



(43) International Publication Date
22 June 2017 (22.06.2017)

(10) International Publication Number
WO 2017/105496 A1

(51) International Patent Classification:
B60C 1/00 (2006.01)

(21) International Application Number:
PCT/US2015/066711

(22) International Filing Date:
18 December 2015 (18.12.2015)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicants: **COMPAGNIE GENERALE DES ETABLISSEMENTS MICHELIN** [FR/FR]; 12 Cours Sablon, FR-63000 Clermont-Ferrand (FR). **MICHELIN RECHERCHE ET TECHNIQUE, S.A.** [CH/CH]; Route Louis Braille 10, 1763 Granges-Paccot (CH).

(72) Inventor; and

(71) Applicant (*for US only*): **JURS, Craig** [US/US]; c/o Michelin North America IP Law Group, 515 Michelin Road, Building 31, Greenville, South Carolina 29605 (US).

(74) Agent: **WILLIAMS, Tim, F.**; Dority & Manning, P.A., P.O.Box 1449, Greenville, South Carolina 29602-1449 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: CRACK RESISTANT TREAD FOR TIRES

(57) Abstract: A tire tread having improved resistance to crack formation and propagation. The tread includes an outer cover layer of rubber material that provides a ground contacting surface and includes one or more tread features including at least one groove. At least one layer of fatigue resistant rubber material is positioned radially inward of the cover layer and the at least one groove. Additional layers of fatigue resistant rubber material may be used as well. The one or more layers of fatigue resistant rubber material are positioned so as provide improved resistance to cracking by preventing crack formation, minimizing the growth of cracks, and/or re-directing the direction of crack growth away from the carcass.



WO 2017/105496 A1

CRACK RESISTANT TREAD FOR TIRES

FIELD OF THE INVENTION

[0001] The subject matter of the present disclosure relates to tread constructions for tires that prevent or impede the growth of cracks.

BACKGROUND OF THE INVENTION

[0002] During the operation of a vehicle, the tread portion of a tire rolls over the road surface and is subjected to repeated contact with the road surface along a location commonly referred to as the contact patch or contact portion. The tread and sidewalls are repeatedly subjected to deformation and different stresses as the tread cycles through the contact patch, the magnitudes of which depend on factors such as the vehicle weight, area of the contact patch, and other variables.

[0003] The tread portion is typically provided with various tread elements such as e.g., tread blocks, tread ribs, and other elements for purposes of performance and aesthetics. The tread elements may include grooves, sipes, or lamellae (all referred to collectively herein as “grooves”) that can provide e.g., improved wet traction performance, resistance to irregular wear, and desirable aesthetics. The size, orientation, shape, and density of such grooves can vary considerably between different tire models.

[0004] Unfortunately, such grooves in the tread features of a tire can create areas of high stress that are prone to crack initiation and propagation. Typically, the crack starts at the base of the groove and creeps radially inward towards the carcass. In extreme cases, the cracks can result in chunking where e.g., a feature such as all or part of a tread block is ripped away from the tire. The crack may also reach the

carcass or body ply, which is undesirable because such ply helps maintain the shape of a pneumatic tire under inflation.

[0005] Conventionally, several approaches have been applied for preventing or mitigating the previously described cracks. For example, in certain high torque applications, grooves along the shoulder portions of the tread where particularly high stresses can occur may be avoided altogether. However, this solution is not preferable because of the loss of performance advantages such as improved traction and wear performance that can be achieved using such grooves. Another approach is the placement of a large radius at the base of the groove, but such has provided mixed results for crack avoidance. Some tread designs attempt to avoid placement of grooves in other areas of the tread where high stresses occur but it can be difficult to accurately identify such areas particular for all potential applications in which the tire may be used.

[0006] Accordingly, a tread for a tire having a resistance to crack initiation and growth would be useful. More particularly, a tread that can utilize various grooves while resisting the formation of cracks, minimizing the growth of cracks, and/or guiding the growth of such cracks to slow their deleterious effect would be beneficial.

SUMMARY OF THE INVENTION

[0007] The present invention relates to a tire tread having improved resistance to crack formation and propagation. The tread includes an outer cover layer of rubber material that provides a ground contacting surface and includes one or more tread features including at least one groove. At least one layer of fatigue resistant rubber material is positioned radially inward of the cover layer and the at least one groove. Additional layers of fatigue resistant rubber material may be used as well. The one or more layers of fatigue resistant rubber material are positioned so as provide improved resistance to cracking by preventing crack formation, minimizing the growth of cracks, and/or redirecting the direction of crack growth away from the carcass. Additional objects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

[0008] In one exemplary embodiment, the present invention provides a tread for a tire that defines radial, circumferential, and axial directions. The tread includes a cover layer of rubber material forming a radially outermost, ground contacting surface of the tread. The cover layer defines at least one groove extending radially inward from the ground contacting surface. The cover layer has an MFTR score of 130,000 or less. A first layer of fatigue resistant rubber material is positioned radially inward of the cover layer and the at least one groove, and has an MFTR score of at least 200,000. The first layer of fatigue resistant rubber material can have a thickness D_{FL} of $0.5 \text{ mm} \leq D_{FL} \leq 5 \text{ mm}$.

[0009] In certain embodiments, a second layer of fatigue resistant rubber material may be positioned radially inward of the first layer of fatigue resistant rubber material. The second layer may have an MFTR score of at least 200,000. In some embodiments, the groove may not extend into the first layer of fatigue resistant rubber material while in other embodiments the groove may have e.g., a groove bottom positioned in the first layer of fatigue resistant rubber material.

[0010] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

[0012] FIG. 1 illustrates a cross-section view, taken along a meridian plane, of an exemplary tire of the present invention.

[0013] FIG. 2 a partial perspective view of one side of an exemplary crown portion of the exemplary tire of FIG. 1.

[0014] FIG. 3 is a side view of the exemplary crown portion of FIG. 2.

[0015] FIG. 4 provides a partial perspective view of one side of another exemplary tread portion as may be used with the crown portion of the exemplary tire of FIG. 1.

[0016] FIG. 5 is a side view of the exemplary crown portion of FIG. 4.

[0017] FIG. 6 provides a partial perspective view of one side of another exemplary tread portion as may be used with the crown portion of the exemplary tire of FIG. 1.

[0018] FIG. 7 is a side view of the exemplary crown portion of FIG. 6, while FIG. 8 is an even closer side view thereof.

[0019] FIG. 9 is cross-sectional view of an exemplary embodiment of a crown portion as may be used with the exemplary tire of FIG. 1.

[0020] FIG. 10 is another cross-sectional view of an exemplary embodiment of a crown portion as may be used with the exemplary tire of FIG. 1.

[0021] The use of the same or similar reference numerals in the figures denotes the same or similar features.

DETAILED DESCRIPTION

[0022] For purposes of describing the invention, reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment, can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0023] As used herein:

[0024] MFTR, expressed in cycles, refers to a measurement of fatigue resistance conducted in accordance with ISO 6943-2011, Standard for Determination of Fatigue.

[0025] “Rubber material” or “rubber materials” are those based upon a rubber composition reinforced with a filler such as carbon black, an inorganic filler or combinations thereof. The term “based upon” as used herein recognizes that the treads or other rubber articles are made of vulcanized or cured rubber materials that were, at the time of their assembly, uncured. The cured rubber material is therefore “based upon” the uncured rubber composition. In other words, the cross-linked rubber composition is based upon the cross-linkable rubber composition. The term rubber and elastomer are used interchangeably.

[0026] Diene elastomers or rubber is understood to mean those elastomers resulting at least in part (i.e., a homopolymer or a copolymer) from diene monomers (monomers bearing two double carbon-carbon bonds, whether conjugated or not). Essentially unsaturated diene elastomers are understood to mean those diene elastomers that result at least in part from conjugated diene monomers, having a content of members or units of diene origin (conjugated dienes) that are greater than 15 mol. %.

[0027] Thus, for example, diene elastomers such as butyl rubbers, nitrile rubbers or copolymers of dienes and of alpha-olefins of the ethylene-propylene diene terpolymer (EPDM) type or the ethylene-vinyl acetate copolymer type do not fall within the preceding definition, and may in particular be described as “essentially saturated” diene elastomers (low or very low content of units of diene origin, i.e., less than 15 mol. %). Particular embodiments of the present invention include no essentially saturated diene elastomers.

