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(54) ON-WHEEL AIR MAINTENANCE SYSTEM

(57) An air maintenance system comprising a rotatable radially inner ring (11) associated with a vehicle wheel or fixed to a vehicle rim (9); a stationary radially outer ring (13) maintaining a constant angular position, the stationary outer ring (13) including ring segments (15) secured together by a plurality of connecting shafts (53); an occlusion roller (50) rotationally fixed to the stationary outer ring (13) by a first connecting shaft of the plurality of connecting shafts (53), the occlusion roller (50) having a protruding portion (51) preferably centered axially at a radially outer surface of the occlusion roller (50) with axially outer portions of the occlusion roller (50) being radially recessed from the protruding portion (51) and supported by bearing surfaces (12) of the rotatable inner ring (11); spacer rollers (70) rotationally fixed to the stationary radially outer ring (13) by second and third connecting shafts of the plurality of connecting shafts (53) and rotationally supported by the bearing surfaces (12); and a flexible tube (20) defining a pump cavity, the air maintenance system (10) being is configured for pumping a fluid from the ambient environment into a pneumatic tire by applying an occluding force against the flexible tube (20) thereby periodically occluding portions of the pump cavity. The spacer rollers (70) have axially outer surfaces for rotational support by bearing surfaces (12) of the rotatably inner ring (12) and a recess (72) preferably centered axially at the outer surface of the spacer rollers (70) for avoiding any contact between the spacer rollers (70) and the flexible tube (20).

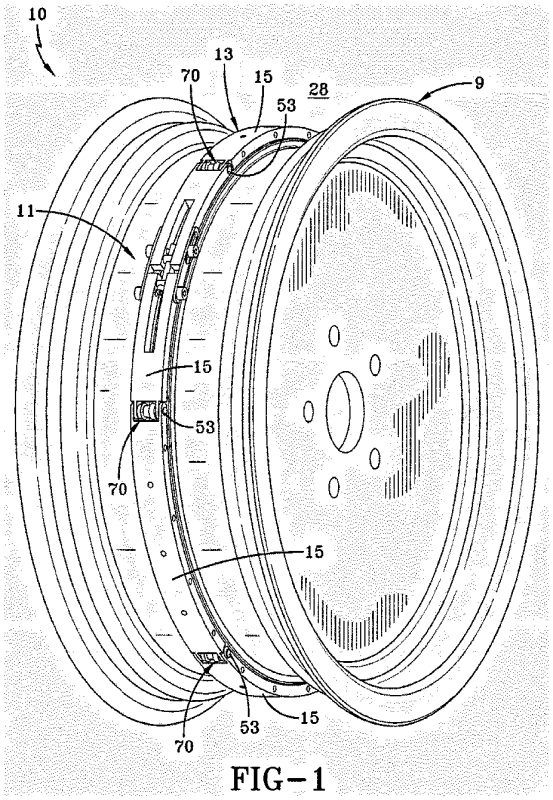

FIG-1

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Description

Technical Field

[0001] The present invention relates generally to the automotive field, and more specifically, to a new and useful tire air maintenance system in the automotive field.

Background of the Present Invention

[0002] Non-optimally pressurized pneumatic tires contribute to low fuel efficiency. These effects are particularly felt in the trucking industry, where long distances and large loads amplify the effects of an underinflated tire. However, it is often inconvenient and inefficient for truck drivers to constantly stop, check, and inflate the vehicle tires to the optimal pressure, leading to the persistence of less-than-optimal fuel efficiency in truck fleets. This challenge has led to several conventional auto-inflating tire systems. Conventional auto-inflating tire systems may be either central or distributed, but each suffers from its own set of drawbacks. Central inflation systems are complex and expensive, and require significant work for aftermarket installation (drilling through axles, tapping existing air lines, etc.). Distributed systems are mounted at each wheel and can be less expensive, but the potential for reduced cost is typically at the expense of the continuous replacement of the device (which fails due to the harsh wheel environment). Thus, there is a need in the automotive field to create a new and useful air maintenance system for pneumatic tires.

Summary of the Invention

[0003] The invention relates to a system in accordance with claim 1.

[0004] Dependent claims refer to preferred embodiments of the invention.

[0005] An air maintenance system in accordance with a preferred aspect of the present invention includes a rotating inner ring associated with, or secured to, a vehicle wheel or rim, a stationary outer ring maintaining a constant angular position, the stationary outer ring including ring segments secured together by a plurality of connecting shafts, an occlusion roller rotationally fixed to the stationary outer ring by a first connecting shaft of the plurality of connecting shafts, the occlusion roller having a protruding portion centered axially at a radially outer surface of the occlusion roller with axially outer portions of the occlusion roller being radially recessed from the protruding portion and supported by bearing surfaces of the rotating inner ring, spacer rollers rotationally fixed to the stationary outer ring by second and third connecting shafts of the plurality of connecting shafts and rotationally supported by the bearing surfaces, and a flexible tube defining a pump cavity, the air maintenance system pumping a fluid from the ambient environment into a pneumatic tire by applying an occluding force against the flexible tube, periodically occluding portions of the pump cavity. The spacer rollers have axially outer surfaces for rotational support by bearing surfaces of the rotating inner ring and a recess centered axially at the outer surface of the spacer rollers for avoiding any contact between the spacer rollers and the flexible tube.

