotation frequency of said wheel.

10. Method of detection according to one of Claims 1 to 9, in which no alarm can be set off when the speed of said vehicle is below a given threshold value.

11. Method of detection according to one of Claims 1 to 10, in which the location of the tire in run-flat condition is identified and transmitted to the driver of the vehicle.

12. Method of detection according to one of Claims 1 to 11, in which, the vehicle containing a wheel antilock device, the measuring signals are derived from sensors of said wheel antilock device.

13. System of detection of a run-flat condition of a vehicle tire, said tire being mounted on a wheel, including:

- first means for sensing a quantity f(α,t) which varies with the angular displacement of the wheel in time,
- second means for operating the method of detection according to one of claims 1 to 12;
- third means for transmitting said alarm to the driver of the vehicle; and
- fourth means arranged in the mounted tire/wheel assembly to generate vibrating warning signals generating at least one sinusoidal function, the period of which is a submultiple of a turn of the wheel, on a run-flat condition of the tire.

14. System according to Claim 13, in which said means for generating vibrating warning signals appreciably generate only one sinusoidal function, the period of which is a submultiple of a turn of the wheel.

15. System according to one of Claims 13 or 14, in which, the vehicle being equipped with a wheel antilock device, the first and second means include the sensors and computer of said wheel antilock device.

16. System according to any one of Claims 13 to 15 wherein said fourth means includes a safety insert intended to be radially mounted outside the rim of a wheel, said safety insert containing on a radially outer surface thereof axially oriented bars, characterized in that said bars have sides whose inclination from normal to the tread in the circumferential direction varies as a function of azimuth.

17. System according to Claim 16 wherein said circumferential inclination of the bars as a function of azimuth is at least a sinusoidal function whose period is a submultiple of the turn of the insert.

18. System according to any one of Claims 13 to 15 wherein said tire contains a tread, two sidewalls and two beads as well as support elements intended to support the tread in case of run-flat condition, said support elements containing means for generating rotation speed variations on a run-flat condition of said tire.

19. System according to Claim 18, in which said means for generating rotation speed variations of said wheel entail a variation as a function of azimuth of the radius under load of said tire on running on camber above a given threshold.

20. System according to Claim 19, in which said variation as a function of azimuth of the radius under load of said tire is at least a sinusoidal function, the period of which is a submultiple of a turn of the insert.

21. System according to any one of Claims 13 to 15, in which a wheel contains means for generating rotational speed variations of said wheel on a run-flat condition of said tire.

22. System according to Claim 21, in which said wheel presents a variation as a function of azimuth of the radial height of at least one of its hooks.

23. System according to Claim 22, in which said variation of radial height of at least one of the hooks of said wheel as a function of azimuth is obtained by the addition of an extra part at least partially covering the radial end of said hook.

24. System according to Claim 22 or 23, in which said variation of radial height of at least one of the hooks of said wheel as a function of azimuth is at least a sinusoidal function, the period of which is a submultiple of a turn of the insert.

DATED this 7th day of November 2002
SOCIETE DE TECHNOLOGIE MICHELIN AND MICHELIN RECHERCHE ET TECHNIQUE S.A.

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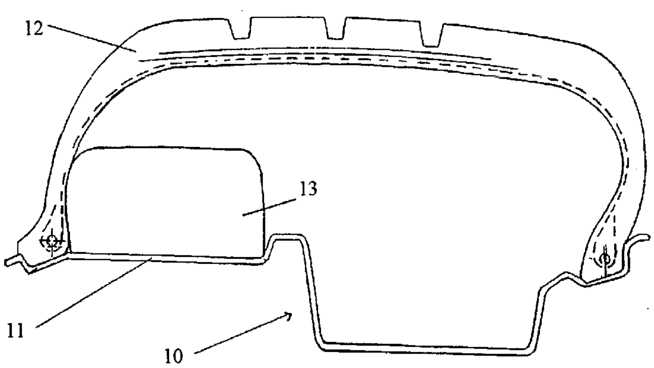