[0028] Within the category of essentially unsaturated diene elastomers are the highly unsaturated diene elastomers, which are understood to mean in particular diene elastomers having a content of units of diene origin (conjugated dienes) that is greater than 50 mol. %. Particular embodiments of the present invention may include not only no essentially saturated diene elastomers but also no essentially unsaturated diene elastomers that are not highly unsaturated.

[0029] The rubber elastomers suitable for use with particular embodiments of the present invention include highly unsaturated diene elastomers, for example, polybutadienes (BR), polyisoprenes (IR), natural rubber (NR), butadiene copolymers,

isoprene copolymers and mixtures of these elastomers. The polyisoprenes include synthetic cis-1,4 polyisoprene, which may be characterized as possessing cis-1,4 bonds at more than 90 mol.% or alternatively, at more than 98 mol.%.

[0030] Also suitable for use in particular embodiments of the present invention are rubber elastomers that are copolymers and include, for example, butadiene-styrene copolymers (SBR), butadiene-isoprene copolymers (BIR), isoprene-styrene copolymers (SIR) and isoprene-butadiene-styrene copolymers (SBIR) and mixtures thereof.

[0031] Suitable highly unsaturated elastomers for the rubber compositions may include polybutadienes (BR), polyisoprenes (IR), natural rubber (NR), butadiene copolymers, isoprene copolymers, butadiene-styrene copolymers (SBR), butadiene-isoprene copolymers (BIR), isoprene-styrene copolymers (SIR) and isoprene-butadiene-styrene copolymers (SBIR) and mixtures thereof.

[0032] It should be noted that any of the elastomers may be utilized in particular embodiments as a functionalized elastomer. These elastomers can be functionalized by reacting them with suitable functionalizing agents prior to or in lieu of terminating the elastomer. Exemplary functionalizing agents include, but are not limited to, metal halides, metalloid halides, alkoxysilanes, imine-containing compounds, esters, ester-carboxylate metal complexes, alkyl ester carboxylate metal complexes, aldehydes or ketones, amides, isocyanates, isothiocyanates, imines, and epoxides. These types of functionalized elastomers are known to those of ordinary skill in the art. While particular embodiments may include one or more of these functionalized elastomers, other embodiments may include one or more of these functionalized elastomers mixed with one or more of the non-functionalized highly unsaturated elastomers.

[0033] The rubber materials disclosed herein may contain a single diene elastomer or a mixture of several diene elastomers, the diene elastomer(s) possibly being used in association with any type of synthetic elastomer other than a diene one, or even with polymers other than elastomers, for example thermoplastic polymers.

[0034] In addition to the elastomer the rubber material further includes a reinforcing filler, such filler being inorganic, organic or combinations thereof. The inorganic reinforcing filler is to be understood here to mean any inorganic or mineral

filler, whatever its colour and its origin (natural or synthetic), also referred to as "white" filler or sometimes "clear" filler in contrast to carbon black. Such inorganic filler is capable, on its own, without any other means than an intermediate coupling agent, of reinforcing a rubber composition intended for the manufacturing of a rubber article in its reinforcement function. Such fillers may include, for example, a filler of the siliceous or aluminous type, or a mixture of these two types of fillers.

[0035] The silica (SiO_2) used may be any reinforcing silica known to the person skilled in the art. Particular embodiments include any precipitated or pyrogenic silica having a BET surface area and a specific CTAB surface area both of which are less than $450 \text{ m}^2/\text{g}$, or from 30 to $400 \text{ m}^2/\text{g}$. Highly dispersible precipitated silicas (referred to as "HD") are included in particular embodiments, in particular for those embodiments used for the manufacturing of tires having a low rolling resistance. "Highly dispersible silica" is understood in known manner to mean any silica having a substantial ability to disagglomerate and to disperse in an elastomeric matrix, which can be observed in known manner by electron or optical microscopy on thin sections. As non-limitative examples of such preferred highly dispersible silicas, mention may be made of the silicas BV3380 and Ultrasil 7000 from Degussa, the silicas Zeosil 1165 MP and 1115 MP from Rhodia, the silica Hi-Sil 2000 from PPG, the silicas Zeopol 8715 or 8745 from Huber, and treated precipitated silicas such as, for example, the aluminium -"doped" silicas.

[0036] The reinforcing alumina (Al_2O_3) used in particular embodiments is a highly dispersible alumina having a BET surface area from 30 to $400 \text{ m}^2/\text{g}$, or between 60 and $250 \text{ m}^2/\text{g}$, an average particle size at most equal to 500 nm, or at most equal to 200 nm. Non-limitative examples of such reinforcing aluminas are in particular the aluminas A125 or CR125 (from Baïkowski), APA-100RDX (from Condéa), Aluminoxid C (from Degussa) or AKP-G015 (Sumitomo Chemicals). The invention can also be implemented by using as reinforcing inorganic filler the specific aluminium (oxide⁻) hydroxides.

[0037] The physical state in which the reinforcing inorganic filler is present is immaterial, whether it is in the form of a powder, micro-beads, granules, balls or any other densified form.

[0038] Of course, "reinforcing inorganic filler" is also understood to mean mixtures of different reinforcing inorganic fillers, in particular of highly dispersible siliceous and/or aluminous fillers such as described above.

[0039] The amount of reinforcing inorganic filler may be between 60 and 120 phr, or between 70 and 100 phr approximately, in particular when the tread is intended for a passenger-car tire. The person skilled in the art will readily understand that the optimum will be different according to the nature of the reinforcing inorganic filler used and according to the type of tire in question, for example a tire for a motorcycle, passenger vehicle or alternatively for a utility vehicle such as a van or a heavy vehicle. The amount of reinforcing inorganic filler is not meant to be limited and may be at any quantity suitable for a particular purpose.

[0040] Carbon black, which is an organic filler, may be used as a sole filler or in combination with one or more inorganic fillers. The compounding amount of the carbon black in the elastomer composition is not limited. In particular embodiments of the present invention, the compounding amount of the carbon black may be up to about 200 phr or between about 10 and about 180 phr. Other useful ranges of carbon black loading may include between 30 and 120 phr in some embodiments of the present invention and between 50 and 100 phr.

[0041] Suitable carbon blacks are any carbon blacks, in particular the blacks of the type HAF, ISAF and SAF, which are conventionally used in tires, and particularly in treads. Non-limitative examples of carbon blacks include, for example, the N115, N134, N234, N330, N339, N343, N347, N375, N550, N650, N665 and N787 carbon blacks.

[0042] In addition to the elastomer, reinforcement filler, particular embodiments of the rubber composition may further include all or part of the additives usually used in sulfur-cross-linkable diene rubber compositions intended for the manufacturing of treads or other rubber articles, such as, for example, plasticizers, including plasticizer oils and/or resins, pigments, protective agents of the type antioxidants, antiozonants, a cross-linking system based either on sulfur or on sulfur and/or peroxide and/or bismaleimide donors, vulcanisation accelerators, vulcanisation activators, extender oils, and so forth. There may also be associated with the reinforcing inorganic filler,

if necessary, a conventional non-reinforcing white filler, such as for example particles of clay, bentonite, talc, chalk, kaolin or titanium oxides.

[0043] The rubber compositions that are embodiments of the present invention may be produced in suitable mixers, in a manner known to those having ordinary skill in the art, typically using two successive preparation phases, a first phase of thermo-mechanical working at high temperature, followed by a second phase of mechanical working at lower temperature.

[0044] The first phase of thermo-mechanical working (sometimes referred to as "non-productive" phase) is intended to mix thoroughly, by kneading, the various ingredients of the composition, with the exception of the vulcanization system. It is carried out in a suitable kneading device, such as an internal mixer or an extruder, until, under the action of the mechanical working and the high shearing imposed on the mixture, a maximum temperature generally between 110° C and 190° C, more narrowly between 130° C and 170° C, is reached.

[0045] After cooling of the mixture, a second phase of mechanical working is implemented at a lower temperature. Sometimes referred to as "productive" phase, this finishing phase consists of incorporating by mixing the vulcanization (or cross-linking) system (sulfur or other vulcanizing agent and accelerator(s)), in a suitable device, for example an open mill. It is performed for an appropriate time (typically between 1 and 30 minutes, for example between 2 and 15 minutes) and at a sufficiently low temperature lower than the vulcanization temperature of the mixture, so as to protect against premature vulcanization.