[0006] According to another preferred aspect of the system, the flexible tube is molded directly into the vehicle wheel.

[0007] According to still another preferred aspect of the system, the flexible tube is machined on to the vehicle wheel.

[0008] According to yet another aspect preferred of the system, the rotating inner ring rotates concentrically relative to the stationary outer ring.

[0009] According to still another preferred aspect of the system, the bearing surfaces of the inner rotating ring provide a smooth conical surface for the spacer rollers and the occlusion roller.

[0010] According to yet another preferred aspect of the system, the stationary outer ring encircles the air maintenance system and applies an inward radial force against the spacer rollers when assembled.

[0011] According to still another preferred aspect of the system, the inward radial force maintains the inner rotating ring and the spacer rollers in a concentric relationship.

[0012] According to yet another preferred aspect of the system, the inner rotating ring has a substantially homogeneous weight distribution such that no portion of the inner rotating ring is substantially heavier than another portion.

[0013] According to still another preferred aspect of the system, the inner rotating ring is substantially rigid and made of metal.

[0014] According to yet another preferred aspect of the system, the inner rotating ring is made of a rigid polymer.

[0015] According to still another preferred aspect of the system, the mass of the stationary outer ring overcomes inertia and friction generated by rotation of the inner rotating ring and rotating wheel such that the stationary outer ring stays substantially static while the inner rotating ring and vehicle wheel rotate.

[0016] According to yet another preferred aspect of the system, the stationary outer ring maintains the angular position relative to a road surface as the vehicle wheel rotates and provides torque, generated by gravity, that opposes the rotation of the stationary outer rotating ring with the vehicle wheel.

[0017] According to still another preferred aspect of the system, the mass of the stationary outer ring prevents the stationary outer ring from rotating with the vehicle wheel and the inner rotating ring.

[0018] According to yet another preferred aspect of the system, the spacer rollers retain non-slip contact between the spacer rollers and the bearing surfaces of the inner rotating ring.

[0019] According to still another preferred aspect of

the system, the system includes three spacer rollers.

[0020] According to yet another preferred aspect of the system, the flexible tube defines a deformable surface that occludes the pump cavity.

[0021] According to still another preferred aspect of the system, the flexible tube has an oval cross section.

[0022] According to yet another preferred aspect of the system, the flexible tube comprises a flexible, elastomeric material.

Definitions

[0023] "Axial" and "axially" means lines or directions that are parallel to the axis of rotation of the tire.

[0024] "Equatorial plane (EP)" means the plane perpendicular to the tire's axis of rotation and passing through the center of its tread.

[0025] "Radial" and "radially" means directions radially toward or away from the axis of rotation of the tire.

Brief Description of Drawings

[0026] The present invention will be described by way of example and with reference to the accompanying drawings, in which:

Fig. 1 schematically illustrates a perspective view of part of an air maintenance assembly in accordance with the present invention.

Fig. 2 schematically illustrates a cross-sectional view of another part of an air maintenance assembly in accordance with the present invention.

Fig. 3 schematically illustrates a detailed cross-sectional view of the part Fig. 2.

Fig. 4 schematically illustrates a detailed cross-sectional view of the part Fig. 3 under a different condition.

Fig. 5 schematically illustrates another part of an air maintenance assembly in accordance with the present invention.

Detailed Description of Example Embodiments of the Present Invention

[0027] A conventional tire inflation system may mount to the wheel of a vehicle. The tire inflation system may include a pumping ring that rotates with the wheel and a positioning system rotatably coupled to the wheel. The positioning system may include a positioning mechanism and an eccentric mass. A planetary roller may be disposed in non-slip contact with the pumping ring and the positioning system. A flexible diaphragm may define a pump cavity wherein relative motion between the pumping ring and positioning system may be translated by the planetary roller into an occluding force that deforms the diaphragm and thereby occludes the pump cavity. Relative motion between the pumping ring and the positioning system may be achieved by coupling the eccentric mass to the positioning mechanism to offset the center of mass of the positioning system from the center of rotation of the positioning system. Such a system are known from US-B-8,763,661.

[0028] Another example air maintenance system may include a rotating inner ring, a stationary outer ring, an eccentric mass, an occlusion roller located proximate to the eccentric mass, and a flexible tube that defines a pump cavity. The air maintenance system may be coupled to a rotating wheel wherein the rotating inner ring rotates with the rotating wheel while the eccentric mass maintains a constant angular position relative to the rotating wheel. This arrangement may thereby generate relative motion between the rotating inner ring and the eccentric mass. The air maintenance system may translate this relative motion into mechanical work or other energy forms. The air maintenance system may pump a fluid from the ambient environment into a pneumatic tire seat to the rotating wheel by applying an occluding force against the flexible tube, periodically occluding portions of the pump cavity. The air maintenance system may be coupled to the rim of the wheel, such as that of a truck, compact vehicle, motorcycle, bicycle and/or other vehicle. Relative diameters between the inner rotating ring and roller elements may collaborate to achieve a desired gear ratio and pumping speed. The pumping rate, pressure, and frequency may also be controlled with a passive or an active control mechanism.

