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COMPLETE SPECIFICATION

Improvements in Pneumatic Tyres

We, DUNLOP RUBBER COMPANY LIMITED, a British Company, of 1, Albany Street, London, N.W.1, and HENRY WILLIAM TREVASKIS, a British Subject, of the Dunlop Rim and Wheel Company Limited, Foleshill, Coventry, 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 pneumatic tyres and to a method and apparatus for their production.

Pneumatic tyres are customarily built on a collapsible cylindrical building drum from plies of fabric cut on the bias from a length of rubberized tyre cord fabric. Several plies are wrapped around the drum in a manner such that the cords in adjacent plies are disposed in opposite directions, each of the plies overlapping each end of the drum.

A preformed endless bead wire is slipped over the overlapping portion of the plies at each end face and the plies are turned up and wrapped around the bead wires to enclose them securely. An extruded strip of rubber to form the tread and sidewalls is then wrapped around the drum, the drum is collapsed and the cylindrical cover removed therefrom. An annular airbag is then located within the cover and lightly inflated to shape the cylindrical cover into one of customary toroidal cross-section, the cover and airbag are inserted within a mould and, after fully inflating the airbag, the cover is moulded under heat and pressure.

It is the object of the present invention to provide tyres containing a reinforcement constructed from a winding of cord in which the usual bead wires are dispensed with and which will grip an associated rim on inflation. This is the reverse of the effect obtained with existing commercially-available tyres, which contain bead wires and which tend to be blown off the rim by the inflation pressure.

According to the present invention a pneumatic tyre comprises a body of natural rubber or other suitable resilient material containing, as an internal reinforcement, a winding of cord arranged in the form of at least one double layer in which the cord of one layer crosses the cord of the other layer to form a lattice and the cord in each layer extends in a series of unit waves progressing continuously around the tyre in the same direction, each unit wave of cord being completely embedded in the resilient material and consisting of two substantially diagonally opposite arcuate portions, each extending through and being substantially confined to one bead of the tyre, alternating with portions passing through the side walls and crown of the tyre which leave and approach the arcuate portions substantially tangentially and take a path which is substantially a geodesic with respect to the surface defined by the layer, the arcuate portions of cord in the unit waves being sufficiently long to ensure that, on inflation of the tyre, each of the beads thereof will tend to contract in diameter over a major portion of the transverse dimension of the foot of the bead as a result of the tension imposed on the cord.

It will be noted that, in the tyre according to the invention, each unit wave of the cord is completely embedded in the rubber or other resilient material. The arcuate portions of cord in the tyre are substantially confined to the beads and when the tyre is inflated the distribution of stress in all the unit waves of cord is substantially the same.

In practice it is usually most convenient to wind the whole of the reinforcement from a single length of cord, though it is possible to use more than one long length if so desired. For instance, each double layer can be wound from a separate length of cord.

The tendency of the beads of the tyre to contract in diameter on inflation will cause the tyre to grip a wheel rim on which it is mounted. This is the most important characteristic of tyres in accordance with the invention, as it makes it possible to dispense with

[*Price 3s. 6d.*]

bead wires and has other advantages which are referred to hereinafter. This tendency is due to the configuration of the unit waves of cord, each of which, as stated above, consists of an arcuate portion in one bead of the tyre, a curved portion running through the walls and crown of the tyre to the other bead, an arcuate portion in this other bead and a curved portion running back to the first bead.

The cord may be made of steel or of a suitable natural or artificial textile material, e.g. cotton, rayon, nylon or the polyester made from terephthalic acid and ethylene glycol and sold under the Registered Trade Mark "Terylene," and preferably consists of a number of twisted strands, each of which consists of a number of twisted filaments.

The resilient material may be natural rubber or a synthetic rubber, for example a butadiene-styrene copolymer or the copolymer of isobutylene with a small proportion of butadiene known as butyl rubber.

The invention also comprises a method of making a pneumatic tyre which comprises winding cord progressively around a former having thereon a winding surface of substantially part-spherical shape to form a reinforcement having edges of equal diameter and constituted by at least one double layer of cord, the cord of one layer crossing the cord of the other layer to form a lattice and each layer consisting of a series of turns which are spaced equidistantly around the former, extend obliquely around it in a geodesic path and make tangential contact with opposite edges of the reinforcement at positions substantially diagonally opposite, removing the reinforcement from the former and thereafter subjecting it together with a vulcanizable composition containing natural rubber or other suitable resilient material to a shaping, heating and moulding treatment to vulcanize the composition and form a tyre in which each turn of the cord is completely embedded in the resilient material, this treatment displacing the edges of the reinforcement axially inwardly, expanding the crown portion of the reinforcement and deforming the cord so that portions thereof extend arcuately in the beads of the tyre to an extent sufficient to cause each of said beads to tend to contract in diameter over a major portion of the transverse dimension of the foot of the bead when the tyre is inflated.

An important advantage of tyres in accordance with the invention is that the building of the reinforcement can be carried out semi-automatically by means of a machine which lays the cord on a former in the required path by the appropriate relative motions of the former and the cord feed. In such a machine both the former and the feed may move or one may be stationary and the other move. The process of tyre building may thus be largely mechanized.

Thus the invention includes apparatus for the manufacture of a pneumatic tyre which comprises a former, means for feeding cord on to the former and means for effecting relative movement between the former and the feeding means to lay the cord on a winding surface of the former, which surface is substantially part-spherical throughout its area and has two parallel circular edges of equal diameter, in a series of turns progressing around the former in the same direction, each turn extending obliquely around the former in a geodesic path and making tangential contact with each edge of the winding surface at substantially diametrically opposite points.

The former is preferably a sphere or spheroid truncated at opposite ends of a diameter to provide circular faces of equal area, said circular faces having cylindrical or frusto-conical portions extending axially therefrom to prevent the turns of cord from falling off the edges of the former proper. With a former of this shape the cord is wound in a series of turns in such a manner that, from a point of origin on the spherical surface of the former at the boundary of one of the circular faces, it leaves the edge tangentially and follows a curved path which is a geodesic over the curved outer surface of the former to a second point, substantially diagonally opposed and on the spherical surface of the former at the boundary of the other circular face. The cord touches this other face tangentially and continues in a curved path, which is a geodesic over the curved outer surface of the former, back to make tangential contact with the first face thereof at a location adjacent the point of origin.

The cord may be laid in this manner by rotating the former slowly about an axis of symmetry and simultaneously traversing the cord in a geodesic path inclined to the axis at such an angle that the cord makes tangential contact with the circular edges of the former. By adjustment of the relative rates of rotation of the former and traverse of the cord it can be arranged that each turn is displaced circumferentially relative to the preceding turn to the extent required.

The cord is preferably rubber-covered, e.g. it may be sprayed or dipped in rubber solution or coated with a rubber composition containing a vulcanizing agent, and accelerator such as is customarily used for the production of tyre cord fabric, and is preferably wound on to a layer of rubber secured to the former. A reinforcement comprising one or more double layers of cord may be provided.

When the reinforcement has been built up a layer of rubber may be applied to the outer cord layer and the tyre may then be completed in the usual manner by the application of a tread strip and chafer strips, followed by removal from the former, insertion of an air-bag and shaping and vulcanizing in a mould

In the method of winding the cord onto the former, as hereinabove described, the cord merely touches the circular faces of the former tangentially at substantially diagonally-opposed locations at opposite edges of the former. However, after stripping the assembly from the former the beads are forced axially towards one another and the crown is forced radially outwardly. During shaping and moulding the length of cord in each geodesic, which was hitherto substantially in the shape of a circular arc, is deformed into somewhat elliptical shape and the portions of the cord at the edges of the reinforcement are repositioned so that in a cured and moulded tyre they extend arcuately through the beads and constitute the bead reinforcements.

The spacing between adjacent turns, the strength of the cord and the number of double layers may vary and will be chosen in accordance with the strength required in the tyre.

