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(54) A METHOD OF MANUFACTURING A PNEUMATIC TIRE

(71) We, THE GOODYEAR TIRE & RUBBER COMPANY, a corporation organised under the laws of the State of Ohio, United States of America, of 1144 East Market Street, Akron, Ohio, United States of America, 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 tires and more particularly to a method of manufacturing a pneumatic tire.

During the molding and curing portion of the manufacturing operation, the pneumatic tire blank is forced by means of internal pressure to conform to the internal contour of a mold and heated to cure the rubber. The green tire being a plastic unvulcanized body and having various reinforcing components such as cords or wires experiences a certain degree of shifting of the reinforcing elements and flow of the rubber. It is desirable to control and reduce this shifting and flow in order to provide a uniform and durable structure in the finished tire.

Further, if this shifting or flow could be reduced, it would permit the elimination of extra rubber gauge on the reinforcing elements to allow for localized reduction in the rubber gauge caused by this shifting or flow.

Attempts in the past at controlling this shifting and flow phenomenon during the shaping and curing operation have included such things as precuring various components of the tires. These proposals have not met with much success for various reasons. For example, the components that were precured prior to shaping and vulcanizing the tire could become overcured during the final vulcanization of the composite structure. Further, adhesion between the various components of the tire was reduced because the greatest curing during the precuring operation occurred on the surface of the components and reduced the amount of cross-linking available between the various components or layers during the curing of the composite structure. Surface precuring also reduces building tack which makes it difficult for components to adhere to each other during the building operation. Tack, as is known to those skilled in the arts, it that quality of the rubber in the uncured state which permits it to adhere to another component.

The inventor, however, has found that by using an electron radiation treatment of selected components in a critical range of radiation dosage the components can be rendered sufficiently stiff or rigid to control the shifting and flow phenomenon yet permit a good bond between components and also avoid overcure of the components. This process is particularly useful since during electron radiation curing the cross-linking is a carbon-to-carbon bond as opposed to the carbon-sulfur-carbon bond which occurs during normal heat curing utilizing steam or hot water. The component can then undergo additional curing during the vulcanization of the entire structure by a steam or hot water method and including carbon-sulfur-carbon bonds.

Further, if electron radiation treatment is used within certain critical ranges of electron dosage the greatest cure can be made to occur just below the surface of the component, leaving the surfaces less cured and with sufficient tack.

According to the invention there is provided a method of manufacturing a pneumatic tire comprising forming a tire component containing vulcanizable elastomeric material, effecting a partial cure of said component by electron radiation with the degree of partial cure being

higher within said component than on the surface of said component, forming a toroidal tire blank incorporating the partially cured component and curing said tire blank under heat and pressure.

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

Figure 1 is a cross-sectional view of a portion of a tire manufactured by a method in accordance with this invention;

Figure 2 is an enlarged view of a shoulder portion of the tire of Figure 1;

Figure 3 is an enlarged cross-sectional view of a shoulder portion of a prior art tire;

Figure 4 is a perspective view illustrating a tire component being treated with electron radiation;

Figure 5 is a flow diagram illustrating the preferred method steps in the present invention; and,

Figure 6 is a graph illustrating the critical ranges of electron dosages utilized in carrying out the method of the present invention.

With reference to the drawings and in particular Figure 1, the cross-sectional view of a pneumatic tire 10 illustrates the various components. The tire includes a tread portion 12, a pair of sidewalls 14 and 16 extending radially inwardly from the lateral edges or shoulder portions 18 and 20 and terminating in the radially inward direction in annular bead portions 22 and 24, a pair of carcass plies 26 and 28 extend circumferentially about the tire and from bead portion 22 to bead portion 24 with the radially inner ends 30 and 32 turned about the respective inextensible bead cores 34 and 36.

The tire 10 may also include a pair of belt or breaker plies 38 and 40 which extend circumferentially about the carcass plies 26 and 28 and beneath the tread 12. Shoulder wedge strips 42 and 44 may also extend circumferentially about the tire and be located between the axially outer edges of the belt plies 38 and 40 and the carcass plies 26 and 28.

Additionally, a flipper strip 46, 48 may be provided about each bead core 34, 36 as well as a rubber apex strip 50, 52 extending radially outwardly from the bead core and disposed between the ends of the flipper strips 46, 48. Further, a chafer ply 54, 56 may extend around the toe and heel of the respective bead portion 22, 24 in the usual manner. Also, additional reinforcing members in the form of annular "chipper" (i.e. lower sidewall reinforcing) strips 58, 60 extending from the bead portions 22, 24 into the lower part of the sidewall 14, 16 may be provided.