[0029] The inner rotating ring may apply an occluding force against the flexible tube. The inner rotating ring also may provide a smooth bearing surface for the roller elements and an occlusion roller, and may additionally contain or constrain other components of the air maintenance system. The inner rotating ring may rotate with the rotating wheel, and may be statically, but removably, coupled to the rotating wheel. An outer ring may encircle the air maintenance system and apply an inward radial force against the rollers when assembled. This inward radial force may maintain the inner rotating ring and the rollers. The inner rotating ring may have a substantially homogeneous weight distribution such that no portion of the inner rotating ring is substantially heavier than another portion. The inner rotating ring may be substantially rigid and made of metal (e.g. stainless steel, aluminum, titanium), but may alternately be made of a rigid polymer (e.g. polyacetylenes, polyfluroenes, nylon, and polyimides) or a ceramic.

[0030] The eccentric mass may overcome the inertia and friction generated by the rotation of the inner rotating ring and rotating wheel such that the eccentric mass stays substantially static while the inner rotating ring rotates. Further, the eccentric mass may be coupled to the air maintenance system to maintain the angular position of the eccentric mass relative to the road surface (which is contacted by the wheel) as the wheel rotates and provides torque, generated by gravity, that opposes the rotation of the inner rotating ring with the wheel. In other words, the eccentric mass may prevent the outer ring

from rotating with the wheel and the inner rotating ring. This relative motion, enabled by the gravitational pull on the eccentric mass, may be harvested to do mechanical work.

[0031] This relative motion may occur because the center of mass of the eccentric mass is not located at the center of rotation such that the pull of gravity on the eccentric mass may allow it to remain substantially static relative to the road surface while the inner rotating ring rotates relative to the road surface. The weight of the eccentric mass may be large enough to generate the amount of mechanical work desired, in addition to being large enough to overcome friction and adequately dampen induced oscillations resulting from non-rotating motion (e.g. from bumps). The eccentric mass may be rectangular, spherical, or amorphous. The eccentric mass may be made of metal, such as stainless steel, copper, aluminum, etc., but may alternately be made of plastic, ceramic, and/or a fluid/gel. The roller elements may additionally retain non-slip contact between the roller elements and the inner rotating ring, but may not provide a direct occluding force. The air maintenance system may include two, three, five, or any suitable number of rollers.

[0032] The flexible tube may define the pump cavity that holds a fluid and a deformable interface that occludes the pump cavity. The flexible tube may have a circular or oval cross section. The flexible tube may comprise a flexible, elastomeric material such as rubber or thermosets, thermoplastics, or any other suitable material. The flexible tube may include an inlet port and an outlet port each in fluid connection with tubes and a pressure regulator assembly.

[0033] The pressure regulator assembly may include a control valve, check valves, a filter, and an inlet port for receiving ambient air. A housing of the pressure regulator assembly may be secured to the wheel with the inlet port located externally to the tire cavity of the tire and the remaining structures of the pressure regulator assembly located internally to the tire cavity.

[0034] The air maintenance system may utilize a peristaltic or reciprocating pump method. In the peristaltic method, the occlusion roller may constrict a portion the flexible tube that is adjacent the occlusion roller thereby deforming the flexible tube segment by segment between an expanded condition and an at least partially collapsed condition in response to respective segment by segment deformation by the occlusion roller located, with the eccentric mass, by gravity statically at the bottom of the outer ring.

[0035] The rotating inner ring may be disposed concentrically within the stationary outer ring with the roller elements determining its orientation relative to the stationary outer ring. The roller elements may be rotatably secured to the stationary outer ring by a shaft. The stationary outer ring may comprise a plurality of segments (e.g., 3, 4, 5, etc.) having a female mating connection at one end and a male connection at its opposite end. The rotating inner ring may comprise a roller element track for receiving the roller elements, a plurality of segments (e.g., 1, 2, 3, 4, etc.) with a female recess at one end for mating with a male clip connection at its opposite end. Each end may further have slots for securing the flexible tube. The rotating inner ring may be secured to wheel by connecting the ends. The occlusion roller may be rotatably attached to the stationary outer ring by a shaft such that the occlusion roller, held stationary by the eccentric mass, rolls and squeezes the flexible tube as the rotating inner ring and wheel rotate. The roller elements may travel along the roller element track and the occlusion roller may sequentially squeeze the flexible tube as the wheel rotates. The housing of the pressure regulator assembly may include a fill port for regular tire pressure maintenance (e.g., an initial air fill up, etc.). Such a system is described in US-A-2016/0167465.

[0036] As shown in Figs. 1-5, an air maintenance system 10 in accordance with the present invention includes a segmented ring 13 equipped with rollers 50, 70 installed on shafts 53 at the intersection of ring segments 15. Slack compensation may be implemented by an extendable segment 17 which allows tuning of the circumferential length of the segmented ring 13 and also allows extension of the segmented ring for mounting operations. The ring segments 15 may be connected by axles/shafts 53 on which may be installed rollers 50, 70 and lubricated or non-lubricated bearings surfaces 12. Configurations of roller bearings or needles bearings may alternatively be used. The bearings 12 thus allow the segmented ring 13 to rotate concentrically with an inner ring 11 attached to a vehicle rim 9. The system 10 may be secured to a modified rim 9 which allows mounting of a tire without removing the system from the rim.

