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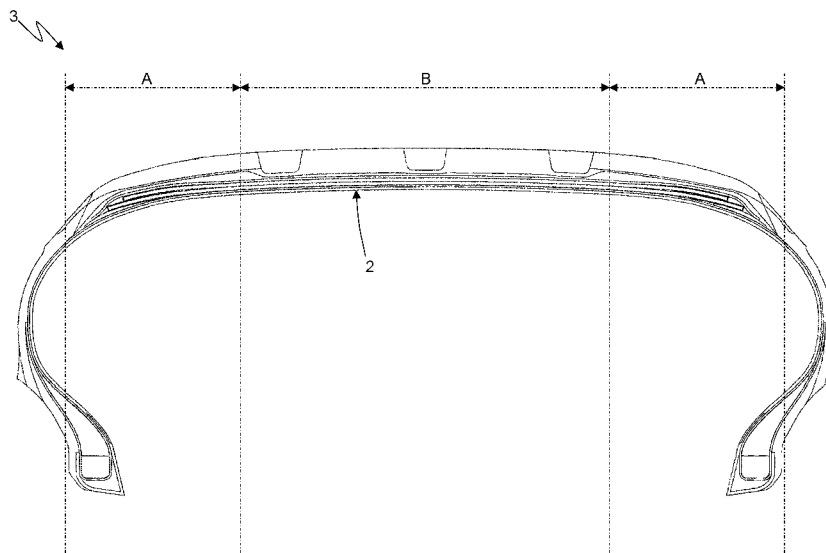


Fig. 3

(57) Abstract: Method and system (1) for cleaning the inner surface (2) of a tyre (3) and having the steps of: emitting a laser beam (9) that is directed against the inner surface (2) by means of an emitter device (8); performing deeper cleaning within at least a first annular zone (A) of the inner surface (2) in applying, by means of the laser beam (9), to the first annular zone (A) a first surface energy density; and performing less thorough cleaning within at least a second annular zone (B) of the inner surface (2) by applying, by means of the laser beam (9) to the second annular zone (B) a second surface energy density that is lower than the first surface energy density.

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METHOD AND SYSTEM FOR CLEANING AN INNER SURFACE OF A TYRE

DESCRIPTION

Technical Sector

The present invention relates to a method and to a system for cleaning an inner surface of a tyre.

Prior Art

In recent years tyre development has been directed towards tyres with an inner lining that is manufactured with a sealing agent that is intended to seal any punctures. Normally, in order to ensure both a sealing action in relation to any holes and the stability thereof within the inner cavity regardless of the conditions of the tyre, the sealing agent has a high level of viscosity. The sealing agent is applied to the inner surface (namely above the innerliner) of a pre-vulcanised tyre at the area of the tyre that comes into contact with the road (namely the area of the tyre wherein punctures can potentially occur). In particular, the sealing agent is applied at the tread and partially at the sidewalls.

In recent years the development of tyres has also been directed towards tyres that are internally provided with a sound-absorbing material (generally a sponge) for reducing the noise generated by a tyre rolling on a road surface. The sound-absorbing material is applied to the inner surface (namely above the innerliner) of an already vulcanised tyre and in particular it is glued to the inner surface of the tyre at the tread (namely at the area of the tyre that comes into contact with the road) and possibly also at part of the side walls.

Before applying a sealing agent or a sound-absorbing material to the inner surface (consisting of the innerliner) of a tyre and in order to ensure optimal adhesion of the sealing agent or sound-absorbing material to the inner surface, it is necessary to clean the inner surface in order to eliminate any dirt and processing residues (for example residues from the releasing agent applied to the inner walls of the vulcanization mold).

The patent applications WO2017082162A1 and EP3281810A1 describe a system for cleaning an inner surface of a tyre wherein a laser emitter is inserted into the already vulcanised tyre which emits a laser beam that is directed against the inner surface of the

tyre whilst the tyre is being made to turn upon itself at a constant speed; the laser emitter is progressively translated axially (i.e., along the central axis of rotation of the tyre) in such a way that the laser beam travels through a spiral that sweeps the entire inner surface of the tyre from start to finish.