[0046] FIG. 1 is a schematic illustration of an exemplary tire 100 as may be used with the present invention. Tire 100 is shown in a cross-section taken along a meridian plane of the tire. The meridian plane includes the axis of rotation, which is parallel to axial direction A and about which tire 100 rotates during use. Radial direction R is orthogonal to axial direction A. As used herein, "radially-outward" refers to a radial direction away from the axis of rotation while "radially-inward" refers to a radial direction towards the axis of rotation. Circumferential direction C (FIGS. 2 and 3) is orthogonal to both radial direction R and axial direction A at any

given point about the circumference of the tire, corresponds with the periphery of the tire, and is defined by the direction of rotation of the tire about the axis of rotation.

[0047] Tire 100 is symmetrical about the equatorial plane EP and, therefore, equatorial plane EP bisects tire 100 into opposing halves of substantially the same construction. Accordingly, tire 100 includes a pair of opposing bead portions 102 and a pair of opposing sidewall portions 104. Tire 100 also includes a crown portion 106 connected to a radially outer extent of each opposing sidewall portion 104 and extending therebetween. A tread portion 108 forms the radially outermost portion of crown portion 106.

[0048] A body ply 110 extends from each bead portion 102, through each sidewall portion 104, and through the crown portion 106. As used herein, the term “ply” or “plies” refers to a layer or reinforcement of the tire and is not limited to a particular method of manufacturing a tire or the ply itself. Each end 112 of body ply 110 is anchored in a respective bead portion 102. In certain embodiments, body ply 108 may be wrapped around a respective bead core 114 as shown though such is not required. Tire 100 is a pneumatic tire and, as such, includes an inner liner 111 for providing air impermeability when inflated. However, the present invention may be used with a variety of tire constructions including non-pneumatic tires and tires having different shapes and constructions from tire 100 shown in FIG. 1.

[0049] Tread portion 108 of crown 106 includes a plurality of ribs including a pair of opposing shoulder ribs 116, a pair of opposing intermediate ribs 123, and center rib 120. The ribs are separated by grooves extending along circumferential direction C including grooves 113, 115, 117, and 119. Tread portion 108 is provided by way of example only. The present invention may be used with treads of other constructions having a different arrangement of ribs and grooves, tread blocks, and combinations thereof.

[0050] FIG. 2 is a partial perspective view of one side of exemplary crown portion 106 while FIG. 3 is a partial side view thereof. As shown, for this embodiment, tread portion 116 is constructed from a cover layer 118 of rubber material that forms a radially outermost, ground contacting surface 121. Cover layer 118 includes a

plurality of grooves 122 that extend radially inward from ground contacting surface 121.

[0051] For this embodiment, grooves 122 are parallel to each other, linear in shape, and oriented along axial direction A. However, grooves of a variety of sizes, shapes, and orientations may be used. For example, grooves that are wavy along radial direction R, axial direction A, or both may be used. Grooves that are not parallel may also be used. Grooves of different angles or orientations relative to axial direction A and radial direction R may also be employed. By way of example, grooves 122 may be provided to increase traction performance, tread wear, and to provide other performance advantages.

[0052] For this exemplary embodiment, grooves 122 each include a rounded or circular-shaped groove bottom 124 that creates an open channel 128 along axial direction A. The radius used for the shape of groove bottom 124 can be selected so as to help prevent stress concentrations that can lead to cracks. Other shapes may also be employed.

[0053] Cover layer 118 is constructed from a rubber material having an MFTR score of at most 130,000. Rubber materials having different MFTR scores may be used at different locations along cover layer 118. However, in each case, for cover layer 118 of exemplary tire 100, the rubber material used has an MFTR score of at most 130,000.

[0054] Continuing with FIGS. 2 and 3, a first layer 126 of fatigue resistant rubber material is positioned radially inward of cover layer 118 and grooves 122. For this exemplary embodiment, first layer 126 is shown as having an axial width, W_{FL} , along axial direction A and a thickness, D_{FL} , along radial direction R. For example, first layer 126 may have an axial width W_{FL} that is limited to all or a portion of shoulder ribs 116 such that first layer 126 is positioned only along opposing sides of tire 100. Such an embodiment may be used, for example, to target areas in shoulder ribs 116 where concentrations of stress are anticipated that could lead to cracking in groove bottoms 124.

[0055] In other embodiments, first layer 126 may extend e.g., across the entire axial width of tire 100. Regardless, first layer 126 is constructed from a fatigue

resistant rubber material and is positioned to provide increased resistance to cracking that may initiate and propagate from groove bottom 124 during operation of tire 100. As such, first layer 126 is constructed from fatigue resistant rubber material having an MFTR of at least 200,000. The thickness D_{FL} that is employed will depend upon e.g., the MFTR of first layer 126, the anticipated level of stress in groove 122 and particularly groove bottom 124 during operation of tire 100, and other factors as will be understood by one of ordinary skill in the art using the teachings disclosed herein. In one exemplary embodiment of the invention, thickness D_{FL} is in the range of $0.5 \text{ mm} \leq D_{FL} \leq 5 \text{ mm}$. In still another exemplary embodiment, thickness D_{FL} is in the range of $0.5 \text{ mm} \leq D_{FL} \leq 3 \text{ mm}$. For the exemplary embodiment of FIG. 2, a thickness D_{FL} of, for example, about 2 mm may be used.

[0056] Notably, for this exemplary embodiment, groove bottom 124 is located within cover layer 118 as groove 122 does not extend into first layer 126. As such, a crack migrating from groove bottom 124 along radial direction R towards body ply 110 will eventually encounter first layer 126. Due to the fatigue resistance of the rubber material used for first layer 126, the crack may be slowed or prevented from additional growth. Alternatively, first layer 126 may cause the crack to turn and continue along radial direction R, circumferential direction C, or a combination thereof so as to avoid undesirable growth radially inward towards body ply 110.

[0057] FIG. 4 is a partial perspective view of one side of another exemplary embodiment for tread 108 as may be used for crown portion 106 while FIG. 5 is a partial side view of this embodiment. The embodiment of FIGS. 4 and 5 is similar in most respects to the embodiments of FIGS. 2 and 3 except that groove bottoms 124 are no longer positioned within cover layer 118. Instead, grooves 122 extend radially inward and into first layer 126 of rubber material such that groove bottoms 124 are located within first layer 126. As with the previous embodiment, first layer 126 is constructed from a rubber material having an MFTR of at least 200,000. Due to its fatigue resistance, the rubber material of first layer 126 helps prevent crack formation and will also help deter a crack from migrating towards body ply 110 from groove bottom 124 along radial direction R. At the same time, the embodiment of FIGS. 4

and 5 allows for an increased overall depth, O_D , of grooves 122 as may be desirable in certain applications.

[0058] For each of the embodiments FIGS. 2, 3, 4, and 5, the first layer 126 of fatigue resistant rubber material is adjacent to, and in contact with, outer cover layer 118. In addition, in each of the embodiments, first layer 126 has a radially inner surface 126_i and a radially outer surface 126_o that are substantially parallel to one another and substantially planar. However, in other embodiments of the invention, first layer 126 may be constructed in other shapes and configurations.

[0059] For example, FIGS. 6, 7, and 8 depict another exemplary embodiment of the present invention in which FIG. 6 provides a partial perspective view of one side of crown portion 106 while FIG. 7 is a partial side view thereof. As shown, tread portion 108 includes a cover layer 118 and a first layer 126 of fatigue resistant rubber material as described with previous embodiments. The radially outer surface 126_o of first layer 126 is substantially planar.

[0060] Unlike previous embodiments, the radially inner surface 126_i of first layer 126 follows a curvy or sinusoidal pattern along circumferential direction C. A second layer 130 of fatigue resistant material is positioned radially inward of first layer 126 of fatigue resistant material. Second layer 130 has a radially outer surface 130_o contacting inner surface 126_i , forming an interface I therewith, and having a complementary shape with inner surface 126_i . As shown in FIG. 8, groove bottoms 124 are located within a trough 132 positioned between peaks 134 of interface I.

[0061] The fatigue resistant rubber material of second layer 130 has an MFTR of at least 200,000. As such, the fatigue resistance material of first layer 126 acts to prevent the creation and growth of cracks throughout first layer 126. In the event such cracks form, the progress of the crack will be impeded by the higher fatigue resistance of second layer 130 relative to first layer 126. Additionally, assuming a crack initiates in a groove 122 and grows radially inward, the crack can be redirected or turned away from second layer 130 due to the difference in the fatigue resistance or MFTR ratings of first layer 126 relative to second layer 130. Such change in direction should be away from body ply 110, which is advantageous as previously described.