The apparatus in one specific embodiment comprises a substantially part-spherical collapsible former in the shape of a sphere equally truncated at opposite ends of a diameter and provided at said ends with axially outwardly flaring frusto-conical portions to retain the edges of the reinforcement. The former is mounted on a spindle passing centrally through its truncated ends and an arm is provided, mounted on a shaft and so angled that the end thereof in one angular position of the shaft is located adjacent the edges of one truncated portion of the former and for a 180° revolution of the shaft said end moves around to a location adjacent the edge of the other portion. The end of the arm lays the cord in substantially circular turns around the former and from one edge to the other and at the same time the former is slowly rotated to form a latticed envelope of cord on the former. The arm can be very light and can be made to move very rapidly around the former so that the envelope is quickly laid.

In order that the invention may be more fully described, reference is made to the accompanying drawings, which relate to a tyre reinforcement constructed by winding on a part-spherical former and to a preferred apparatus for constructing such a reinforcement and of which: —

Figure 1 is a fragmentary, part-sectioned, perspective view of a tyre containing a reinforcement constructed in accordance with the present invention.

Figure 2 is a perspective view of a similar tyre which illustrates the unit waves formed by the cord in a moulded tyre, only a few of the unit waves being shown and those being widely spaced apart for the sake of clarity.

Figure 3 is a perspective skeletal view of the reinforcement of a moulded tyre, the unit waves of cord being spaced widely apart for the sake of clarity.

Figure 4 is another view of the reinforcement shown in Figure 3.

Figures 5A to 5E are related views of a former having a single turn of cord wound thereon.

Figures 6, 7 and 8 are three related diagrammatic views of a single turn in an unmoulded reinforcement, i.e. on a former, and of the corresponding unit wave in a tyre after it has been moulded.

Figure 9 illustrates, in developed form, the length and configuration of one unit wave of cord around a tyre of given dimensions.

Figure 10 is a diagrammatic view of apparatus for constructing a reinforcement according to the present invention, and

Figure 11 shows graphically for a particular tyre the relation between cord elongation and minimum bead lap angle.

The tyre and the method and apparatus for making the tyre hereinafter described with reference to the accompanying drawings relate to a preferred embodiment of the invention wherein the reinforcement is constructed by winding on a part-spherical former.

The tyre shown in Figure 1 comprises an inner layer 1 of rubber, a rayon cord reinforcement 2 and an outer layer 3 of rubber which is provided with a tread 4. The rayon cord reinforcement comprises two double layers 5 and 6 of rubberised rayon cord, the portions of cord of each single layer crossing the portions of cord of an adjacent layer over the crown and side walls of the tyre to form a close lattice. The portions of cord extending in arcs in the vicinity of the edges of the tyre together form the beads 7. The cords of each layer extend continuously around the tyre and from one bead to the other and approach and leave the arcuate portion in each bead substantially tangentially and trace a path across the crown and side walls of the tyre between successive points at which the cord parts from one bead and meets the other bead which is substantially a geodesic with respect to a surface defined by the layer. Each unit wave of cord comprises an arc extending through one bead, a substantially geodesic portion extending across the crown and sidewalls, an arc extending through the other bead and another substantially geodesic portion extending back across the crown and side walls to the original bead.

The construction of the cord reinforcement is more fully shown in Figure 2. One length of cord only is employed, the portion shown in the Figure starting at 8 and finishing at 9. One complete unit wave is shown shaded at 10 to illustrate more fully the configuration thereof in a completed and moulded tyre.

The perspective view of the tyre reinforcement shown in Figure 3 illustrates how the bead 11 is built up. A portion of cord, shown shaded at 12, extending across the crown and side walls of the tyre, meets the bead at 13

and extends in an arc through said bead to a location at 14 whence it leaves the bead to return across the crown and side walls to the other bead. The arcuate portion of cord from 13 to 14 subtends at the centre of the tyre an angle θ, herein termed the bead lap angle. The cord enters the bead at 13 and leaves it at 14 in directions substantially tangential to the arcuate portion from 13 to 14.

The view of the tyre reinforcement shown in Figure 4 illustrates the configuration of the portions of cord in the crown and shoulders of the tyre. The double layer of cord 15 and 16, or 16 and 17, extends over the crown in lattice formation, as illustrated, the cords 16 overlying the cords 15 over one half of the tyre, i.e. as far as cord 15*a*, where they dip below cords 17 at 17*a* to form the under layer over the other half of the tyre. It will be understood that on the other side of the tyre the cords 16 similarly change from under layer to upper layer. Each layer of the double layer is generated simultaneously. The double layer develops at diagonally opposed regions, starting at the beads, as each winding crosses corresponding parts of previously-laid windings with opposite bias.

The angles of intersection of the cords of the lattice in the circumferential direction increase from zero at each edge to a maximum at the crown. The cord density per unit area of former increases from the crown to the edges of the reinforcement. As will be seen there is no interweaving of the cords in the two layers and any tendency of a cord to chafe at points of crossing is therefore reduced to a minimum.

A method of manufacturing a tyre constructed in accordance with the invention will now be described. A collapsible former, of part-spherical shape, i.e. equally truncated at opposite ends of a diameter, is rotatable about an axis passing centrally through the truncated ends. This former is covered with a sheet of uncured rubber which constitutes the inside of the complete tyre, and this sheet forms a tacky surface to which the cord will readily adhere.

Rayon cord is led from a bobbin, through a nozzle which applies a coating of a vulcanizable rubber composition and through a tensioning device and is then fed on to the former as it rotates slowly by means of a winding arm which is rotatable about an axis intersecting the rotational axis of the former and inclined thereto at the required angle. The arrangement is such that in one complete rotation of the end of the arm around the former, the cord would, if the former were stationary, extend in a circle from a point at one edge of the former geodesically across to a diagonally opposed point at the other edge and then back again to the original point, touching both points tangentially.

This is illustrated in the accompanying diagrammatic Figures 5A to 5E which show five related views of a former 18 having a part-spherical outer periphery 19 and circular flat portions 20 at opposite ends of a diameter. The spigots 21 indicate its axis of rotation. A turn of cord 22 is shown extending geodesically around the former from one edge to the other, meeting and leaving said edges tangentially.

On account of the slow rotation of the former the cord is not laid in a truly circular path as shown but in one which deviates from such a path by an amount depending on the relative rates of rotation of the arm and the former, so that the points of contact of the cord with each edge of the former advance or retreat progressively as the winding continues until, when the former has made approximately one rotation, an envelope comprising a double layer of cord has been formed.

As the cord reinforcement is built up on the former the thickness thereof increases from the crown to the edges, and if desired the configuration of the former may be slightly more convex than spherical so that, when the reinforcement is finally built up, a surface lying between the inner and outer peripheries of the reinforcement is truly part-spherical. Two double layers of rayon cord are provided in all and a layer of sheet rubber may be applied between the double layers of cord. A breaker strip or strips may then be fitted to reinforce the crown of the casing and an outer layer of rubber and a tread strip is fitted. Chafing strips may also be added.

The unmoulded tyre so formed is removed from the former by collapsing the former. The tyre at this stage follows the configuration of the former and each turn of cord is substantially circular. During shaping and moulding the edges are moved axially-inwardly to form the beads and at the same time the crown of the tyre is forced radially outwardly to give a conventional tyre section.

This is illustrated diagrammatically in Figures 6, 7 and 8 which show three related views of a single turn of cord as it extends on a former, and also of the corresponding unit wave as it extends in a tyre after it has been shaped and cured in a mould. Reference number 23 indicates the former and 24 indicates the moulded tyre. On the former the cord 25 of each turn leaves a location at one edge tangentially, extends geodesically across the former to a substantially diametrically-opposed location at the other edge, arriving at and departing from said location tangentially, and extends geodesically back across the former to arrive tangentially at a location at the first edge adjacent said first location.

When the reinforcement is completely wound and the tread strip and other elements are assembled the tyre is removed from the former, placed in a mould, inflated by means of an air-bag and moulded. The edges of the tyre

are moved axially inwardly, as best shown in Figure 7, and the crown of the tyre is moved outwardly. The portions of cord forming each geodesic, hitherto in the shape of a semi-circle, are displaced into substantially semi-elliptical shape, the loop 26 of each part-ellipse extending over the crown of the moulded tyre, the intermediate portions 27 extending down the sidewalls to the beads and the end portions 28 being moved axially inwardly during the moulding process so that, in the moulded tyre, they extend in diagonally-opposite arcs in the beads. Thus in a moulded tyre each unit wave is illustrated at 29 ~~A this movement of the cords takes place on moulding~~.