The patent applications WO2017082162A1 and EP3281810A1 describe completely cleaning, and in the same way, the entire inner surface of the tyre; in this manner however the cleaning cycle is rather long and therefore, in order to have an hourly productivity that is suitable for the requirements of a production plant, it is necessary to provide numerous cleaning stations, all of which operate in parallel, with an associated increase in costs and dimensions. To solve this problem (i.e., to render the cleaning cycle quicker), the patent applications EP3175974A1 and EP3175975A1 describe causing the laser beam that cleans the inner surface of the tyre to follow a discontinuous and non-linear (i.e. wavy) path that cleans the inner surface of the tyre in strips, i.e., alternating between evenly cleaned strips and completely uncleaned strips; this solution has drawbacks, however, in that it does not always make it possible to obtain optimal adhesion of the sealing agent or of the sound-absorbing material to the inner surface.

Description of the Invention

The object of the present invention is to provide a method and a system for cleaning an inner surface of a tyre, which method and system for cleaning are free from the drawbacks described above and, in particular, make it possible to quickly perform a cleaning cycle, ensuring, at the same time, optimal adhesion of the sealing agent or of the sound-absorbing material to the inner surface under all conditions.

According to the present invention, a method and a system are provided for cleaning the inner surface of a tyre, according to that determined within the attached claims.

The claims describe preferred embodiments of the present invention forming an integral part of the present description.

Brief Description of the Drawings

The present invention will now be described with reference to the attached drawings, which illustrate an exemplary, non-limiting embodiment, wherein:

- Figure 1 is a schematic side view, with parts removed for clarity, of a cleaning system manufactured in accordance with the present invention;

- Figure 2 is a schematic front view, with parts removed for clarity, of the cleaning system of figure 1;
- Figure 3 is a schematic and cross-sectional view of part of a tyre, highlighting the differentiated cleaning areas created by the cleaning system of figure 1; and
- Figures 4, 5, and 6 show variations of the schematic view in figure 3.

Preferred Embodiments of the Invention

In figures 1 and 2, the number 1 indicates, in the entirety thereof, a cleaning system 1 for cleaning (at least) part of the inner surface 2 (consisting of the innerliner) of a tyre 3 before the application of a sealing agent or of a sound-absorbing material. In other words, the tyre 3 has a toroidal shape that is delimited by an external surface and by the inner surface 2 opposite to the external surface, and the sealing agent or the sound-absorbing material are applied to (at least) part of the inner surface 2; before being able to apply the sealing agent or the sound-absorbing material to the inner surface 2 of the tyre 3, it is necessary to clean the inner surface 2 in order to eliminate any dirt and processing residues (for example residues from the releasing agent applied to the inner walls of the vulcanization mold).

The cleaning system 1 comprises a support device 4 which is suitable for supporting the tyre 3 arranged in a vertical position, and that is also suitable for bringing the tyre 3 into rotation about an axis of rotation 5 that coincides with the central axis of symmetry. According to a preferred embodiment, the support device 4 comprises an expansion gripper which is mounted rotating and that is suitable for internally gripping the tyre 3. Alternatively (as illustrated in the attached figures), the support device 4 comprises side rails (not illustrated) which hold the tyre 3 stable in the vertical position and comprises motorised rollers (illustrated schematically) whereupon the tyre 3 rests and is driven. According to a further embodiment, the support device 4 is shaped differently and is suitable for supporting the tyre 3 which, rather than being arranged in a vertical position is instead arranged in a horizontal position.

The cleaning system 1 comprises a position sensor 6 which is suitable for determining the angular position of the tyre 3 about the axis of rotation 5; the position sensor 6 may, for example, be an angular encoder coupled to one of the motorised rollers of the support device 4, or else the position sensor 6 may directly read the displacement of the tyre 3.