[0062] For the embodiment of FIGS. 6, 7, and 8, a wavy or sinusoidal shape for interface I along circumferential direction C is employed. Alternatively, or in addition thereto, interface I could be wavy along axial direction A. In still another embodiment, interface I could be substantially flat along both the axial and circumferential directions. As with all previous embodiments, first and second layers 126 and 130 could be positioned radially inward of cover layer 118 on one or more tread features such as ribs 116, 123, and 120, or could be positioned radially inward of the entire cover layer 118.

[0063] FIG. 9 is a perspective view of a cross-section of an exemplary crown portion 106. As with previous embodiments, the tread portion 108 includes a cover layer 118 and a first layer 126 positioned radially inward of cover layer 118. For this exemplary embodiment, first layer 126 is present as discrete portions only on shoulder ribs 116 and intermediate ribs 123. Variations as described with previous embodiments may be used as well. For example, first layer 126 could extend as continuous layer across the axial width of ribs 116 and 123 in crown portion 106. A discrete portion of first layer 126 could be positioned under center rib 120. For this embodiment, first layer 126 is substantially planar along axial direction and circumferential direction C. Thickness D_{FL} of first layer 126 can be according to the ranges previously described. For the exemplary embodiment of FIG. 9, a thickness D_{FL} of, for example, about 2 mm may be used.

[0064] FIG. 10 is a perspective view of a cross-section of another exemplary crown portion 106. As with previous embodiments, the tread portion 108 includes a cover layer 118 and a first layer 126 positioned radially inward of cover layer 118. For this exemplary embodiment, first layer 126 is present as discrete portions only on shoulder ribs 116 and intermediate ribs 123. Variations as described with previous embodiments may be used as well. For example, first layer 126 could extend as continuous layer across the axial width of ribs 116 and 123 in crown portion 106. A discrete portion of first layer 126 could be positioned under center rib 120. Unlike the embodiment of FIG 10, first layer 126 is wavy along axial direction A. Additionally, grooves 122 extend along circumferential direction C. Other orientations may also be used for grooves 122 as previously described. Thickness D_{FL}

of first layer 126 can be according to the ranges previously described. For the exemplary embodiment of FIG. 10, a thickness D_{FL} of, for example, about 2 mm may be used.

[0065] The following example provides further description and understanding of exemplary aspects of the present invention.

[0066] Test Methods

[0067] Where reported in the example, dynamic properties such as the max tan delta (max tan δ) for the rubber compositions were measured on a Metravib Model VA400 ViscoAnalyzer Test System in accordance with ASTM D5992-96. The response of a sample of vulcanized material (double shear geometry with each of two 10 mm diameter cylindrical samples being 2 mm thick) was recorded as it was being subjected to an alternating single sinusoidal shearing stress of a constant 0.7 MPa and at a frequency of 10 Hz over a temperature sweep from -60 °C to 100 °C with the temperature increasing at a rate of 1.5 °C/min. The maximum value of the tangent of the loss angle tan delta (max tan delta) is determined during the return cycle.

[0068] For the example, the moduli of elongation were measured at 10% (MA10) and at 100% (MA100) at a temperature of 23 °C in accordance with ASTM D412 (1998) on ASTM C test pieces. These are true secant moduli in MPa, which is to say the secant moduli calculated reduced to the real cross-section of the test piece at the given elongation.

[0069] For the example, MFTR was measured in accordance with ISO 6943-2011, Standard for Determination of Fatigue. As such, 1.5 mm thick, dumb-bell shaped test pieces were cut with a die in accordance with ISO 6943-201. Each test piece had an overall length of 78.5 mm and a narrow parallel-sided middle portion length of 25 mm. The test pieces were clamped into the fatigue-testing machine that provided reciprocating motion at a frequency of 105 +/- 10 cycles per minute and the test pieces were repeatedly flexed between 0% and 75% strain and the number of cycles to break for each of the samples was counted. The testing was conducted in a room at between 15° C and 35° C. The average number of cycles to break for 12 samples is reported as the cycles to break measurement.

[0070]

[0071] Example One

[0072] Rubber compositions were prepared using the components shown in Table 1 below in accordance with standard procedures known to those skilled in the art. All the components except for the sulfur were mixed in a Banbury mixer until a temperature of between 130° C and 170° C was reached. The mixture was then dropped and cooled on a mill where the sulfur was added. The rubber composition was cured, cut into testing plaques and then tested in accordance with the procedures provided above. The test results are provided in Table 1. The antidegradants and processing aid included antioxidants, wax and AFLUX 42. The curing package included sulfur, stearic acid, zinc oxide and accelerators.

[0073] Table 1

	F1	F2
Components		
NR	35	100
BR	65	
CB	5.4	25
Silica		25
Silane Coupling Agent		2.5
Antidegradants/Processing Aid	6	3.5
Curing Package	6.5	8.5
Physical Properties		
MA10,MPa	5.3	4.6
MA100, MPa	1.9	2.1
Cycles to Failure	361,700	68,000
Max Tan Delta	0.19	0.10

[0074] While the present subject matter has been described in detail with respect to specific exemplary embodiments and methods thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing may readily produce alterations to, variations of, and equivalents to such embodiments.

Accordingly, the scope of the present disclosure is by way of example rather than by way of limitation, and the subject disclosure does not preclude inclusion of such modifications, variations and/or additions to the present subject matter as would be readily apparent to one of ordinary skill in the art using the teachings disclosed herein.

WHAT IS CLAIMED IS:

1. A tread for a tire, the tire defining radial, circumferential, and axial directions, the tread comprising:

5 a cover layer of rubber material forming a radially outermost, ground contacting surface of the tread, the cover layer defining at least one groove extending radially inward from the ground contacting surface, the cover layer having an MFTR score of 130,000 or less.

a first layer of fatigue resistant rubber material positioned radially inward of the cover layer and the at least one groove, and having an MFTR score of at least 200,000;

10 wherein the first layer has a thickness D_{FL} of $0.5 \text{ mm} \leq D_{FL} \leq 5 \text{ mm}$.

2. The tread for a tire as in claim 1, wherein the at least one groove has a groove bottom positioned within the cover layer of rubber material radially outward of the first layer.

3. The tread for a tire as in claim 1, wherein the at least one groove has a groove bottom positioned within the first layer of fatigue resistant rubber material.

4. The tread for a tire as in any of the preceding claims, wherein the first layer has a thickness D_{FL} of $0.5 \text{ mm} \leq D_{FL} \leq 3 \text{ mm}$.

5. The tread for a tire as in any of the preceding claims, wherein the first layer of fatigue resistant rubber material is adjacent to, and in contact with, the cover layer.

6. The tread for a tire as in any of the preceding claims, further comprising:

a second layer of fatigue resistant rubber material positioned radially inward of the first layer of fatigue resistant rubber material, the second layer of fatigue resistant rubber material having an MFTR score of at least 200,000.

7. The tread for a tire as in claim 6, further comprising an interface defined by a radially inner surface of the first layer of fatigue resistant rubber and a radially outer surface of the second layer of fatigue resistant rubber, wherein the interface is substantially planar along the circumferential and axial directions.

8. The tread for a tire as in claim 6, further comprising an interface defined by a radially inner surface of the first layer of fatigue resistant rubber and a radially outer surface of the second layer of fatigue resistant rubber, wherein the interface is wavy along the circumferential direction.

9. The tread for a tire as in claim 6, further comprising an interface defined by a radially inner surface of the first layer of fatigue resistant rubber and a radially outer surface of the second layer of fatigue resistant rubber, wherein the interface is wavy along the axial direction.

10. The tread for a tire as in any of the preceding claims, wherein the tread defines a plurality of tread ribs, each rib extending along the circumferential direction, and wherein the cover layer is divided into discrete cover layer sections forming each rib and the first layer is divided into discrete first layer sections forming each rib.