The arcs of cord which each extend adjacent the edges of the tyres, together form the bead reinforcement which grips the rim when the tyre is inflated. Each arc subtends at the centre of the cover a bead lap angle which, for any particular shape of tyre, should exceed a theoretical minimum value dependent on the maximum working elongation characteristics of the cord employed. This feature will be more fully explained later in the specification but it may here be noted that for most sizes of tyre for motor road vehicles or aircraft the theoretical minimum bead lap angle, which is calculated for a single unit wave of cord only on the basis indicated in Figure 9 and on the assumption that it contacts with the extreme edges of the tyre and extends between said edges in a truly geodesic path, is of the order of 25° for rayon cord and about 5° for steel cord.

One unit wave of a moulded tyre may be developed as illustrated in Figure 9 which is approximate only because it takes no account of residual tension in the cord. A straight line AB is laid out which is equal to twice the distance around the cross-section of the reinforcement in the moulded tyre plus twice the bead diameter. Arcs LM and PQ of the same diameter as the diameter across the beads of the tyre are struck with centres at A and B. Another arc ST of the same diameter is struck with its centre at O, the point midway between A and B. A line is drawn connecting arc LM at one side of line AB tangentially with arc ST at the other side of line AB and another line is drawn connecting arc ST at the same side of line AB tangentially with arc PQ at the original side of line AB. The resulting composite line MQ gives a close approximation to the theoretical length and developed configuration of a single unit wave of cord around the moulded tyre and the theoretical bead lap angle θ is clearly shown. It will be seen that this angle increases with increase in the bead diameter, if the circumferential length remains constant.

Figure 9 illustrates the theoretical bead lap angle obtained with a single unit wave in respect of one type of car tyre. In practice, the effects of friction and rubber adhesion between the layers of cord during shaping and moulding of the tyre cause a slight displacement of the portions of the cord extending between the beads from the truly geodesic path and, due to the crowding of the cords at the beads, the arcuate portions of cord in the beads assume a path of varying radius which is circular with respect to the centre of the tyre over a relatively small angle only. Nevertheless, due to the close packing of the cords and bonding material in the beads, these arcuate portions of cord have a sufficiently large effective bead lap angle to produce the required grip on the wheel rim.

When the tyre according to the invention is inflated, each bead contracts in diameter to grip the wheel rim around the whole of the periphery of the rim and over a major portion of the transverse dimension of the base of the bead and preferably across the whole of the base of the bead from heel to toe. The invention is best applied to the manufacture of tyres in which the bead diameter is neither too large nor too small in relation to the crown diameter. Where the bead diameter is very small in relation to the crown diameter, as in a doughnut tyre, little, if any, grip on the wheel rim is obtained when the tyre is inflated. Where on the other hand, the bead diameter is only slightly less than the crown diameter, as in a tyre for a pedal cycle, a satisfactory grip on the wheel rim is obtained on inflation but if the cords are laid sufficiently close to provide a satisfactory reinforcement of the crown of the tyre the zone of the tyre in which the cords are crowded extends so far up the side walls of the tyre as to make the side walls excessively rigid.

For any given tyre dimensions, the dimensions of a former on which it may be constructed may be readily computed. In the case of a sphere truncated at opposite ends of a diameter, the diameter of the sphere is equal to the length of line MQ (taken from Figure 9) divided by π. The truncated portions of the sphere have a diameter substantially equal to the diameter of the tyre bead although, in practice, a small percentage is added to this to compensate for relaxation of the cord, which is wound under tension, on removal of the reinforcement from the former.

An apparatus for making a tyre in accordance with the invention is shown diagrammatically in Figure 10. A rayon cord 30 is led from a rotatable spool 31 and through a drying chamber 32, which comprises a fan blowing air through an electrically-heated element and thence onto the cord as it continually passes through said chamber. The heat from the drying chamber dries out moisture from the cord and also preheats it for the next operation in which the cord passes through an extruder unit 33 where a thin sheath of rubber is continuously extruded around the

cord.

The extruder unit 33 comprises a chamber into which an unvulcanised rubber composition is continuously fed by means of a driven screw conveyor. The cord passes into the chamber through a nipple at one side and the rubber is extruded around the cord as it emerges from an extruder nipple at the other side, said extruder nipple being dimensioned to allow a thin coating only of rubber on the cord, and being also electrically heated to better ensure even distribution of rubber on the cord.

From the extruder unit 33 the cord passes through a clutch mechanism, indicated generally at 34, which controls the tension in the cord.

In order to ensure that the completed tyre is symmetrical and free from bulges and also to ensure that the correct bead diameter of the moulded tyre is attained it is necessary, for any particular type of cord, that a predetermined winding tension is accurately maintained. Thus for rayon cord a steady winding tension of the order of 1lb. is desirable. However a greater tension, of the order of 3 lbs. is necessary to pull the cord through the extruder unit, and this tension may vary due, e.g. to the degree of plasticity of the rubber.

The clutch mechanism, which is more fully described in the Specification of our co-pending Application No. 3294/55 (Serial No. 786,165) comprises a clutch plate 35 rotatable at a constant and controlled speed, a co-axial floating clutch plate 36 which is also driven and a freely rotatable drum 37 grooved to accommodate the rubber-covered cord. The cord passes over a pulley and around the under part of said drum 37 and over and under another pair of pulleys. From said pulleys it passes around three pulleys, 38, 39 and 40 having their axes parallel and normal to the axes of the previously-mentioned pulleys, the two outer pulleys 38 and 40 being positioned to maintain the general line of direction of the cord whilst the intermediate pulley 39 is offset a short distance, e.g. 3 inches, from the said general line and on the side thereof containing the floating clutch plate 36. Said intermediate pulley is rotatably mounted on one end of a lever arm 41, the other end of which is pivotable about a fixed point 42 and said arm is supported in a bracket 43 to permit movement thereof in a plane containing said pulleys. Adjacent said fixed point 42 and on the side thereof adjacent the floating clutch plate 36 is a member which connects the lever arm with a thrust race 44 which is associated with the floating clutch plate 36. A leaf-spring 45, having one end rigidly secured, reacts against the lever arm to tend to move it angularly about its fixed point 42 and away from pulleys 38 and 40.

The rubber-coated cord passes under and over and around these various pulleys and drum, the operation of the clutch mechanism being as follows.

The desired tension in the cord between the clutch and the winding machine is imparted by the spring-loaded arm and with a tension of an order of 1 lb., the clutch is in constant operation, hunting on and off so rapidly that it draws the cord through the extruder with a force such that the desired tension of 1 lb. only is left in the cord between the clutch and the winding machine. If the friction or drag in the extruder increases, the tension in the cord on the winding machine side of the clutch tends to increase and this moves the lever arm against the spring to so operate the clutch mechanism that it exerts a greater force to draw the cord through the extruder, thus allowing the winding tension to revert to 1 lb. Similarly, if the force to draw the cord through the extruder decreases so that the winding tension drops substantially below 1 lb. then the lever arm is moved in the other direction by the spring so that the clutch exerts a lesser drawing force.

From the roller 40 of the clutch mechanism the rubber-coated cord passes through a tension meter 46 and thence to the winding apparatus. Said apparatus comprises a former 47 in the form of a sphere truncated at opposite ends of a diameter to form two equisized circular ends and having frusto-conical portions 48 flaring axially outwardly therefrom. The former is collapsible and detachably mounted on a spindle 49 fitted centrally through said frusto-conical portions. One end of this spindle is mounted in bearings and this end of the spindle is driven, through reduction gearing 50, by a shaft 51. A housing (not illustrated for the sake of clarity) is located adjacent the former and a hollow shaft 52 is mounted in bearings therein, the axis of said hollow shaft intersecting the rotational axis of the former and being inclined thereto at an angle of the order of 45°. The axis of the hollow shaft is axially-aligned with the centre of the part-spherical former.