The cords in the various reinforcing layers may be of any suitable material such as, by way of example only, nylon, rayon, polyester, fiberglass, or wire. The cords further may be parallel cords or in a "square-woven" fabric. There may be one or more belt plies, (two belt plies 38 and 40 being shown), and the or each belt ply may be of a folded construction or unfolded as illustrated. "Square woven" means woven with mutually perpendicular warp and weft of about equal strength.

The carcass plies may be either bias or radial. Bias ply tires may or may not include the belt or breaker plies 38 and 40.

Certain components of the tire are treated with a specific amount of electron radiation prior to incorporation in the tire blank, in order to achieve partial vulcanisation or curing. The specific components and specific portion of each component which is treated depends upon the specific irregularity or distortion problem involved. For example, in Figure 3 there is illustrated a pneumatic tire which was made according to standard manufacturing processes illustrating some imperfection that can exist as a result of rubber flow during shaping and curing. It will be noted that in the shoulder area 18 of the tire the carcass plies 26′ and 28′ are wavy and distorted and of unequal thickness. It will further be observed that the shoulder wedge strips 42′ are also distorted and non-uniform. Further, it can be observed that the lateral edges of the belt plies 38′ and 40′ are curved and of irregular thickness.

In order to alleviate and avoid these irregularities and in accordance with the present invention, the carcass plies 26 and 28 are treated at least in the area of the shoulders 18, 20 with a specific critical dosage of electron radiation. Also, the shoulder wedge strips 42 and 44 may be treated with an electron radiation treatment as well as at least the lateral edges of the belt plies 38 and 40.

With reference to Figure 4, there is schematically illustrated an electron radiation treating unit 60 and a method of treating a ply 62 of rubber impregnated layer of fabric. The ply 62 passes beneath the electron radiation source at a given speed. The electrons strike a certain width W of the ply 62 which is to be treated. It will be appreciated that while the electron treatment is concentrated over the width W that there will be some overspray of electrons. Also with some electron radiation units the width of treatment can be adjusted to meet the required width of treatment of the component. This is sometimes accomplished by providing an electron source which is rectangular or elliptical in shape and rotating it about an

axis 64.

The dosage or treatment of the component with electron radiation must be carefully controlled within limits which are chosen to produce the desired degree of part vulcanisation or curing, taking into consideration the dimensions of the component to be treated. The dosage distribution of the radiation treatment within a specific component is illustrated in Figure 6 and is dependent upon the voltage of the electron source. It is convenient and normally preferable that the radiation treatment be applied to one side of the component. Also, it is desirable that the dosage be contained entirely within the component as opposed to some energy passing completely through the component.

Thus from a consideration of the graph in Figure 6 it can be seen that for thin components relatively low electron voltages are used in order that all of the electrons lose their energy within the component. A relatively low voltage may also be chosen in order that no dose is received by the under side of the component; that is, the side opposite the electron source. The under side is, therefore, left completely uncured.

For a typical layer or ply reinforcing component with a thickness of 0.06 inch (1.5 millimeters), a voltage of 500 kilovolts would be chosen. This voltage results in the under side or side of the component opposite the electron source receiving no electron radiation treatment and the side facing the electron source receiving only 80 percent of the maximum dosage that is received by the interior region of the component.

For thicker components high electron voltages would preferably be chosen in order to provide a low relative dose on the side of the component facing the electron source as well as the side opposite the electron source. Thus, if the component were 0.16 inch (4.1 millimeters) thick, an electron voltage of 1,000 kilovolts would be chosen. The side facing the source would receive only approximately 55 percent of the maximum dosage deposited within the component. It can therefore be seen that there is a large degree of radiation treatment in the interior portion of the component yet both exterior surfaces receive relatively less treatment or none at all.

The total dosage applied to a unit width component (neglecting air and accelerator window losses) is directly proportional to the product of the output voltage and the current of the accelerator and is inversely proportional to the speed at which the material or component traverses the radiation treating unit. If the electron source is adjusted to treat a wider portion W of a component passing through the unit with no change in voltage, current or speed of the component the dosage received by the component would be reduced by an amount which is directly proportional to the increase in width of the treated area. The dose can be determined empirically by use of any one of the various dosimeters available which lends itself conveniently to the particular operation.