[0037] The system 10 may have a diameter smaller than the bead seat diameter in order to allow tire mounting operations without contacting the system. A flexible tube 20 may be added as an additional part secured to the modified rim 9. Alternatively, the inner ring 11 and/or the flexible tube 20 may be molded and/or machined directly on/into the modified rim 9 to reduce complexity (e.g., number of parts, etc.) and to improve integration (e.g., co-axiality, balance, weight, etc.) with the modified rim.

[0038] Parts of the system 10 may be tested on a lab drum 7 (Fig. 5). The driving device may be tested and the influence of the tube pinching device parameters on the dynamic behavior of the system 10 may be evaluated. These tests can be performed without tube connections or valves, since no pneumatic pumping is tested.

[0039] As shown in Figs. 1-4, a system 10 in accordance with the present invention includes an occlusion roller 50. The occlusion roller 50 includes a protruding portion 51 for constricting a portion the flexible tube 20 that is adjacent the occlusion roller and deforming the flexible tube, segment by segment, between an expanded condition and an at least partially collapsed condition in response to respective segment by segment deformation by the occlusion roller sustained, with an eccentric

mass (not shown), by gravity statically at the bottom of an outer segmented ring 13. The flexible tube 20 is fixed to an inner ring 11. The inner ring 11 is fixed to a vehicle rim 9. The protruding portion 51 is preferably centered axially at a radially outer surface of the occlusion roller 50 with axially outer portions of the occlusion roller being radially recessed from the protruding portion and supported by bearing surfaces 12 on the inner ring 11.

[0040] The system 10 may further include at least two spacer rollers 70 for maintaining a concentric relationship between the inner ring 11 and an outer ring 13 to which the occlusion roller 50 is rotationally secured. The spacer rollers 70 may have axially outer surfaces 71 for rotational support by the bearing surfaces 12 of the inner ring 11. A recess 72 of the spacer rollers 70 may be centered axially at the outer surface of the spacer rollers for avoiding any contact between the spacer rollers and the flexible tube 20. A pressure regulator assembly (not shown) may harvest the pressure generated with the system 10 for maintaining appropriate air pressure within a tire cavity 28.

Claims

1. An air maintenance system comprising:

   a rotatable radially inner ring (11) associated with a vehicle wheel or fixed to a vehicle rim (9);
   a stationary radially outer ring (13) maintaining a constant angular position, the stationary outer ring (13) including ring segments (15) secured together by a plurality of connecting shafts (53);
   an occlusion roller (50) rotationally fixed to the stationary outer ring (13) by a first connecting shaft of the plurality of connecting shafts (53), the occlusion roller (50) having a protruding portion (51) preferably centered axially at a radially outer surface of the occlusion roller (50) with axially outer portions of the occlusion roller (50) being radially recessed from the protruding portion (51) and supported by bearing surfaces (12) of the rotatable inner ring (11);
   spacer rollers (70) rotationally fixed to the stationary radially outer ring (13) by second and third connecting shafts of the plurality of connecting shafts (53) and rotationally supported by the bearing surfaces (12); and
   a flexible tube (20) defining a pump cavity, the air maintenance system (10) being is configured for pumping a fluid from the ambient environment into a pneumatic tire by applying an occluding force against the flexible tube (20) thereby periodically occluding portions of the pump cavity;

   wherein the spacer rollers (70) have axially outer surfaces for rotational support by bearing surfaces (12) of the rotatably inner ring (12) and a recess (72) preferably centered axially at the outer surface of the spacer rollers (70) for avoiding any contact between the spacer rollers (70) and the flexible tube (20).

2. The air maintenance system as set forth in claim 1 wherein the flexible tube (20) is molded directly into the vehicle wheel or is machined on to the vehicle wheel.

3. The air maintenance system as set forth in claim 1 or 2 wherein the rotatable inner ring (11) is configured to rotate concentrically relative to the stationary outer ring (13).

4. The air maintenance system as set forth in at least one of the previous claims wherein the bearing surfaces (12) of the inner ring provide a smooth conical surface for the spacer rollers (70) and the occlusion roller (50).

5. The air maintenance system as set forth in at least one of the previous claims wherein the stationary outer ring (13) encircles the air maintenance system and applies an inward radial force against the spacer rollers (70) when assembled, the inward radial force preferably maintaining the inner ring (11) and the spacer rollers (70) in a concentric relationship.

6. The air maintenance system as set forth in at least one of the previous claims wherein the inner ring (11) has a substantially homogeneous weight distribution such that no portion of the inner ring (11) is substantially heavier than another equivalent portion.

7. The air maintenance system as set forth in at least one of the previous claims wherein the inner ring (11) is substantially rigid and made of metal or wherein the inner ring (11) is made of a rigid polymer.

8. The air maintenance system as set forth in at least one of the previous claims wherein the mass of the stationary outer ring (13) is configured to overcome inertia and friction generated by a rotation of the inner ring (11) and a rotating wheel such that the outer ring (13) stays substantially static while the inner ring (11) and vehicle wheel rotate.

9. The air maintenance system as set forth in at least one of the previous claims wherein the outer ring (13) is configured to maintain the angular position relative to a road surface as the vehicle wheel rotates and to provide torque, generated by gravity, that opposes a rotation of the outer rotating ring (13) with the vehicle wheel.