An arm 53 is secured to the end of the hollow shaft adjacent the former, said arm being angled as illustrated so that the end thereof in one angular position of the shaft is located adjacent one edge of the truncated sphere and for a 180 revolution of the shaft the said end moves round to a location adjacent the opposite edge diametrically opposite the first location. The arm is provided with rollers 54 to guide the rubber-coated cord which is led thereby from the tension meter 46 and through the hollow shaft on to the surface of the truncated sphere. A counter weight (not illustrated) may be provided on an extension of said arm 53.

A motor 55 drives the hollow shaft to rotate the arm, and the hollow shaft 52 drives the shaft 51 by means of gearing 56. The gearing is such that for every revolution of the hollow

shaft and arm the former rotates a fraction of a revolution only corresponding with the required pitch of the turns of cord.

As described above, on inflation of the tyre, the cord is tensioned and undergoes strain so introducing a change in the lattice pattern due to the varying angles of intersection. The effects of friction at the cross-over points of the cord and the bonding of the rubber on the cord in conjunction with the strain change in the lattice pattern cause a radially outward displacement of the cross-over points of the cord outside the bead arc so that unwinding takes place at each end of the bead arc, the unwinding increasing with increase of inflation pressure. This is accompanied by a tensioning of the ends of the arcuate portions of cord in the beads, which tend to straighten and move radially inwards to grip an associated wheel rim. If at a particular pressure the angle of unwinding at each end of the bead arc exceeds half the value of the bead lap angle then the grip on the wheel rim will be lost. The reinforcement must therefore be such that this will not occur within the working pressure range.

The theoretical minimum bead lap angle is largely dependent on the elongation characteristics of the cord employed as reinforcement for the tyre. Figure 11 shows graphically the approximate relation between cord elongation and theoretical minimum bead lap angle in an aircraft tyre having an outside diameter of 36" and a bead diameter of 16½".

In this Figure the ordinate represents the theoretical minimum bead lap angle in degrees and the abscissa represents the percentage maximum working cord elongation. It will be seen that with such a tyre and a cord having a maximum working elongation of 5 % a theoretical minimum bead lap angle of the order of 36° is required to ensure a grip on the wheel rim. With cords having a lower elongation characteristic, e.g. steel wire, a smaller theoretical minimum bead lap angle is sufficient.

As indicated above, tyres having a construction in accordance with the present invention have a number of desirable properties, one being that it is possible to dispense with the rigid metal bead wires used in the known types of tyres, as the cord itself forms the beads. Further, on inflating the tyre, the portions of the cords lying adjacent the edges of the tyre move or tend to move radially inwardly to grip an associated rim. This result differs from that obtained on inflating a conventional pneumatic tyre when the beads tend to move away from the rim. An advantage stemming from this result comprises a lesser tendency to tyre creep relative to the rim. Further a reduction in the height of the rim flange for retaining the tyre on the rim is made practicable and a consequent reduction in the weight of the wheel is obtained. Since the improved tyre need not be a tight fit on the rim when deflated, stripping and assembly of the tyre off and on the rim is facilitated.

A further advantage of tyres constructed in accordance with the present invention is that the absence of the conventional bead wires renders them more flexible and so facilitates fitting them to rims of the one-piece type, having flanges integral with the base which may itself be flat or contain a central well. This is of particular importance in tyres for heavy commercial vehicles and aircraft which cannot normally be fitted to such rims on account of the rigidity of their beads. Tyres of conventional construction have therefore to be fitted to two or three piece rims, which are not normally leakproof and, unless special measures are taken to make them so, tubeless tyres cannot be used. Tyres constructed in accordance with the present invention are capable of being fitted to the one-piece rim, which is leakproof, and can therefore be of tubeless construction.

Another advantage of such tyre constructions which is particularly valuable in tubeless tyres is that, on inflating the tyre, the beads thereof, which are normally rubber-covered, are forced into fluid-tight engagement with the wheel rim.

The strength/weight ratio of a tyre constructed in accordance with the present invention is high and since the normal bead wires are dispensed with the tyre is light and flexible.

A further advantage of tyres constructed in accordance with the present invention is that the winding of the cord on the former can be carried out automatically with very little attention from the operator who can readily supervise simultaneously a number of cord winding machines. Far less skill and labour are required to form the reinforcement by winding on a former in accordance with the invention than are involved in the case of the conventional method, referred to above, in which the reinforcement is built up manually on a drum from plies of rubberized tyre cord fabric.

What we claim is:—

1. A pneumatic tyre comprising a body of natural rubber or other suitable resilient material containing, as an internal reinforcement, a winding of cord arranged in the form of at least one double layer in which the cord of one layer crosses the cord of the other layer to form a lattice and the cord in each layer extends in a series of unit waves progressing continuously around the tyre in the same direction, each unit wave of cord being completely embedded in the resilient material and consisting of two substantially diagonally opposite arcuate portions, each extending through and being substantially confined to one bead of the tyre, alternating with portions passing through the side walls and crown of the tyre which leave and approach the arcuate

shaft and arm the former rotates a fraction of a revolution only corresponding with the required pitch of the turns of cord.

As described above, on inflation of the tyre, the cord is tensioned and undergoes strain so introducing a change in the lattice pattern due to the varying angles of intersection. The effects of friction at the cross-over points of the cord and the bonding of the rubber on the cord in conjunction with the strain change in the lattice pattern cause a radially outward displacement of the cross-over points of the cord outside the bead arc so that unwinding takes place at each end of the bead arc, the unwinding increasing with increase of inflation pressure. This is accompanied by a tensioning of the ends of the arcuate portions of cord in the beads, which tend to straighten and move radially inwards to grip an associated wheel rim. If at a particular pressure the angle of unwinding at each end of the bead arc exceeds half the value of the bead lap angle then the grip on the wheel rim will be lost. The reinforcement must therefore be such that this will not occur within the working pressure range.

The theoretical minimum bead lap angle is largely dependent on the elongation characteristics of the cord employed as reinforcement for the tyre. Figure 11 shows graphically the approximate relation between cord elongation and theoretical minimum bead lap angle in an aircraft tyre having an outside diameter of 36" and a bead diameter of 16½".

In this Figure the ordinate represents the theoretical minimum bead lap angle in degrees and the abscissa represents the percentage maximum working cord elongation. It will be seen that with such a tyre and a cord having a maximum working elongation of 5% a theoretical minimum bead lap angle of the order of 36° is required to ensure a grip on the wheel rim. With cords having a lower elongation characteristic, e.g. steel wire, a smaller theoretical minimum bead lap angle is sufficient.

As indicated above, tyres having a construction in accordance with the present invention have a number of desirable properties, one being that it is possible to dispense with the rigid metal bead wires used in the known types of tyres, as the cord itself forms the beads. Further, on inflating the tyre, the portions of the cords lying adjacent the edges of the tyre move or tend to move radially inwardly to grip an associated rim. This result differs from that obtained on inflating a conventional pneumatic tyre when the beads tend to move away from the rim. An advantage stemming from this result comprises a lesser tendency to tyre creep relative to the rim. Further a reduction in the height of the rim flange for retaining the tyre on the rim is made practicable and a consequent reduction in the weight of the wheel is obtained. Since the improved tyre need not be a tight fit on the rim when deflated, stripping and assembly of the tyre off and on the rim is facilitated.

A further advantage of tyres constructed in accordance with the present invention is that the absence of the conventional bead wires renders them more flexible and so facilitates fitting them to rims of the one-piece type, having flanges integral with the base which may itself be flat or contain a central well. This is of particular importance in tyres for heavy commercial vehicles and aircraft which cannot normally be fitted to such rims on account of the rigidity of their beads. Tyres of conventional construction have therefore to be fitted to two or three piece rims, which are not normally leakproof and, unless special measures are taken to make them so, tubeless tyres cannot be used. Tyres constructed in accordance with the present invention are capable of being fitted to the one-piece rim, which is leakproof, and can therefore be of tubeless construction.

Another advantage of such tyre constructions which is particularly valuable in tubeless tyres is that, on inflating the tyre, the beads thereof, which are normally rubber-covered, are forced into fluid-tight engagement with the wheel rim.