The dose applied to any component is determined by the tire engineer and will be dependent upon the strength or structural integrity desired prior to curing by heat and pressure. If more strength is desired, a higher dose will be applied and conversely a lower dose if lower strength is desired. Doses of between one and ten megarads may be used with doses of two to four megarads being the preferred range for most tire applications.

After the desired electron radiation treatment has been applied to the various components to be treated, the tire blank is then assembled in the normal manner on a tire building drum. The sequential operation of building a tire blank in accordance with the present invention is illustrated in Figure 5. First the various components are prepared. The "tread ply fabric" (see below) is calendered and treated with electron radiation. The bead cores are manufactured in the normal manner. The liner is prepared in the normal manner and treated with electron radiation if desired. The carcass ply fabric is calendered in the normal manner to provide the coating of rubber on the cords and again electron radiation treated. Shoulder wedges are formed by e.g. an extrusion process and treated with an electron radiation. The tread rubber is also preformed.

The liner is wrapped about the tire building drum, the carcass plies are wrapped around the liner stock, and the bead cores are set on the drum in a predetermined position. Additional components such as chafers and flippers are added, the axially outer ends of the carcass plies are turned about the bead cores and then chippers added in a known manner. Particularly with regard to radial ply tires, the carcass may now be shaped to the toroidal form.

The previously treated shoulder wedges are then applied to the tire building drum and the belt plies wrapped circumferentially thereabout. Tread and sidewall rubbers are then applied to the carcass. If the tire blank has not already been shaped to the toroidal form, it is now so shaped and the green tire is cured in a mold under pressure and heat.

A tire built according to the foregoing process is illustrated in Figure 1. It will be

noted that the carcass plies, liner, and tread plies all exhibit a smooth contour and even thickness. Also, the shoulder wedges 42 and 44 have maintained their desired shapes.

Although in the specific example illustrated portions of the tire in the shoulder areas were treated with a radiation precure, it is intended that the present invention includes the concept of radiation treating any component containing vulcanisable elastomeric material within the tire in which it is desired to increase the structural integrity of the component prior to shaping and curing to avoid distortion or flow during the shaping and curing operation. Such examples of additional components which might be treated with radiation precure are the flipper strips 46 and 48, the apex strips 50 and 52, the chafers 54 and 56, and the reinforcing strips 58 and 60. It is desirable to treat the liner 61 in order to provide uniform gauge around the tire as well as to provide sufficient strength to permit elimination of the shaping the curing bag during the curing operation.

The present invention, therefore, has provided a method of increasing the structural strength or integrity of various components containing vulcanisable elastomeric material prior to curing without detrimental loss of tack or adhesion between the various components. This results in several specific advantages in the finished tire. For example, the gauge of rubber applied to the various structural components can be reduced since it is no longer necessary to provide additional thickness of rubber on the cords to assure a minimum gauge in the cured tire since the amount of flow and distortion is substantially reduced. Second, the shape and contour and specific location of the various components is maintained smooth and uniform throughout the shaping and curing operation and ultimately in the finished tire.

Also, the present invention avoids the heretofore problems involved with partial precuring of components which were cured by means of a heat cure. In the heretofore methods of applying a partial heat cure to the tire, a carbon-sulfur-carbon bond was accomplished in the partial precure process. When the tire was then subjected to additional heat cure to cure the composite structure including the heavy gauge of rubber in the tread, shoulder, and sidewall additional cure was applied to the partial precured components to the extent that they became overcured. Also, these partial precure treatments resulted in maximum cure on the surface and minimum cure internally of the component which resulted in loss of tack on the surface and attendant lack of adhesion between the various components in the finished tire.

The present invention, however, overcomes these problems by applying a critical specific amount of radiation precure which results in higher cure beneath the surface of the component than on the surface and thus maintains sufficient tack and ability to adhere to other components. Further, the structural integrity or strength of the component is provided by carbon-to-carbon bond in the rubber as opposed to carbon-sulfur-carbon bonds in the old method. This permits additional cure by carbon-sulfur-carbon bonding in the normal heat cure of the composite structure without overcure of the tire or any component.

In Figure 5 and in the above description of Figure 5, "tread ply fabric" means any tread reinforcing material disposed beneath the tread area, including for example belt plies or breaker plies; (a "belt ply" being a circumferentially extending reinforcing member disposed beneath the tread and terminating in the general area of the shoulders and serving to restrict the inflated outer diameter of the tire so something less than it would be were the belt ply not there; a "breaker ply" being a circumferentially extending reinforcing member disposed beneath the tread in the same fashion as a belt ply but being of a structural nature such that is does not affect the inflated outside diameter of the tire).