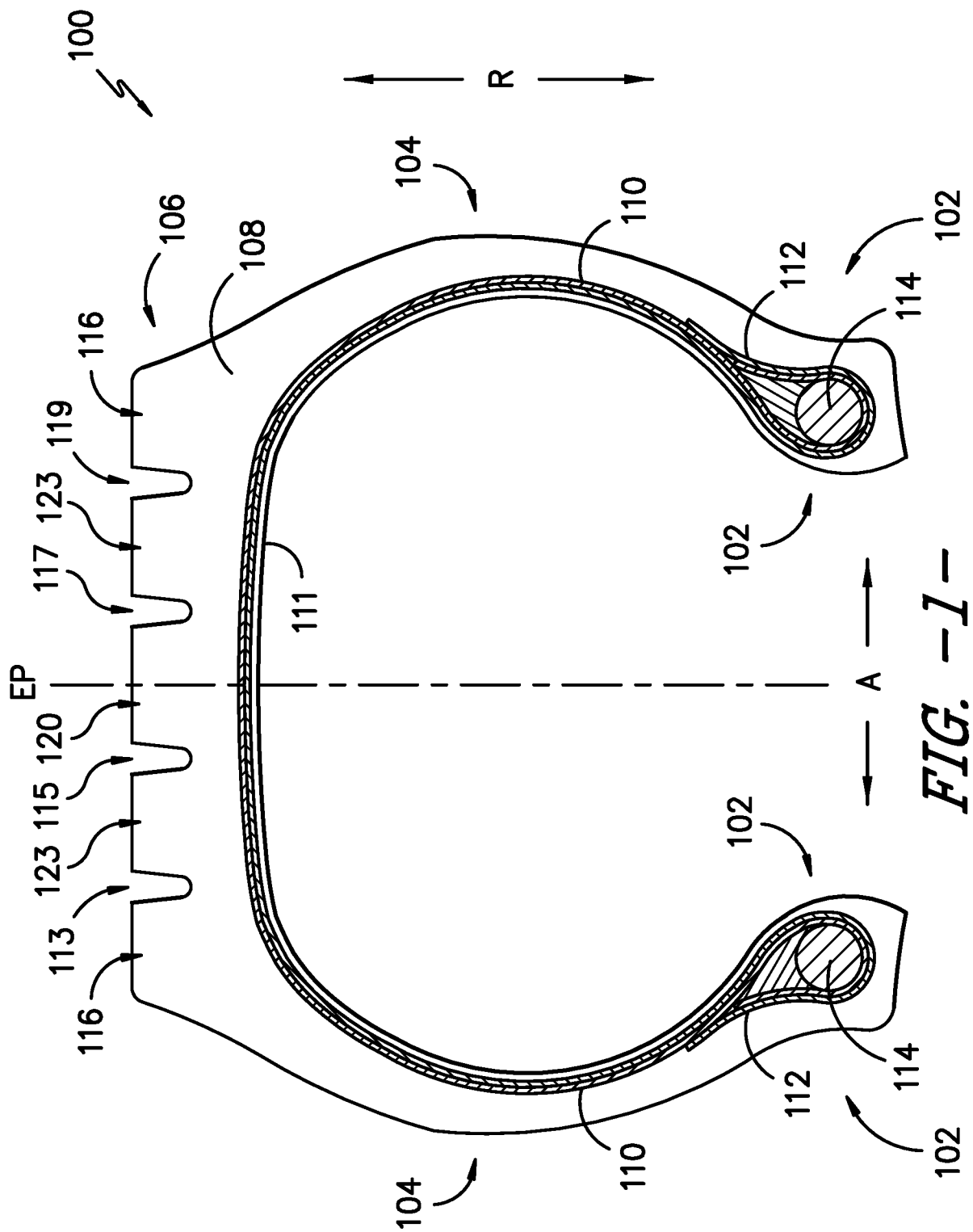
11. The tread for a tire as in any of the preceding claims, wherein the groove extends along the circumferential direction.

12. The tread for a tire as in any of the preceding claims, wherein the groove extends along the axial direction.

13. The tread for a tire as in any of the preceding claims, wherein the tread defines a shoulder rib, and wherein the at least one groove is defined by the shoulder rib.

14. The tread for a tire as in claim 1, wherein the tread defines a plurality of ribs with each rib comprising the cover layer and the first layer, and wherein all or a portion of the ribs include at least one groove.