The strength/weight ratio of a tyre constructed in accordance with the present invention is high and since the normal bead wires are dispensed with the tyre is light and flexible.

A further advantage of tyres constructed in accordance with the present invention is that the winding of the cord on the former can be carried out automatically with very little attention from the operator who can readily supervise simultaneously a number of cord winding machines. Far less skill and labour are required to form the reinforcement by winding on a former in accordance with the invention than are involved in the case of the conventional method, referred to above, in which the reinforcement is built up manually on a drum from plies of rubberized tyre cord fabric.

What we claim is:—

1. A pneumatic tyre comprising a body of natural rubber or other suitable resilient material containing, as an internal reinforcement, a winding of cord arranged in the form of at least one double layer in which the cord of one layer crosses the cord of the other layer to form a lattice and the cord in each layer extends in a series of unit waves progressing continuously around the tyre in the same direction, each unit wave of cord being completely embedded in the resilient material and consisting of two substantially diagonally opposite arcuate portions, each extending through and being substantially confined to one bead of the tyre, alternating with portions passing through the side walls and crown of the tyre which leave and approach the arcuate

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portions substantially tangentially and take a path which is substantially a geodesic with respect to the surface defined by the layer, the arcuate portions of cord in the unit waves being sufficiently long to ensure that, on inflation of the tyre, each of the beads will tend to contract in diameter over a major portion of the transverse dimension of the foot of the bead as a result of the tension imposed on the cord.

2. A pneumatic tyre according to claim 1 in which the cord reinforcement is embedded between an underlayer of rubber, upon which the cord is wound during manufacture of the tyre, and an upper layer of rubber applied to the reinforcement prior to shaping and moulding of the tyre.

3. The combination of a tubeless tyre according to either of claims 1 or 2 with a wheel having a one-piece rim.

4. A method of making a pneumatic tyre which comprises winding cord progressively around a former having thereon a winding surface of substantially part-spherical shape to form a reinforcement having edges of equal diameter and constituted by at least one double layer of cord, the cord of one layer crossing the cord of the other layer to form a lattice and each layer consisting of a series of turns which are spaced equidistantly around the former, extend obliquely around it in a geodesic path and make tangential contact with opposite edges of the reinforcement at positions substantially diagonally opposite, removing the reinforcement from the former and thereafter subjecting it together with a vulcanisable composition containing natural rubber or other suitable resilient material to a shaping, heating and moulding treatment to vulcanise the composition and form a tyre in which each turn of the cord is completely embedded in the resilient material, this treatment displacing the edges of the reinforcement axially inwardly, expanding the crown portion of the reinforcement and deforming the cord so that portions thereof extend arcuately in the beads of the tyre to an extent sufficient to cause each of said beads to tend to contract in diameter over a major portion of the transverse dimension of the foot of the bead when the tyre is inflated.

5. A method according to claim 4, wherein the former is provided at each end of the winding surface with supports for the edges of the reinforcement.

6. A method according to claim 5, wherein the supports for the edges of the reinforcement are of frusto-conical shape.

7. A method according to any of claims 4—6, wherein the cord is coated with a vulcanisable rubber composition prior to winding on the former.

8. A method according to claim 7, wherein the cord is heated and then drawn through an extruding device to coat it with the composition.

9. A method according to claim 8, wherein means are provided for reducing the tension in the cord between the extruding device and the former.

10. A method according to any of claims 4—9 wherein the cord is wound on a layer of uncured rubber secured to the former.

11. A method according to any of claims 4—10 wherein the cord is laid on the former by a winding arm moving in a circular path around the former and the former is slowly rotated, during winding of the cord, about an axis inclined to the axis of rotation of the winding arm.

12. A method according to any of claims 4—11, wherein the cord is wound on the former under a pre-determined tension.

13. Apparatus for use in the manufacture of a pneumatic tyre as claimed in claim 1, comprising a former, means for feeding cord on to the former and means for effecting relative movement between the former and the feeding means to lay the cord on a winding surface of the former, which surface is substantially part-spherical throughout its area and has two parallel circular edges of equal diameter, in a series of turns progressing around the former in the same direction, each turn extending obliquely around the former in a geodesic path and making tangential contact with each edge of the winding surface at substantially diametrically opposite points.

14. Apparatus according to claim 13, wherein the former is a collapsible former rotatable about an axis normal to the planes of the circular edges of the winding surface, and the apparatus comprises a winding arm rotatable about an axis intersecting the rotational axis of the former and inclined thereto at an acute angle, feed mechanism for feeding cord to the winding arm, and means for rotating the winding arm co-operating with means for imparting slow rotation to the former about its axis to cause the arm to wind the cord around the former in a series of spaced circular turns extending from one edge of the winding surface to the other edge and back again.

15. Apparatus according to claim 14, wherein the feed mechanism includes means for applying a surface coating of a rubber composition to the cord on its way to the winding arm.

16. Apparatus according to claim 14, in which the feed mechanism comprises a device for heating the cord and an extruding device for coating the heated cord with a rubber composition.

17. Apparatus according to claim 16, comprising a device for reducing the tension in the cord between the extruding device and the winding arm and maintaining the winding tension at a predetermined value.

18. A pneumatic tyre substantially as

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described herein with reference to Figures 1—4 of the accompanying drawings.

19. Apparatus for manufacturing a pneumatic tyre substantially as described herein with reference to Figure 10 of the accompanying drawings.

20. A method of making a pneumatic tyre, substantially as described with reference to Figures 5—9 and 11.

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PROVISIONAL SPECIFICATION
No. 6023 A.D 1954

Improvements in Pneumatic Tyres

We, DUNLOP RUBBER COMPANY LIMITED, a British Company, of 1, Albany Street, London, N.W.1, and HENRY WILLIAM TREVASKIS, a British Subject, of the Dunlop Rim and Wheel Company Limited, Foleshill, Coventry, do hereby declare this invention to be described in the following statement:—

This invention relates to casings, and more particularly to casings for pneumatic tyres.

The object of the present invention is to provide an improved casing for a pneumatic tyre. Another object of the invention is to provide a method of and apparatus for making such an improved casing.

According to the invention an improved casing for a pneumatic tyre comprises stranded material which extends continuously around the casing and sinuously from side to side.

By stranded material is meant wire, either in single strands, or several parallel strands together or strands twisted together to form a cable. Braided flat strip metal or glass fibre rovings may be used. Alternatively said material may comprise any suitable textile yarn, Nylon, rayon or any similar material, or a short-staple fibre such as cotton.

The said material may be treated before incorporation in the tyre casing, e.g. the wire may be plated or rubberised, or the yarn or wire may be given a moisture-repellent coating.

The stranded material which extends continuously around the casing preferably extends sinuously from one edge thereof to the other and comprises two or more layers, the material of one layer lying substantially parallel and at a substantially constant angle to the material of an adjacent layer. By virtue of the fact that the said material extends sinuously across the width of the casing as well as continuously around it, it follows that a part of each winding follows the inner periphery of the casing, when formed, and thus, on inflation of the casing, the material is tensioned to firmly grip an associated wheel rim.

Preferably said material comprises strands of cotton-covered steel wire which are coated with rubber or rubber-like material before incorporation in the casing, and the casing may be provided with an inner lining and an outer cover, both of rubber or rubber-like material. A tread may be cemented to the outer cover. The whole assembly may then be shaped and cured in an autoclave which not only bonds the whole assembly integrally together but also prevents displacement of the wire strands and prevents chafe during service.

According to the invention also a method of making a casing for a pneumatic tyre comprises winding a continuous length or lengths of stranded material on to a former in such a manner that the said material passes around the former and from one edge thereof to the other to cover the periphery of the former in a plurality of layers.

Preferably the former is substantially cylindrical and is rotatable about its winding axis and the material is fed from a stationary point. The former is secured with its main axis at a predetermined angle from the winding axis so that, as the former rotates about its winding axis the material is wound thereon and extends diagonally from one edge of the former to the other. The former is rotated relatively slowly about its main axis during the winding operation so that the strands of one layer lie adjacent to one another.