Fig. 1

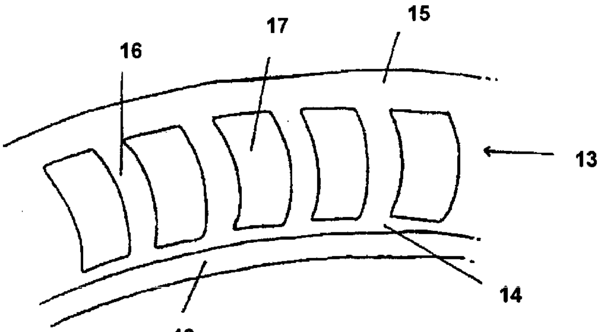

Fig. 2a

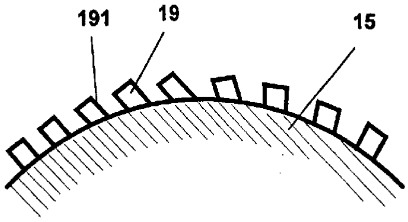

Fig.2b

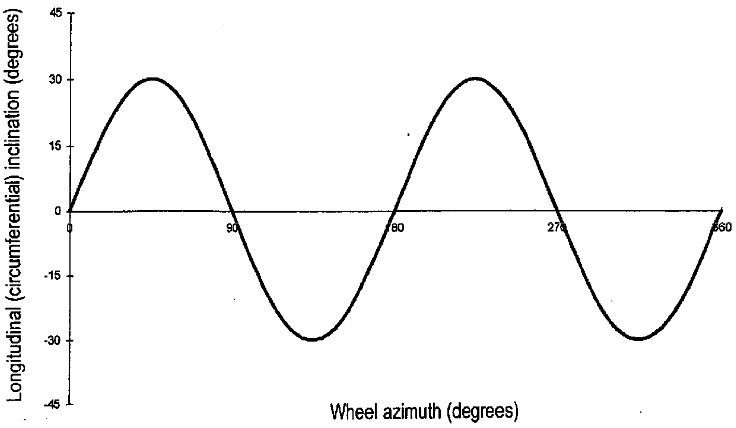
Longitudinal (circumferential) inclination (degrees)
45
30
15
0
-15
-30
-45
0
90
180
270
360
Wheel azimuth (degrees)