15. The tread for a tire as in claim 14, wherein each groove has a groove bottom positioned in the first layer.



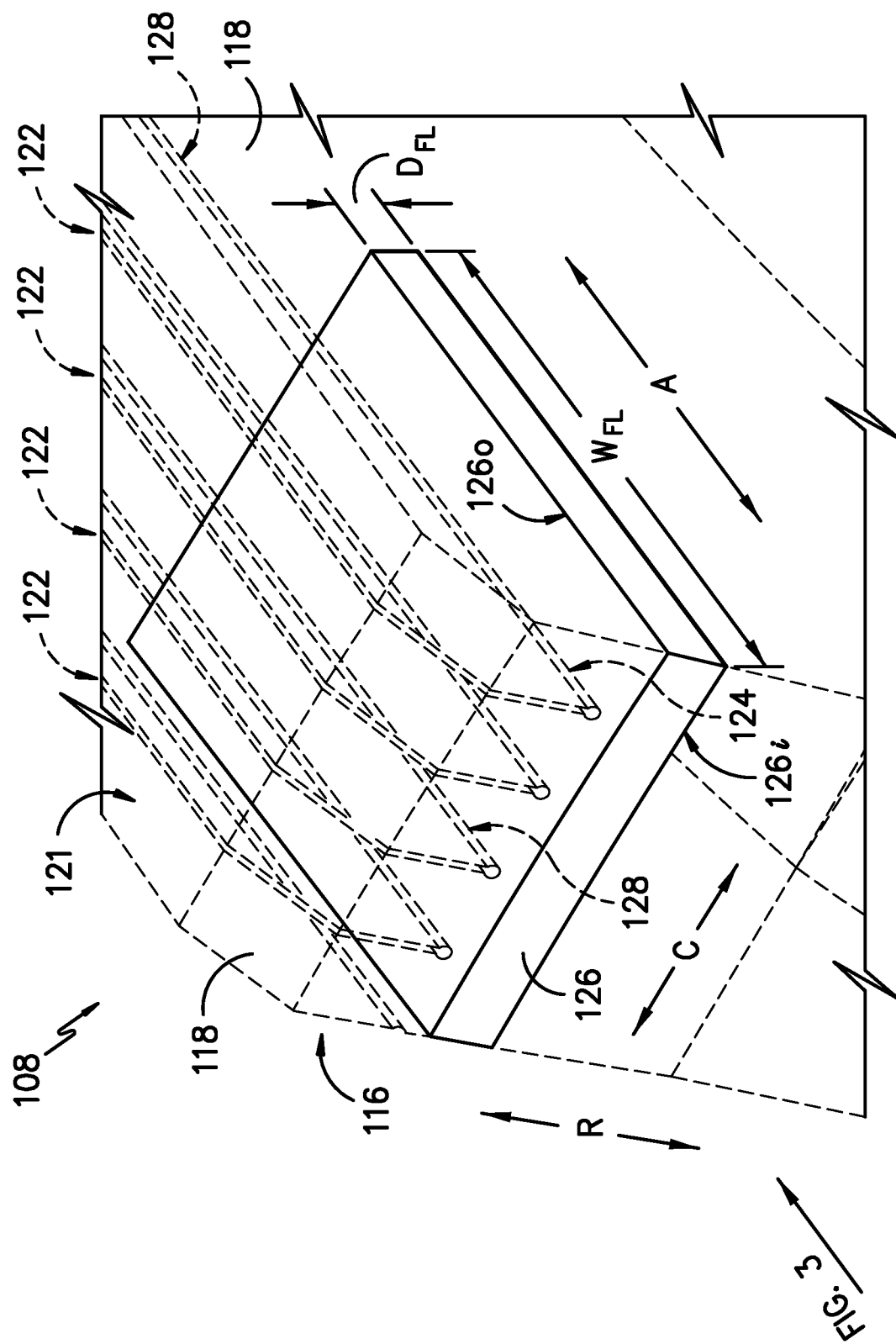


FIG. 2-

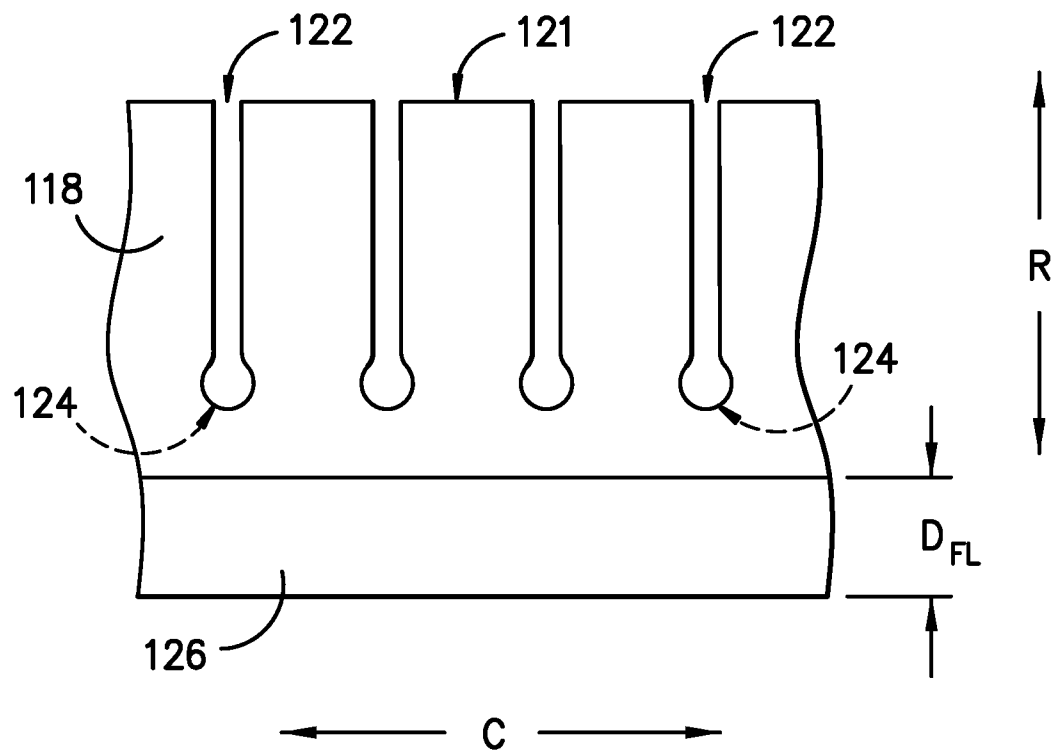
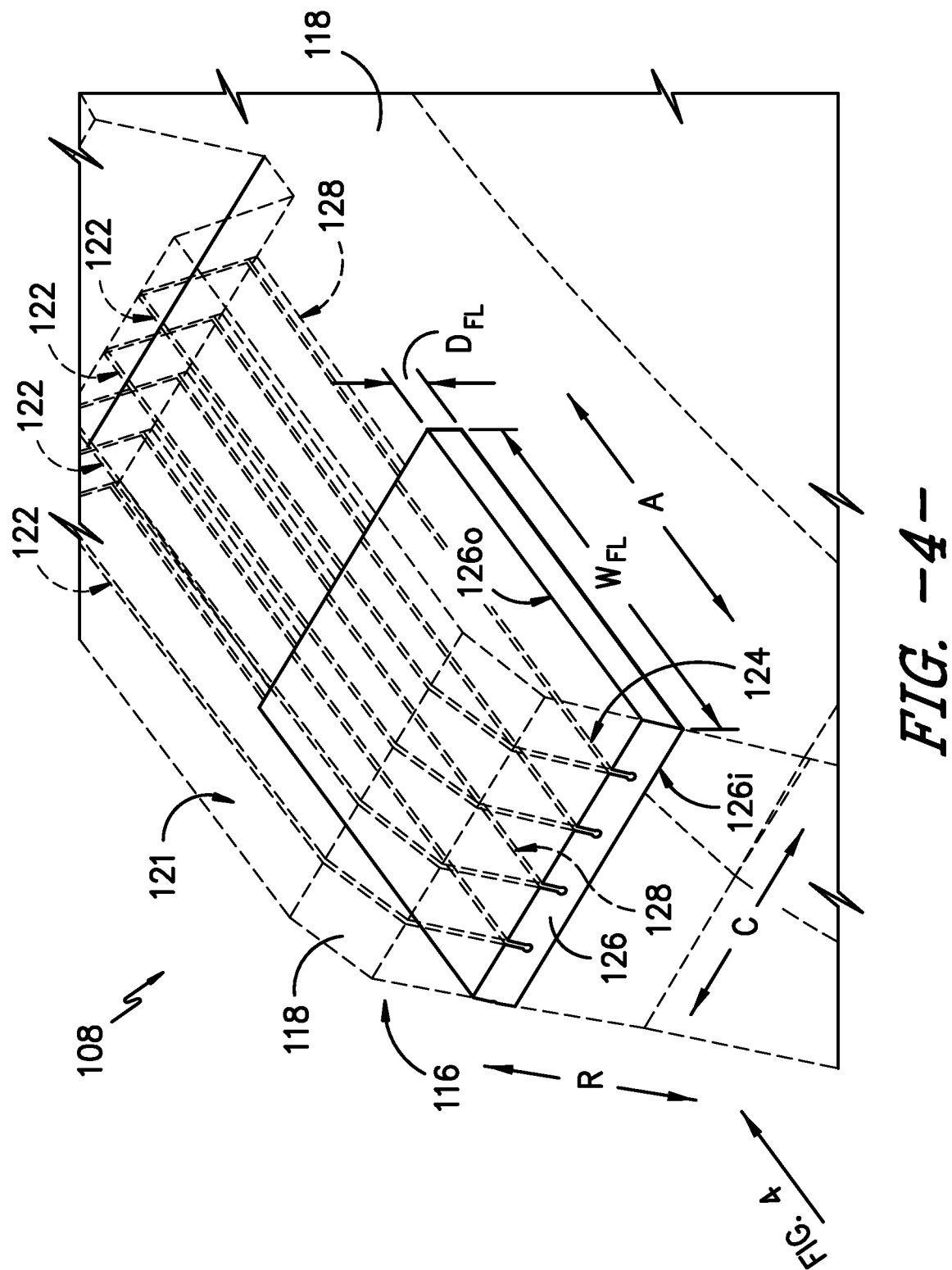