Alternatively the main and winding axes of the former are co-axial and the material is fed on to the rotating former from a shuttle which reciprocates across the effective width of the former, the shuttle speed being geared to the former speed so that the entire surface of the former is covered.

The periphery of the former may be any convenient shape but preferably it is part-spherical, the edges thereof being provided with annular flanges to prevent the material from falling off the edges of the former. With such a former the material is preferably wound from a location on one edge to a diametrically-opposed location on the other edge; this prevents slip and allows the material to be correctly tensioned.

In one embodiment of the invention a pneumatic tyre casing comprises an inner layer of rubber, an outer layer of rubberised fabric and an intermediate layer of steel wire strands. The wire, which is in one continuous length, extends around the casing and from one edge to another, i.e. in one winding of the strand around the casing the strand extends from a location on one edge of the casing, sinuously across to the other edge, along the other edge, sinuously back to the original edge and along said edge to said location. The sinuous portions of each winding are diametric-

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ally opposed, and each subtends an angle of the order of 90°, whilst the portions of the strand extending along each edge are also diametrically opposed and each of said portions also subtends an angle of the order of 90°. The intermediate layer of steel wire strands comprises two sub-layers, the wires of one sub-layer being disposed at a constant angle to those of the adjacent sub-layer, whilst the wires comprising the same sub-layer are contiguous to one another.

The result of this is a strong, flexible and substantially bead-less construction. Its strength lies in the fact that the steel wires extend continuously around the periphery of the casing and from one edge to another and hence the stresses are distributed substantially uniformly around the body of the casing. The burst pressure is therefore high, and this is of particular value in aircraft and vehicle tyres. The edges of the casing, which correspond with the bead in a more conventional tyre, are integral with the casing, and the flexibility of the casing is such that the said edges will move radially inwardly to grip a wheel rim as the inflation pressure in the casing increases. This flexibility and even distribution of stresses also produce a casing wherein the heat build-up is low.

In an alternative embodiment of the invention the wire strands are rubberised so that on shaping and curing the casing the strands are bonded into position and this prevents subsequent movement and chafe.

A preferred method of making a pneumatic tyre casing of this type comprises winding a strand of wire on to a former. The former is cylindrical with a part-spherical periphery and is rotatable about a winding axis. At the same time the former is rotatable about its main axis which is set at an angle from its winding axis, the exact angle depending on the axial width of the former and thus the size of the casing required.

The wire strand is tensioned and fed on to the former and as the former rotates the strand passes circumferentially around the former from a location adjacent one edge thereof to a location adjacent the other edge. After one complete revolution of the former about its winding axis the former is angularly rotated so that the second winding of the wire strand lies alongside the first. This continues until the whole of the former has been completely covered by two layers of strands, each layer running at an angle to one another and equi-angular about the median plane of the former.

A band of unvulcanised rubber may be fitted over the former before winding and the wire strands may be rubber-covered. After winding, a rubber outer cover and tread may be fitted and the whole assembly shaped and cured in an autoclave.

Apparatus for carrying the above invention into effect may comprise a substantially cylindrical former having a part-spherical periphery, the edges of the former each being provided with an outwardly-flared annular flange to provide a gutter and hence prevent the strands of wire or other material from slipping during the winding operation. The former is provided with a threaded hole extending axially therethrough and is secured thereby to a rotatable spigot of the winding apparatus.

In an alternative apparatus the former rotates about its winding axis only and the wire strands or the like are fed in from a shuttle which reciprocates across the axial width of the former. In this apparatus the shuttle speed is regulated by the rotating former so that the entire surface of the former is eventually covered, i.e. the shuttle reciprocates once for just under or just over a complete revolution of the former.

If necessary the portions of the strands which together comprise the edges of the casing may be substantially strengthened. This may be achieved by adjusting the spigot angle of the former, or the reciprocating length of the shuttle, as the case may be, so that the strands tend to ride up the annular flange at each edge of the former, the tension in the strands immediately pulling them down into the gutter. Thus the edges of the casing, instead of being formed by a plurality of comparatively short portions will now be formed by a plurality of longer circumferentially-extending portions between the sinuous portions and these build up to a substantial thickness on each side of the casing.

The invention is not restricted to a casing in which, during one entire revolution of winding, the wire or other strand passes from one edge of the casing to the other edge and back again. On the contrary, for one revolution of winding the strand of wire or the like may only pass from one edge to the other edge or it may, following a sinuous path, pass from one edge to the other a number of times.

Alternatively the sinuous portions of each winding may not subtend an angle substantially equal to that subtended by the winding adjacent an edge, as herein described. For example, the sinuous part of each winding may subtend an angle of the order of 90° whilst the portion adjacent an edge may subtend an angle of the order of 270°.

The casing may be used with a conventional inflatable inner tube or it may be used as a tubeless construction.

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PROVISIONAL SPECIFICATION

No. 20636 A.D 1954

Improvements in Pneumatic Tyres

We, DUNLOP RUBBER COMPANY LIMITED, a British Company, of 1, Albany Street, London, N.W.1, and HENRY WILLIAM TREVASKIS, a British Subject, of the Dunlop Rim and Wheel Company Limited, Foleshill, Coventry, do hereby declare this invention to be described in the following statement:—

This invention relates to casings for pneumatic tyres and more particularly to pneumatic tyre casings of the type forming the subject-matter of our co-pending Application No. 6023/54. The invention also relates to a method and apparatus for constructing a tyre of this type.

According to the invention a casing for a pneumatic tyre comprises stranded or filamentary material which extends continuously around the casing and from one edge to the other and forms an integral reinforcement for the said edges.

The stranded or filamentary material should take the shortest possible path across the casing from one edge to another so that said material is uniformly stressed when the tyre is loaded.

According to the invention also a method of making a casing for a pneumatic tyre comprises winding a stranded or filamentary material continuously around a former and from one edge thereof to the other and rotating the former so that the surface thereof is covered by said material.

Preferably the stranded or filamentary material is rubber-covered and is wound on to an uncured layer of rubber secured to the former. Breaker strips are then added and an outer layer of rubber and a tread may be cemented on. The assembly is then stripped from the former and shaped and cured in an autoclave.

Tyres having a construction in accordance with the present invention have a number of desirable properties, one being that it is possible to dispense with the rigid beads used in the known type of tyres, as the stranded or filamentary material itself forms an integral reinforcement for the edges of the casing.

Further, inflation of the tyres tends to force the edges radially inwardly, thus making it possible to use lighter flanges on the wheel rims. Another feature of the novel construction is that it is possible to obtain a more uniform stress throughout the length of the material than in known constructions.

According to the invention also apparatus for making a tyre casing of the type described comprises a rotatable former having a convex curved surface of revolution, and an arm rotatable about said former for winding a length of stranded or filamentary material around the former to cover the peripheral surface of the former with said material.

Preferably the arm rotates about an axis set at a predetermined angle from the axis of rotation of the spindle so that each complete winding of stranded or filamentary material extends from one side of the former to the other in the shortest possible path. Preferably also the drive for the arm and the drive for the former are associated with one another so that the former rotates fractionally for every complete winding rotation of the arm.

By stranded or filamentary material is meant wire, either in single strands, or several parallel strands together or strands twisted together to form a cable. Braided flat strip metal may be used. Alternatively said material may comprise any suitable textile cords made for example, of a polyester such as that sold under the Registered Trade Mark "Terylene," nylon, rayon or from a short staple fibre such as cotton. The material may comprise cotton-covered wire.

In our co-pending Application No. 6023/54 the stranded material comprising the casing is described as extending continuously around the casing and sinuously from side to side. Whilst said material may, in fact, in one complete winding around said casing, move at least once from one edge of the casing to the other and may move across the width of the casing a number of times in one complete winding, yet it is also desirable, in at least one form of this construction, that each winding should take the shortest possible course obliquely across the lateral curvature of the tyre. Thus when the casing is constructed on a part-spherical or like-shaped former each complete winding lies substantially in a plane inclined to the axis of the former. The complete winding thus traces the shortest possible path around and across the former, or substantially the shortest possible path.