The cleaning system 1 may comprise a camera 7 that faces the outer surface of the tyre 3 at a side wall and that is suitable for reading a graphical identification code (typically a bar code or similar) which is applied to the same side wall; in the case of tyres 4, the graphical identification code is always applied at the same position (also

at the same angular position), and, therefore, when the camera 7 detects the presence of the graphical identification code, the corresponding angular position of the tyre 3 around the axis of rotation 5 is contextually determined in order to obtain an absolute angular reference for the angular position of the tyre 3 around the axis of rotation 5. The support device 4 comprises an angular position sensor (normally an encoder) that detects the angular position of the tyre 2 whilst the tyre 2 is rotated.

The cleaning system 1 includes an emitter device 8 that is capable of emitting a laser beam 9 that is powerful enough to sublime (evaporate) at least part of the foreign material present upon the inner surface 2 (consisting of the innerliner) of the tyre 3; such foreign material may include releasing agents (applied within the vulcanization mold) that can inhibit subsequent production processes. By properly modulating the laser beam 9, it is possible to avoid any damage to the inner surface 2 (consisting of the innerliner) of the tyre 3. The laser beam 9 is consequently capable of cleaning the inner surface 2 of the tyre 3 without running the risk of damaging the inner surface 2 of the tyre 3.

Furthermore, the cleaning system 1 comprises a handling device 10 that implements a relative movement between the emitter device 8 and the tyre 2 carried by the support device 4 (whether moving the support device 4, that carries the tyre 2 and holding stationary the emitter device 8 or else moving the emitter device 8 and holding stationary the support device 4 that carries the tyre 2). At the beginning and at the end of the cleaning cycle, the handling device 10 positions the emitter device 8, respectively, inside the tyre 3 and outside the tyre 3, whilst during the cleaning cycle the movement device 10 moves the emitter device 8 axially (i.e., parallel to the axis of rotation 5) in relation to the tyre 2 from one side of the tyre 3 to the opposite side of the tyre 3 in order to allow the laser beam 9, emitted by the emitter device 8, to clean the entire inner surface 2 of the tyre 3.

According to that illustrated in figure 2, the handling device 10 can comprise a support arm 11, which at one end supports the emitter device 8 and an actuator 12, which axially translates the support arm 11 (i.e., parallel to the axis of rotation 5); according to an alternative embodiment, the handling device 10 can comprise a robotic arm having a greater number of degrees of freedom, as necessary, in order to initially insert the emitter device 8 into the tyre and to subsequently remove the emitter device 8 from the tyre.

According to a possible embodiment, the handling device 10 holds stationary the emitter device 8 during the cleaning of a circular strip (obviously having a width equal to the width, i.e., to the axial dimension of the laser beam 9) of the inner surface 2 and moves the emitter device 8 axially (by one step), only between the end of the cleaning of a circular strip of the inner surface 2 and the beginning of the cleaning of the next and adjacent circular strip of the inner surface 2; in other words, a plurality of circular strips of the inner surface 2, that are independent therebetween and arranged one next to the other, are cleaned (generally

with a certain mutual overlap, i.e., a new circular strip is more or less superimposed onto the adjacent circular strip). According to an alternative embodiment, the movement device 10 axially and continuously moves the emitter device 8 in order to clean a single continuous strip (i.e., seamlessly) of the inner surface 2 having a spiral shape (also in this case, each loop of the spiral is more or less superimposed onto the previous spiral).

The cleaning system 1 comprises a control unit 13, which supervises the operation of the same cleaning system 1 and, amongst other things, controls the activation and deactivation of the emitter device 8, regulates the rotational speed imparted by the support device 4, and controls the axial translational movement imparted by the movement device 10.