10. The air maintenance system as set forth in at least one of the previous claims wherein the mass of the

outer ring (13) prevents the outer ring (13) from rotating with the vehicle wheel or rim (9) and the inner ring (11).

11. The air maintenance system as set forth in at least one of the previous claims wherein the spacer rollers (70) are configured to retain non-slip contact between the spacer rollers (70) and the bearing surfaces (12) of the inner ring (11).

12. The air maintenance system as set forth in at least one of the previous claims wherein the system includes three or more spacer rollers (70).

13. The air maintenance system as set forth in at least one of the previous claims wherein the flexible tube (20) defines a deformable surface that can occlude the pump cavity.

14. The air maintenance system as set forth in at least one of the previous claims wherein the flexible tube (20) has an oval cross section.

15. The air maintenance system as set forth in at least one of the previous claims wherein the flexible tube (20) comprises an elastomeric material.

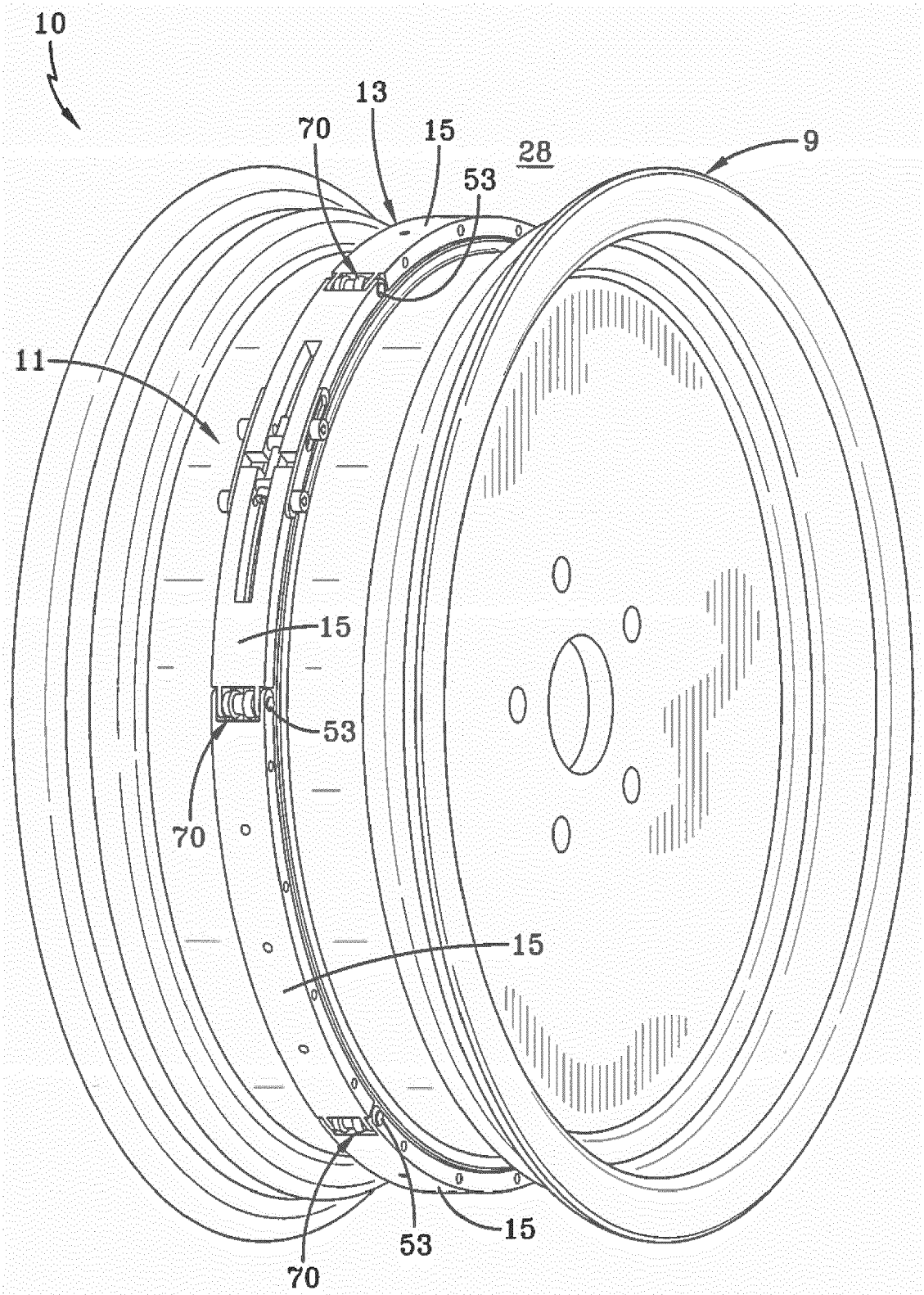
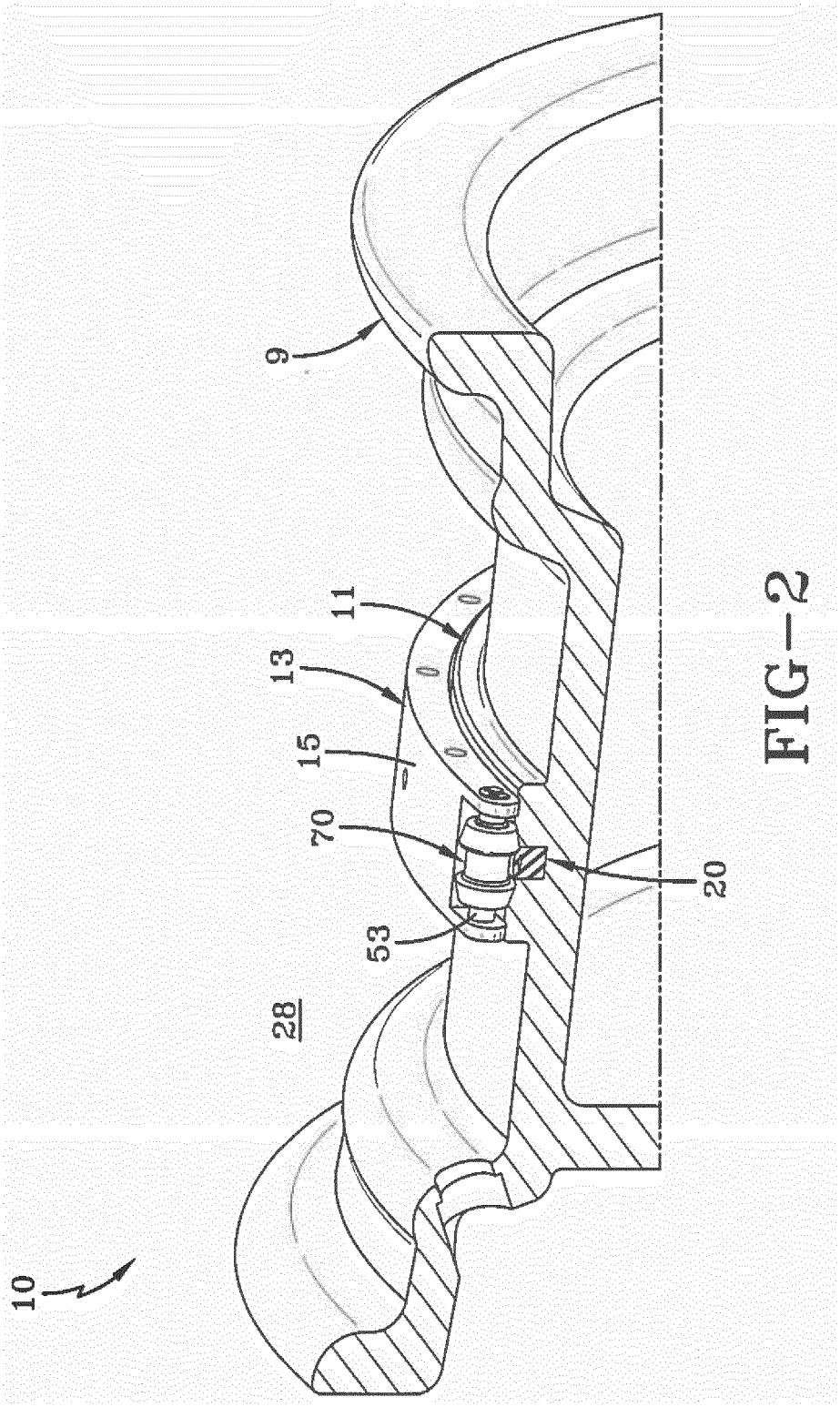
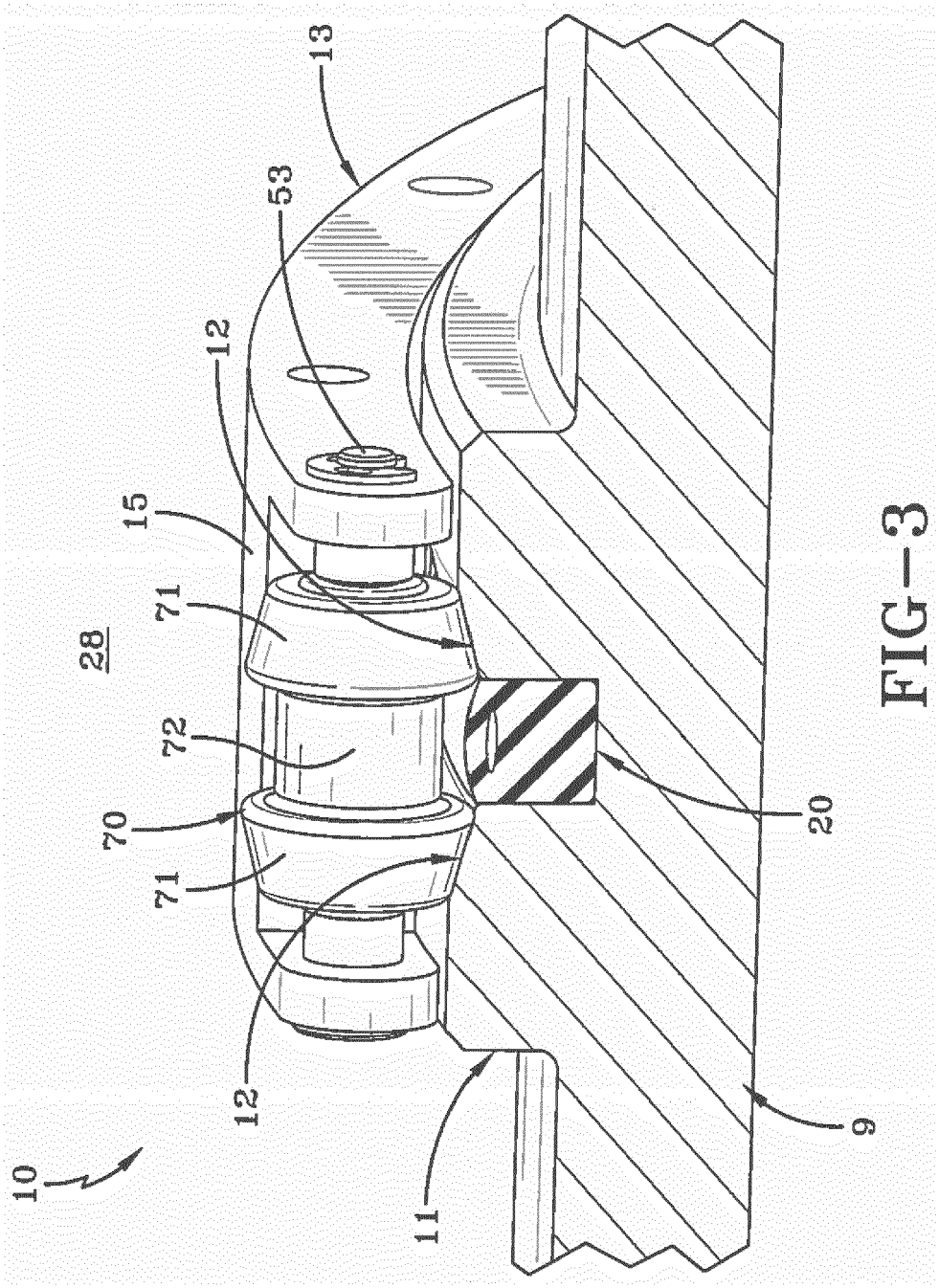