A pneumatic tyre casing constructed in accordance with one embodiment of the invention comprises an inner layer of rubber or rubber-like material, an intermediate layer of nylon cord, an outer layer of rubber or rubber-like material and a tread. The intermediate layer of nylon cord comprises five layers of rubberised cord extending continuously around the casing and from one edge thereof to the other in substantially the shortest possible path.

Each layer comprises two sub-layers crossing one another at a substantially constant angle, the construction being such that a criss-cross pattern is produced all over the casing. Each winding of cord, when under tension, tends to conform to a curve which makes virtual con-

tact with the edges of the casing at two positions diametrically opposed and at opposite sides. It is those portions of the cord lying adjacent the edges of the casing which together form the reinforcement of the edges of the casing, and this reinforcement can be built up in the construction of the casing to an appreciable thickness.

One property of a tyre casing constructed in accordance with the present invention is that, on inflating the tyre, the filamentary or stranded material lying adjacent the edges of the casing (which is integral with the material forming the remainder of the casing and which corresponds with the wired beads of a conventional tyre), moves radially inwardly to grip an associated rim, this radially inward force increasing substantially directly with the increase in pneumatic pressure within the tyre. This result differs from that obtained on inflating a conventional pneumatic tyre when the beads tend to move away from the rim. Advantages stemming from this result comprise an elimination of tyre creep relative to the rim which makes practicable a reduction in the height of the rim flange for retaining the tyre on the rim. Since the improved casing need not be a tight fit on the rim when deflated, stripping and assembly of the casing off and on the rim is facilitated. A further advantage of tyre casings constructed according to the invention is that they are capable of being fitted to shallow well-based rims. Another advantage of such a tyre construction is that it is particularly suitable in a tubeless tyre construction since, on inflating the tyre the edges thereof, which are normally rubber-covered, are forced into fluid-tight engagement with a wheel rim.

A tyre casing constructed in accordance with the present invention may be finally shaped to substantially D-section, i.e. with radially-extending walls, instead of substantially part-circular cross-section as hitherto. The advantage of this form of tyre is that it will take greater loads and, since, when inflated, the edges of the casing will firmly grip the rim, the side loading on the tyre-retaining flanges is greatly reduced. The thickness of the rim flanges may therefore be decreased.

The strength/weight ratio of a tyre constructed in accordance with the present invention is high and there is less internal deformation of the casing when stressed than is the case with a conventional tyre. Since the normal bead wires have been dispensed with the casing is light and flexible.

An apparatus for constructing an aircraft tyre made in accordance with the present invention will now be described. Said apparatus comprises a spherical former truncated at opposite ends of a diameter to form two equisized circular end portions and the former is detachably mounted on a spindle fitted centrally through said end portions. One end of the spindle is mounted in bearings and this end of the spindle is driven, through reduction gearing, by a telescopic shaft. A housing is located adjacent to the former and another shaft is mounted in bearings therein, said shaft being co-planar with the spindle but fixed at an angle of the order of 120° thereto.

An arm is secured, intermediate its ends, to the end of the shaft adjacent the former, the arm on one side of the shaft being angled so that the end thereof in one angular position of the shaft is located adjacent one edge of the former and for a 180° revolution of the shaft the said end moves round to a location adjacent the opposite edge of the former. The arm is provided with a plurality of rollers for guiding stranded or filamentary material to one end thereof and said end is provided with an extension at an angle thereto, thereby to feed said material on to the surface of the former. The other end of the arm is provided with a counterweight.

The shaft is hollow and the material is fed from a bobbin through the shaft to the arm.

A motor drives the shaft to rotate the arm, said motor also driving the telescopic shaft to rotate the spindle and, hence the former secured thereto. The gearing is such that for every revolution of the shaft and arm, the spindle and former rotates once only.

A method of manufacturing a tyre casing constructed in accordance with the invention and using the apparatus described above will now be described. The former, which is collapsible, is covered with a layer of uncured rubber which forms a tacky surface on to which the filamentary material will readily adhere. The filamentary material which may be of any of the filamentary or standard materials hereinabove suggested, is led from a bobbin, through a tensioning device, through the rollers on the arm and thence on to the former. The motor is then started and the apparatus commences to build up the casing by winding the filamentary material around the slowly rotating former until a sufficient thickness, e.g. four or five layers, has been built up.

The filamentary material is covered with rubber or a rubber-like material to prevent chafe and friction in service and also to prevent displacement of the filamentary material during manufacture. Thus liquid rubber may be brushed or sprayed on to each layer of filamentary material as it is built up on the former, or the filamentary material may be run through a bath of liquid rubber before winding on the former, or the filamentary material may be provided with a sheath of soft uncured rubber.

Four or five layers of the filamentary material in all may be wound around the former, i.e. the former may rotate four or five times. Breaker strips may then be fitted to the casing, and said strips may comprise

rubberized fabric cut on a bias, or filamentary material wound on to the casing in the manner described or filamentary material wound circumferentially around the casing. An outer layer of unvulcanised rubber is then fitted and finally a tread is cemented to the outside of the completed casing.

The former is then removed from the apparatus and the casing is removed from the former by collapsing the former. The casing is then shaped and cured in conventional manner by fitting an air bag therein, inflating the bag and curing the assembly in an autoclave. Curing may be effected under either high or low pressure.

The former is preferably of part-spherical shape, i.e. a sphere equally truncated at opposite ends of a diameter, and the two planar portions are lipped to prevent the stranded or filamentary material from slipping off the former. However, the former need not necessarily be part-spherical but may have an ellipsoidal configuration, depending on the required type and dimension of the finished casing.

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PROVISIONAL SPECIFICATION
No. 23854 A.D. 1954

Improvements in Pneumatic Tyres

We, DUNLOP RUBBER COMPANY LIMITED, a British Company, of 1, Albany Street, London, N.W.1, and HENRY WILLIAM TREVASKIS, a British Subject, of the Dunlop Rim and Wheel Company Limited, Foleshill, Coventry, do hereby declare this invention to be described in the following statement:—

This invention relates to casings for pneumatic tyres and more particularly to pneumatic tyre casings of the kind forming the subject-matter of our copending Application No. 6023/54. The invention also relates to a method and apparatus for constructing a tyre of this kind.

According to the invention a casing for a pneumatic tyre comprises a long length or lengths of cord or other filamentary material extending continuously round the casing in a path running to and fro between the edges, the material approaching and leaving each edge at a tangent to the edge and taking the shortest path between the successive points at which it parts from one edge and makes contact with the other edge.

The fact that the filamentary material takes the shortest possible path across the casing from one edge to another has the result that the material is substantially uniformly stressed when the tyre is inflated.

According to the invention also a method of making a casing for a pneumatic tyre comprises winding cord or other filamental material continuously around a former having a convex curved surface of revolution and from one edge thereof to the other and rotating the former so that the surface thereof is substantially covered by said material.

The shape of the curved surface in cross-section is preferably that of an arc of a circle though it may be that of an arc of an ellipse or other curved body.

Preferably the filamentary material is rubber-covered and is wound on to a layer of rubber secured to the former.

In a casing in accordance with the invention the cord runs round the periphery of the casing between the successive parts at which it contacts with and parts from the edge and the cumulative effect of these peripheral portions is to build up a strong reinforced edge on each side of the casing which makes it possible to dispense with the steel wire beads employed in the known tyre constructions.

The length of the arc between the successive points of contact and departure can be varied within wide limits; it may, for example, be such that the arc subtends at the centre an angle of 10° or one of 90°.

Casings in accordance with the invention are preferably produced by winding cord on a collapsible former having the shape of a portion of a sphere formed by slicing two equal caps from opposite ends of a diameter and replacing them by cylindrical portions of the same diameter as the caps. When the cord is wound it forms one or more layers on the former, the windings in each layer running round the junction between one cylindrical portion and the part-spherical portion for a predetermined distance, then over the part-spherical portion to the second junction, leaving and contacting the junctions tangentially and following the shortest possible path between the points of departure and contact, round the second junction and continuing to and fro until a casing of sufficient thickness is built up.

The magnitude of the arc described by the cord between the points of contact and departure can be varied as desired, but usually it is preferable to adjust it so that when the cord has travelled from one junction to the other and back again it contacts the first junction adjacent the point where it left it and continues in a path lying close to the previous path.