Fig. 3

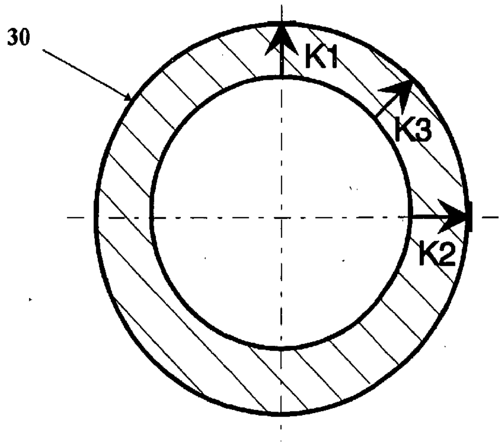
30
K1
K3
K2

Fig. 5

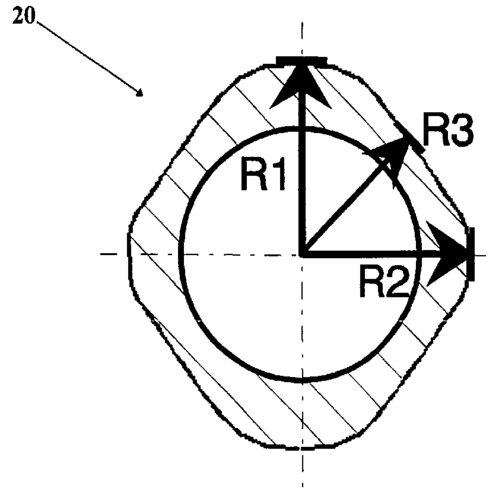

Fig. 4

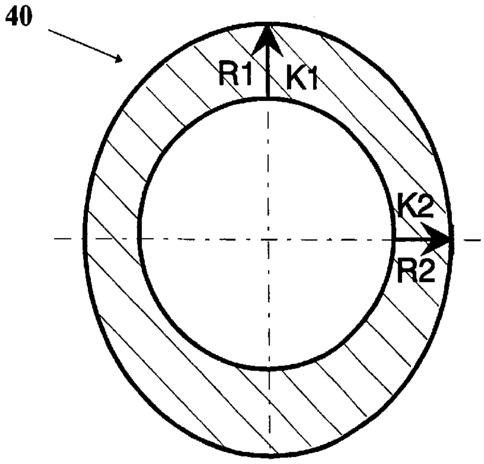

Fig. 6

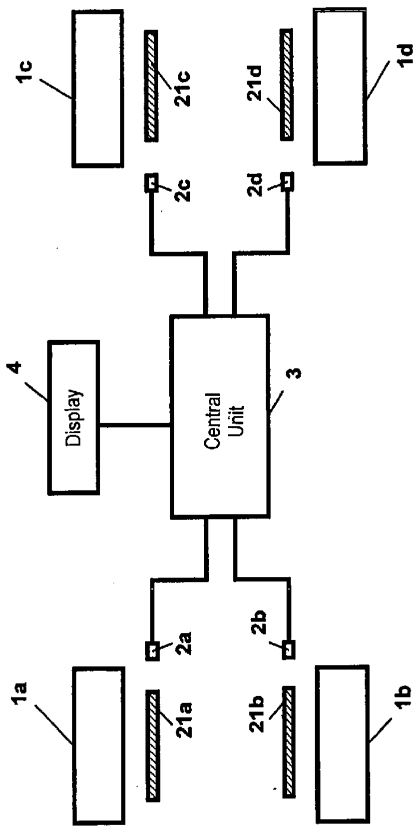

Fig. 7

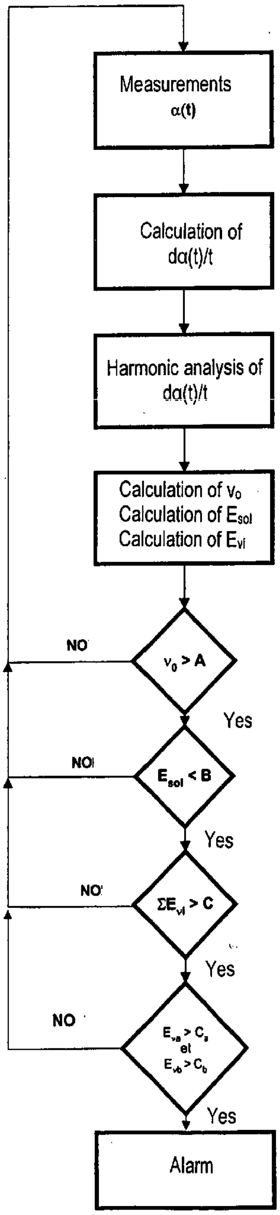
Measurements
α(t)
Calculation of
dα(t)/t
Harmonic analysis of
dα(t)/t
Calculation of v_0
Calculation of E_{sol}
Calculation of E_{vi}
$v_0 > A$
NO
Yes
$E_{sol} < B$
NO
Yes
$\Sigma E_{vi} > C$
NO
Yes
$E_{va} > C_a$
et
$E_{vb} > C_b$
NO
Yes
Alarm

Fig. 8

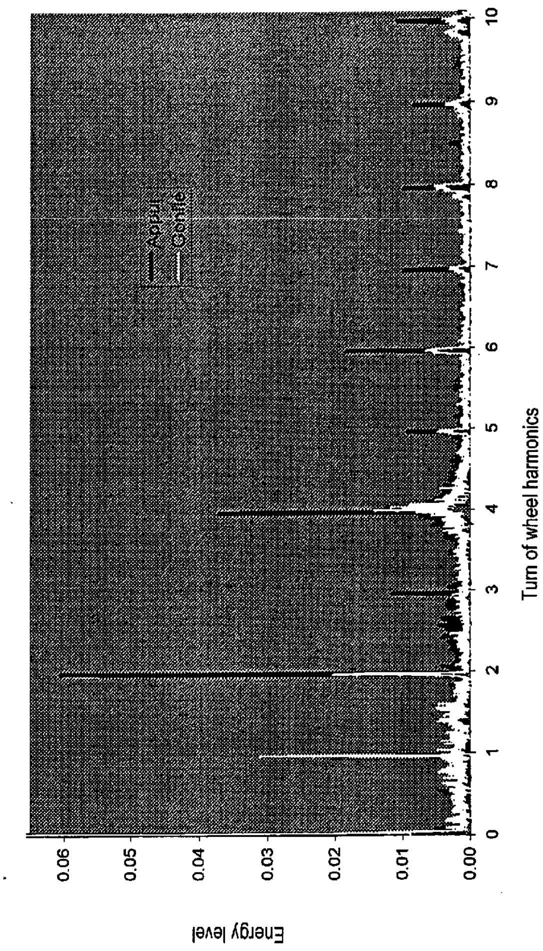
Energy level
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Turn of wheel harmonics
0
1
2
3
4
5
6
7
8
9
10