FIG-1



FIG—2



FIG—3

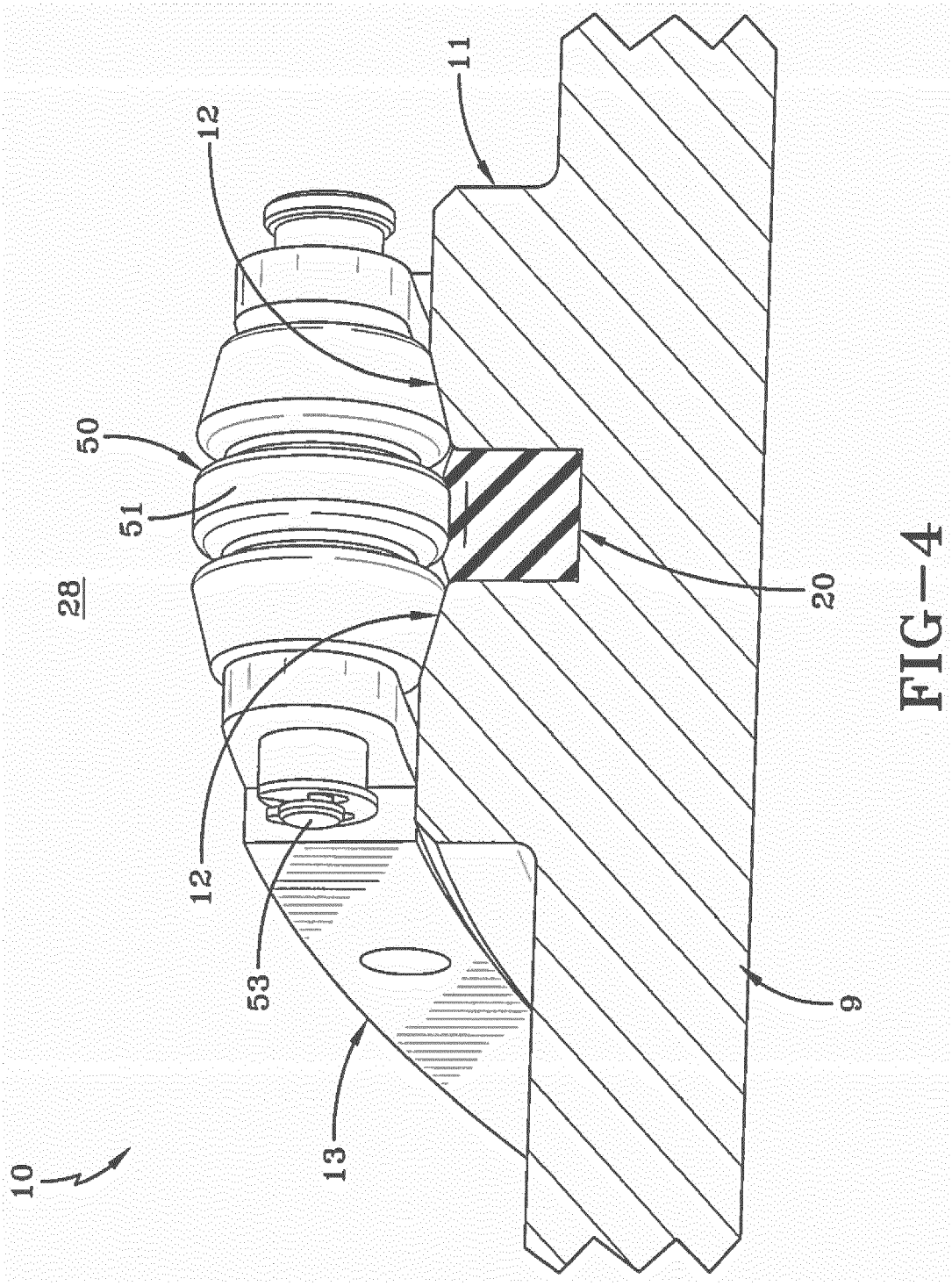
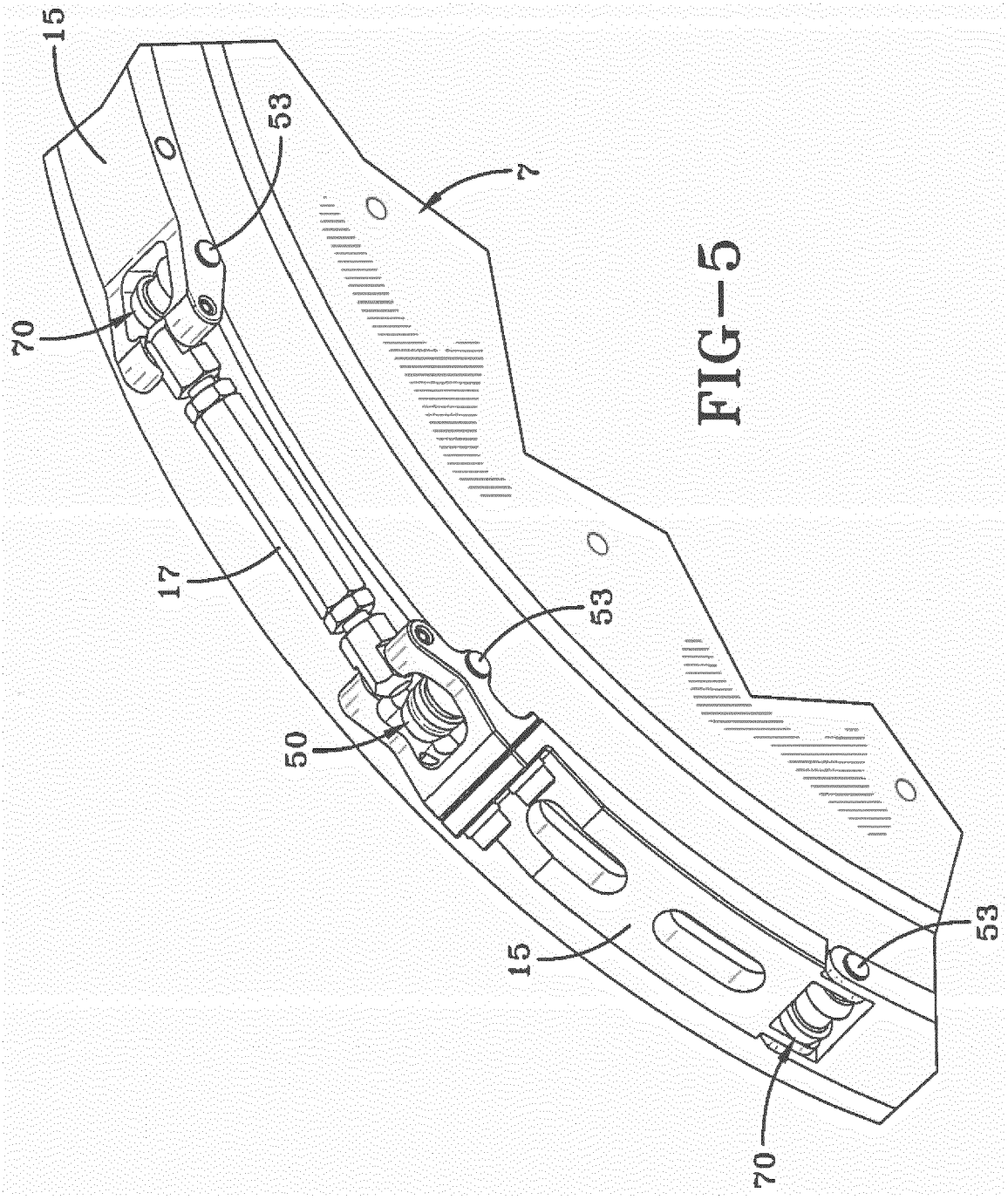


FIG-4



FIG—5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 1035

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,P	EP 3 031 634 A1 (GOODYEAR TIRE & RUBBER [US]) 15 June 2016 (2016-06-15) * paragraph [0038] - paragraph [0051]; figures 1-14 *	1-15	INV. B60C23/12
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TECHNICAL FIELDS SEARCHED (IPC)

F04B
B60C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 February 2017	Billen, Karl

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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