When a casing has been built up from one or more layers of filamentary material wound in accordance with the invention the remainder of the tyre-building operation may be carried

out in a manner similar to that at present employed, by covering the casing with a tread and side-walls and providing breaker and chafer strips. The former can then be withdrawn and the assembly vulcanised in a mould in the usual manner.

Tyres having a construction in accordance with the present invention have a number of desirable properties, one being that it is possible, as stated above, to dispense with the rigid beads used in the known types of tyres, as the filamentary material itself forms an integral reinforcement for the edges of the casing. Further, inflation of the tyres tends to force the edges radially inwardly, thus making it possible to reduce the depth of the flanges on wheel rims. This in turn makes it possible to use a thinner flange, on account of the reduction in bending moment, so that a substantial reduction in the weight of the rims can be obtained. Another feature of the novel construction is that it is possible to obtain a more uniform stress throughout the length of the filamentary material than in known constructions.

According to the invention also apparatus for making a tyre casing in accordance with the invention comprises a rotatable former having a convex curved surface of revolution, and an arm rotatable about said former for winding a length of filamentary material around the former to substantially cover the peripheral surface of the former with said material.

Preferably the arm rotates about an axis set at a predetermined angle from the axis of rotation of the former so that each complete winding of filamentary material extends from one side of the former to the other in the shortest possible path. Preferably also the drive for the arm and the drive for the former are associated with one another so that the former rotates fractionally for every complete winding rotation of the arm.

The filamentary material used may be wire, either in single strands, or several parallel strands together or strands twisted together to form a cable or it may be braided flat strip metal. The material may be covered with cotton or rubber. Alternatively said material may be any suitable textile cords made, for example, of a polyester such as that sold under the Registered Trade Mark "Terylene," nylon, rayon or from a short staple fibre such as cotton.

A pneumatic tyre casing constructed in accordance with one embodiment of the invention comprises an inner layer of rubber or rubber-like material, an intermediate layer of nylon cord, an outer layer of rubber or rubber-like material and a tread. The intermediate layer of nylon cord comprises five layers of rubberised cord extending continuously around the casing from one edge thereof, leaving and approaching each edge at a tangent and taking substantially the shortest possible path between successive points of contact and departure.

Each layer comprises two sub-layers crossing one another at a substantially constant angle, the construction being such that a criss-cross pattern is produced all over the casing. Each complete winding of cord includes two portions which form part of the edges of the casing at two positions diametrically opposed and at opposite sides. It is those portions of the cord lying in the edges of the casing which together form the reinforcement of the edges of the casing, and this reinforcement can be built up in the construction of the casing to an appreciable thickness.

One property of a tyre casing constructed in accordance with the present invention is that, on inflating the tyre, the filamentary material lying adjacent the edges of the casing (which is integral with the material forming the remainder of the casing and which corresponds with the wired beads of a conventional tyre), moves radially inwardly to grip an associated rim, this radially inward force increasing substantially directly with the increase in pneumatic pressure within the tyre. This result differs from that obtained on inflating a conventional pneumatic tyre when the beads tend to move away from the rim. Advantages stemming from this result comprise an elimination of tyre creep relative to the rim which, as stated above, makes practicable a reduction in the height of the rim flange for retaining the tyre on the rim. Since the improved casing need not be a tight fit on the rim when deflated, stripping and assembly of the casing off and on the rim is facilitated. A further advantage of tyre casings constructed according to the invention is that they are capable of being fitted to shallow well-based rims. Another advantage of such a tyre construction which is particularly valuable in a tubeless tyre construction is that, on inflating the tyre, the edges thereof, which are normally rubber-covered, are forced into fluid-tight engagement with the wheel rim.

A tyre casing constructed in accordance with the present invention may be finally shaped to substantially D-section, i.e. with radially-extending walls, instead of substantially part-circular cross-section as hitherto.

The strength/weight ratio of a tyre constructed in accordance with the present invention is high and there is less internal deformation of the casing when stressed than is the case with a conventional tyre. Since the normal bead wires are dispensed with the casing is light and flexible.

An apparatus for constructing an aircraft tyre made in accordance with the present invention will now be described. Said apparatus comprises a spherical former truncated at opposite ends of a diameter to form two equisized circular ends having substantially cylindrical portions extending axially there-

from and the former is detachably mounted on a spindle fitted centrally through said cylindrical portions. One end of the spindle is mounted in bearings and this end of the spindle is driven, through reduction gearing, by a telescopic shaft. A housing is located adjacent to the former and another shaft is mounted in bearings therein, said shaft being co-planar with the spindle but fixed at an angle of the order of 120° thereto.

An arm is secured, intermediate its ends, to the end of the shaft adjacent the former, the arm on one side of the shaft being angled so that the end thereof in one angular position of the shaft is located adjacent one edge of the former and for a 180° revolution of the shaft the said end moves round to a location adjacent the opposite edge of the former. The arm is provided with a plurality of rollers for guiding filamentary material to one end thereof and said end is provided with an extension at an angle thereto, thereby to feed said material on to the surface of the former. The other end of the arm is provided with a counterweight.

The shaft is hollow and the material is fed from a bobbin through the shaft to the arm.

A motor drives the shaft to rotate the arm, said motor also driving the telescopic shaft to rotate the spindle and hence the former secured thereto. The gearing is such that for every revolution of the shaft and arm, the spindle and former rotates a fraction of a revolution only.

A method of manufacturing a tyre casing constructed in accordance with the invention and using the apparatus described above will now be described. The former, which is collapsible, is covered with a layer of uncured rubber which forms a tacky surface onto which the filamentary material will readily adhere. The filamentary material, which may be of any of the materials hereinabove suggested, is led from a bobbin, through a tensioning device, through the rollers on the arm and thence on to the former. The motor is then started and the apparatus commences to build up the casing by winding the filamentary material around the slowly rotating former until a sufficient thickness, e.g. four or five layers, has been built up. The filamentary material is covered with rubber or a rubber-like material to prevent chafe and friction in service and also to prevent displacement of the filamentary material during manufacture. Thus liquid rubber may be brushed or sprayed on to each layer of filamentary material as it is built up on the former, or the filamentary material may be run through a bath of liquid rubber before winding on the former, or the filamentary material may be provided with a sheath of soft uncured rubber.

Four or five layers of the filamentary material in all may be wound around the former, i.e. the former may rotate four or five times. Breaker strips may then be fitted to the casing, and said strips may comprise rubberized fabric cut on a bias, or filamentary material wound on to the casing in the manner described or filamentary material wound circumferentially around the casing. An outer layer of unvulcanized rubber is then fitted and finally a tread is cemented to the outside of the completed casing.

The former is then removed from the apparatus and the casing is removed from the former by collapsing the former. The casing is then shaped and cured in conventional manner by fitting an air bag therein, inflating the bag and curing the assembly in a mould. Curing may be effected under either high or low pressure.

The former is preferably of part-spherical shape, i.e. a sphere equally truncated at opposite ends of a diameter, and the two planar portions are lipped to prevent the stranded or filamentary material from slipping off the former. However, the former need not necessarily be part-spherical but may have an ellipsoidal configuration, depending on the required type and dimension of the finished casing.

Apart from the method of making tyres according to the invention which is hereinabove described, there are other methods and apparatus for making such tyres. For example, the former may be substantially tyre-shaped and be rotatable within a template having a side shaped to the configuration of one winding of the filamentary material around the former. An arm rotates about the former, substantially as herein described, to wind the said material along the shaped side of the template and around the former, which is slowly rotating. Alternatively the former may be of the type previously described and the filamentary material may be wound thereon from a shuttle reciprocating across the effective width of the former, the movement of the shuttle being carefully geared to the angular velocity of the former to obtain the desired winding of the said material. In yet another alternative method and apparatus the former, which is of the type herein described, is mounted on a rotating spigot and the spigot is simultaneously angularly displaceable through a predetermined angle. The filamentary material is fed on to said rotating former and as the spigot is angularly displaced so the former is substantially covered with said filamentary material.

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