Reference is directed to our co-pending patent application No. 10765/74 (Serial No. 1448531) entitled "Method of making radial ply tires".

WHAT WE CLAIM IS:—

1. A method of manufacturing a pneumatic tire comprising forming a tire component containing vulcanizable elastomeric material, effecting a partial cure of said component by electron radiation with the degree of partial cure being higher within said component than on the surface of said component, forming a toroidal tire blank incorporating the partially cured component and curing said tire blank under heat and pressure.

2. A method as claimed in Claim 1, wherein said partial cure is accomplished by effecting carbon-to-carbon bonding between some of the molecules in the elastomeric material.

3. A method as claimed in Claim 1, wherein said partial cure is accomplished by treating the tire component with between 1 and 10 megarads of electron radiation.

4. A method as claimed in Claim 3, wherein said radiation is applied to said component from one side thereof and at a voltage intensity that provides for essentially no radiation passing completely

noted that the carcass plies, liner, and tread plies all exhibit a smooth contour and even thickness. Also, the shoulder wedges 42 and 44 have maintained their desired shapes.

Although in the specific example illustrated portions of the tire in the shoulder areas were treated with a radiation precure, it is intended that the present invention includes the concept of radiation treating any component containing vulcanisable elastomeric material within the tire in which it is desired to increase the structural integrity of the component prior to shaping and curing to avoid distortion or flow during the shaping and curing operation. Such examples of additional components which might be treated with radiation precure are the flipper strips 46 and 48, the apex strips 50 and 52, the chafers 54 and 56, and the reinforcing strips 58 and 60. It is desirable to treat the liner 61 in order to provide uniform gauge around the tire as well as to provide sufficient strength to permit elimination of the shaping the curing bag during the curing operation.

The present invention, therefore, has provided a method of increasing the structural strength or integrity of various components containing vulcanisable elastomeric material prior to curing without detrimental loss of tack or adhesion between the various components. This results in several specific advantages in the finished tire. For example, the gauge of rubber applied to the various structural components can be reduced since it is no longer necessary to provide additional thickness of rubber on the cords to assure a minimum gauge in the cured tire since the amount of flow and distortion is substantially reduced. Second, the shape and contour and specific location of the various components is maintained smooth and uniform throughout the shaping and curing operation and ultimately in the finished tire.

Also, the present invention avoids the heretofore problems involved with partial precuring of components which were cured by means of a heat cure. In the heretofore methods of applying a partial heat cure to the tire, a carbon-sulfur-carbon bond was accomplished in the partial precure process. When the tire was then subjected to additional heat cure to cure the composite structure including the heavy gauge of rubber in the tread, shoulder, and sidewall additional cure was applied to the partial precured components to the extent that they became overcured. Also, these partial precure treatments resulted in maximum cure on the surface and minimum cure internally of the component which resulted in loss of tack on the surface and attendant lack of adhesion between the various components in the finished tire.

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Reference is directed to our co-pending patent application No. 10765/74 (Serial No. 1448531) entitled "Method of making radial ply tires".

WHAT WE CLAIM IS:—

1. A method of manufacturing a pneumatic tire comprising forming a tire component containing vulcanizable elastomeric material, effecting a partial cure of said component by electron radiation with the degree of partial cure being higher within said component than on the surface of said component, forming a toroidal tire blank incorporating the partially cured component and curing said tire blank under heat and pressure.

2. A method as claimed in Claim 1, wherein said partial cure is accomplished by effecting carbon-to-carbon bonding between some of the molecules in the elastomeric material.

3. A method as claimed in Claim 1, wherein said partial cure is accomplished by treating the tire component with between 1 and 10 megarads of electron radiation.

4. A method as claimed in Claim 3, wherein said radiation is applied to said component from one side thereof and at a voltage intensity that provides for essentially no radiation passing completely

through said component.

5. A method as claimed in Claim 4, wherein said component is a carcass ply.

6. A method as claimed in Claim 4, wherein said component is a tread reinforcing ply.

7. A method as claimed in Claim 4, wherein said component is a liner.

8. A method as claimed in any preceding Claim, wherein said component is a carcass ply.

9. A method as claimed in any preceding Claim, wherein said component is a tread reinforcing ply.

10. A method as claimed in any preceding Claim, wherein said component is a liner.

11. A method of manufacturing a pneumatic tyre substantially as described with reference to Figures 1, 2, 4, 5 and 6 of the accompanying drawings.

12. A tire manufactured by a method as claimed in any preceding claim.

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