FIG. -3-



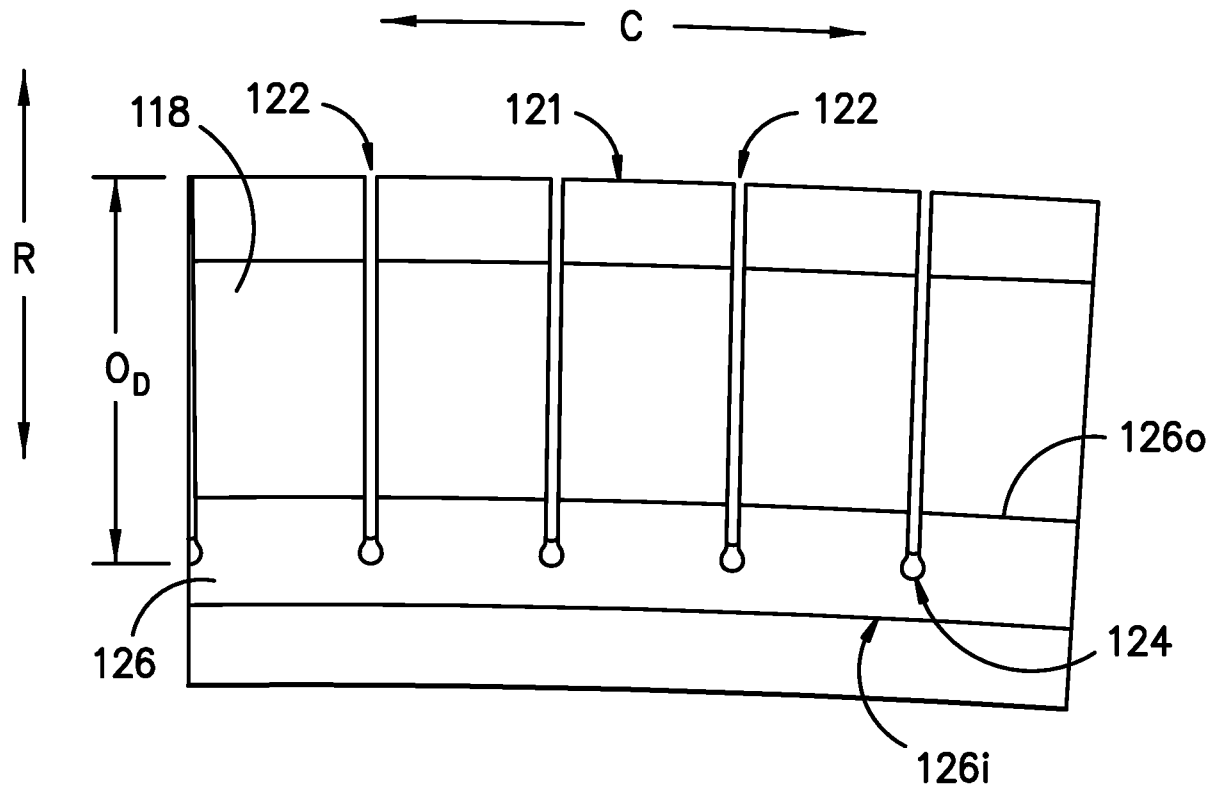
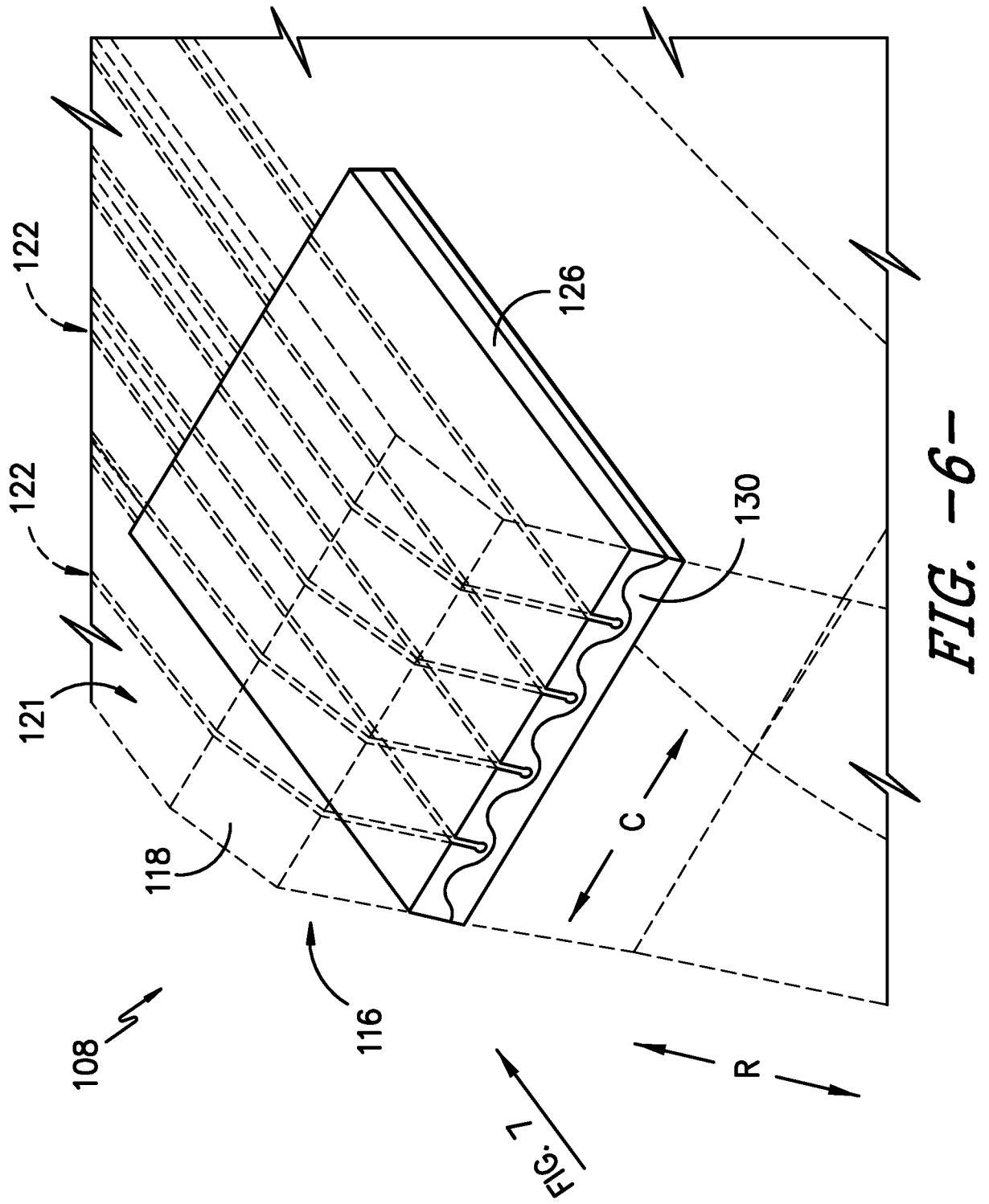