Fig. 9

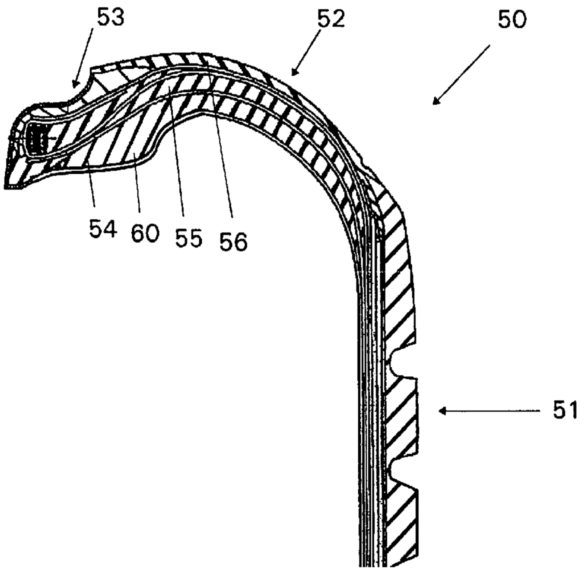

Fig. 10

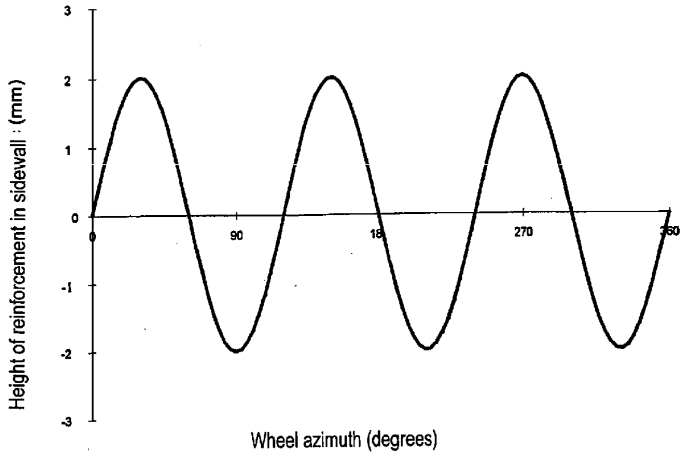
Height of reinforcement in sidewall : (mm)
3
2
1
0
-1
-2
-3
0
90
270
Wheel azimuth (degrees)

Fig. 11

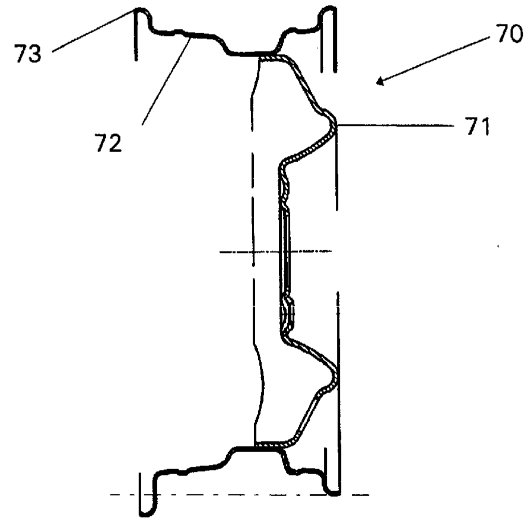

Fig. 12

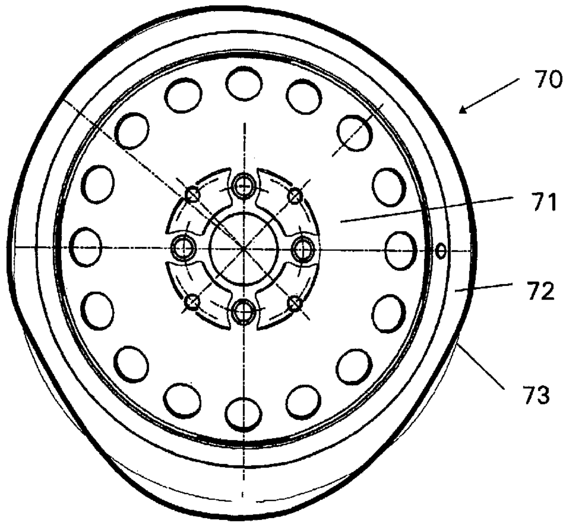

Fig. 13

12.11.02 14:30:17

Fig. 14