FIG. -5-



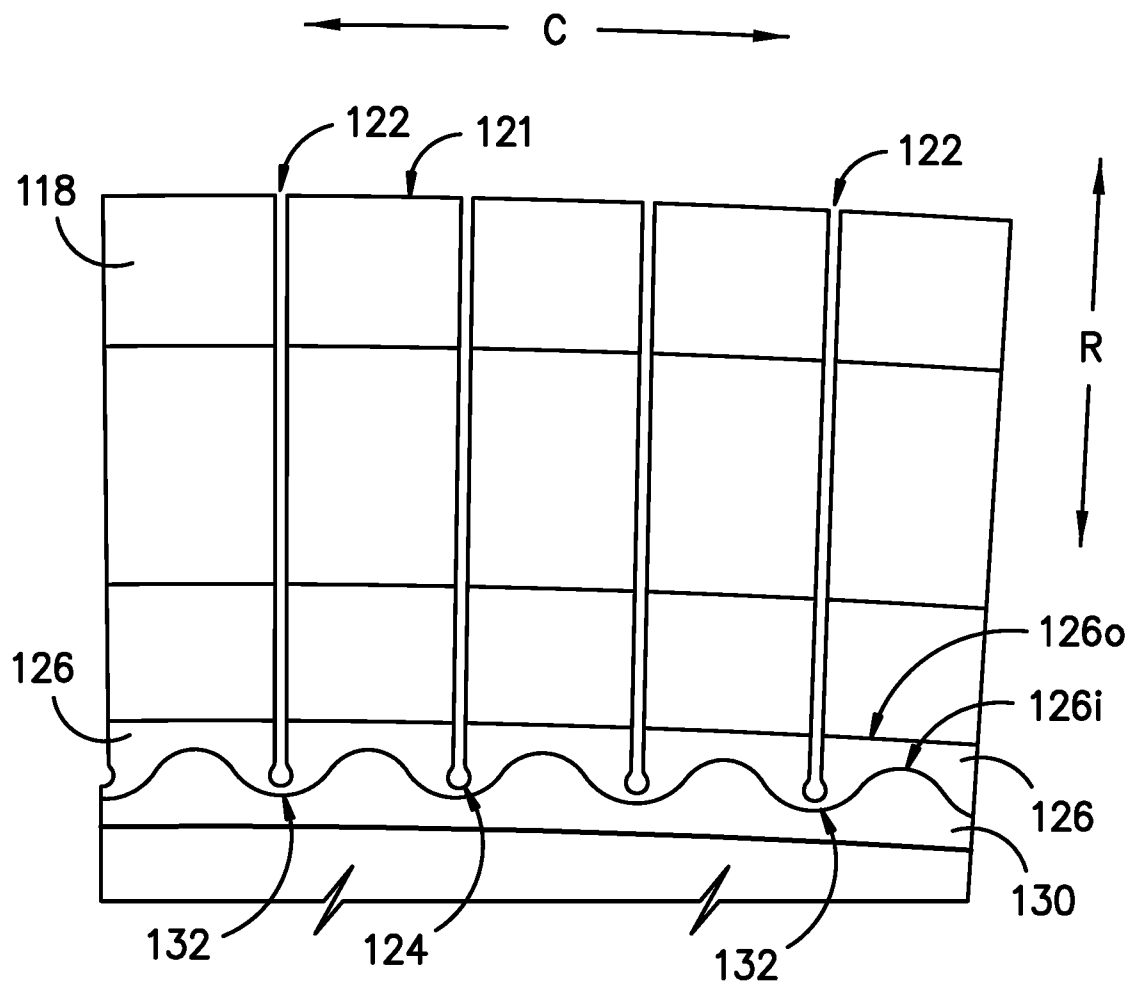


FIG. -7-

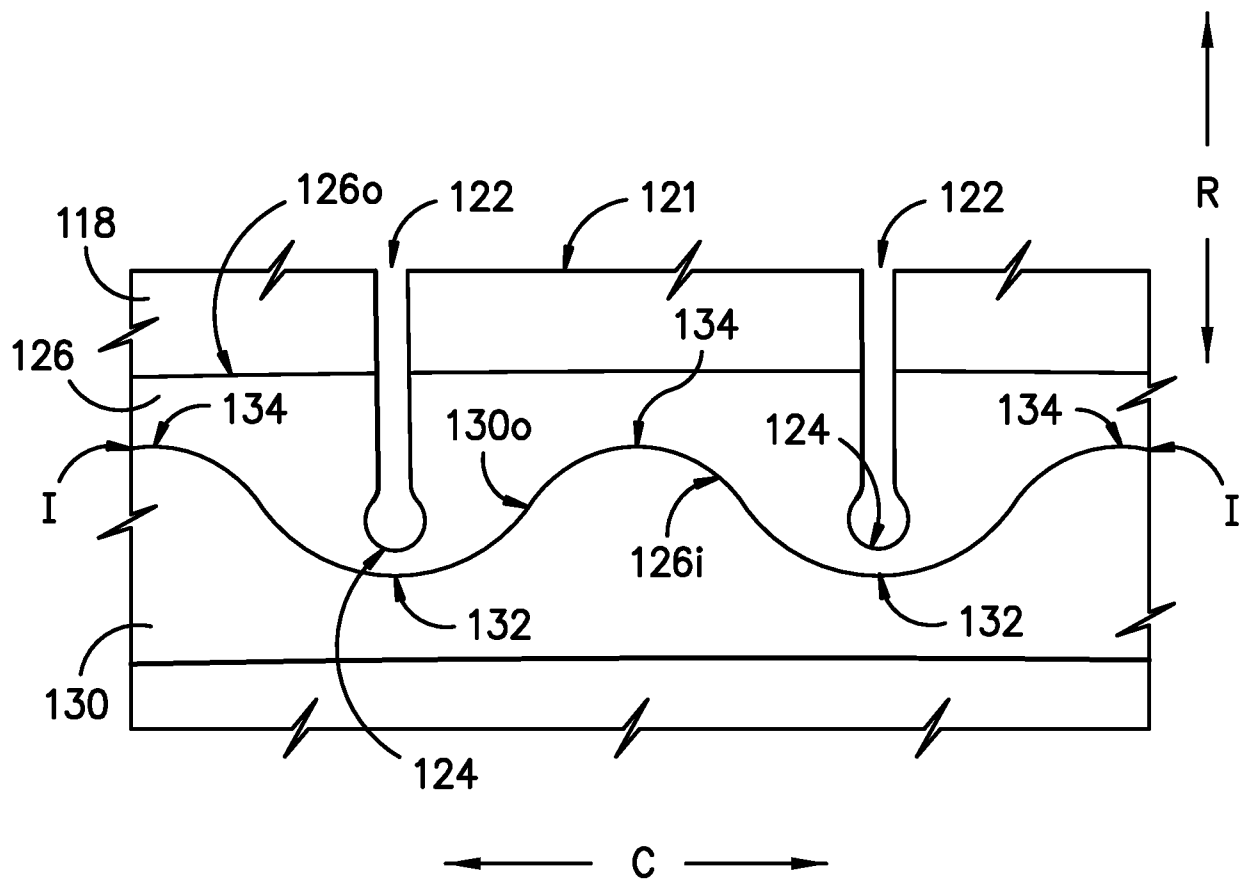


FIG. -8-

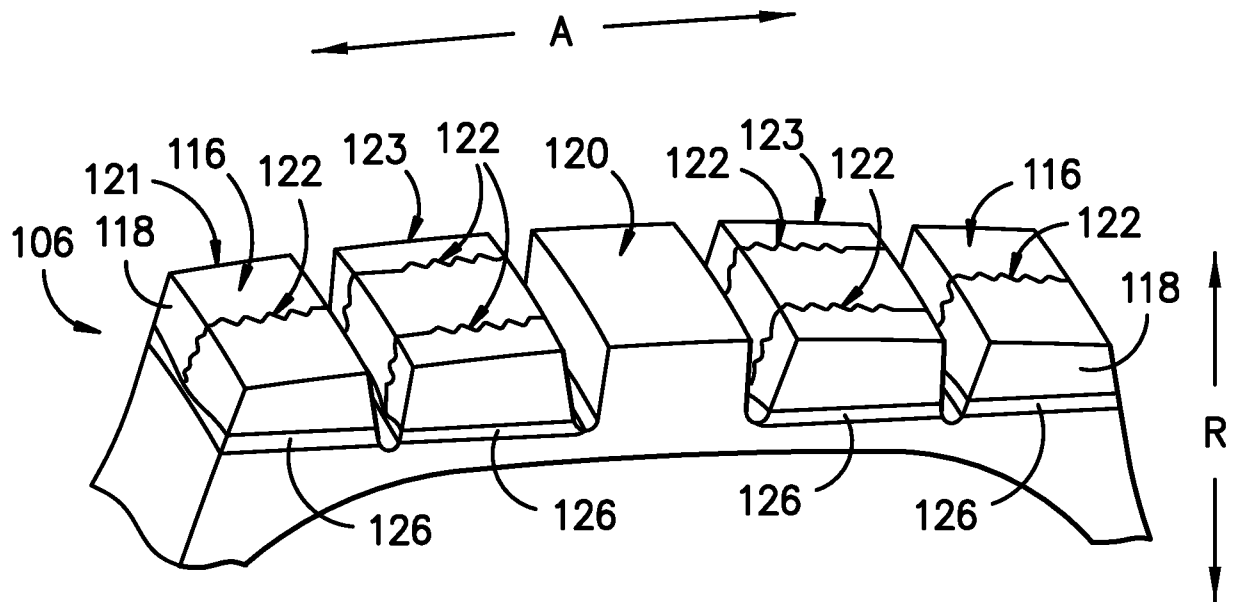


FIG. -9-

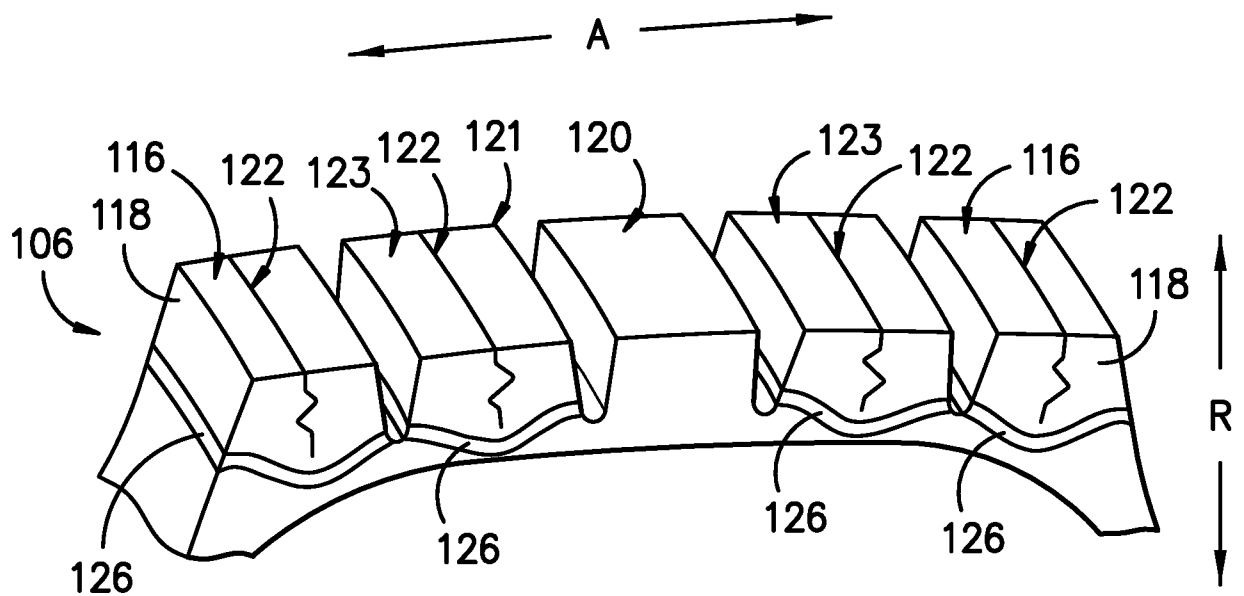


FIG. -10-

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/066711

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60C1/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 511 308 A1 (CONTINENTAL REIFEN DEUTSCHLAND [DE]) 17 October 2012 (2012-10-17) the whole document	1-15
Y	----- EP 1 319 527 A1 (SUMITOMO RUBBER IND [JP]) 18 June 2003 (2003-06-18) the whole document -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

31 March 2016

Date of mailing of the international search report

07/04/2016

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Trauner, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/066711

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2511308	A1	17-10-2012	DE 102011001939 A1
			EP 2511308 A1
			11-10-2012
			17-10-2012
EP 1319527	A1	18-06-2003	CN 1425573 A
			DE 60200479 D1
			DE 60200479 T2
			EP 1319527 A1
			JP 3548169 B2
			JP 2003237316 A
			US 2003127168 A1
			25-06-2003
			17-06-2004
			02-06-2005
			18-06-2003
			28-07-2004
			27-08-2003
			10-07-2003