In use, when a new tyre 3 to be cleaned is mounted onto the support device 4, the handling device 10 is actuated such as to insert the emitter device 8 inside the tyre 3 to be cleaned (or such as to arrange the tyre 3 to be cleaned around the emitter device 8). At this point, the support device 4 rotates the tyre 3 around the axis of rotation 5 and subsequently the emitter device 8 is activated such as to emit the laser beam 9, which is directed against the inner surface 2 of the tyre 3; at the same time, the handling device 10 is actuated such as to produce a relatively slow axial translation between the emitter device 8 and the tyre 2, in such a way that the laser beam 9 can clean the entire inner surface 2 of the tyre 3 from one end to the other. At the end of the cleaning cycle, the emitter device 8 is deactivated and then the handling device 10 is actuated such as to extract the emitter device 8 from the tyre 3 (or such as to remove the tyre 3 from the emitter device 8) and thus allow the clean tyre 3 to be removed from the support device 4 and to fit a new tyre 3 to be cleaned to the support device 4, thereby initiating a new cleaning cycle.

With reference to that illustrated in figure 3, deeper cleaning is performed within (at least) an annular zone A (composed of a series of circular strips or spirals of a fixed width and adjacent therebetween and partially overlapping) of the inner surface 2 in applying, by means of the laser beam 9, to the annular zone A a first surface energy density (generally measured in Joules/cm²); furthermore, less thorough cleaning is carried out within (at least) an annular zone B (also composed of a series of circular strips or spirals of a fixed width and adjacent therebetween and partially overlapping) of the inner surface 2 in applying, by means of the laser beam 9, to the annular zone B a second surface energy density that is lower than the first surface energy density. By way of example, the second surface energy density (applied to zone B) is between 35% and 50% of the first surface energy density (applied to zone A).

As illustrated in the attached figures, the annular zone A is arranged in proximity to the side walls of the tyre 3 (i.e., at the outer edges of the tyre 3) in such a way as to be arranged at the opposite ends of the annular zone B (i.e., the annular zone B is

arranged inside the annular zone A, i.e., the annular zone B is surrounded on the right and on the left by the annular zone A).

In the embodiment illustrated in figure 3, the annular zone B is arranged at the centre of the tyre 3, i.e., it entirely occupies the centre of the tyre 3 and without interruption. In the alternative embodiment illustrated in figure 4, the annular zone A is arranged both in proximity to the side walls of the tyre 3 and at the centre of the tyre 3, and therefore zone B is located within two semi-central bands on opposite sides of the annular zone A which is arranged at the centre.

In the alternative embodiment illustrated in figures 5 and 6, an intermediate cleaning cycle is performed within an annular zone C (composed of a series of circular strips or spirals of a fixed width and adjacent therebetween and partially overlapping) of the inner surface 2 in applying, by means of the laser beam 9, within the annular zone C a third surface energy density that is lower than the first surface energy density (applied within zone A) and higher than the second surface energy density (applied within zone B). By way of example, the second surface energy density (applied within zone C) is between 60% and 80% of the first surface energy density (applied to zone A). The annular zone C is interposed between the annular zone A and the annular zone B.

In the embodiments illustrated in the attached figures, two or three zones A, B and C are provided for, each having a differing degree of cleanliness (i.e., a different surface energy density applied by the laser beam 9); according to other embodiments, not illustrated, more than three (for example four, five, six ...) zones A, B and C may be provided for, each having a different degree of cleanliness (i.e., a different surface energy density as applied by the 9 laser beam).

According to a preferred embodiment, the intensity of the laser beam 9, as emitted by the emitter device 8, is always kept constant (i.e., the emitter device 8 is always operated at the rated power, i.e., at the maximum possible power, in such a way as to always exploit all of the potential of the emitter device 8) and therefore, in order to increase or decrease the surface energy density applied to the inner surface 2 by the laser beam 9, the rotational speed of the tyre 3 about the axis of rotation 5 is decreased or increased.

In fact, with the same laser beam 9 intensity, as emitted by the emitter device 8, the faster the rotation of the tyre 3 around the axis of rotation 5, the lesser the quantity of energy radiated onto the surface area (i.e., the surface energy density generally measured in Joules/cm²).

According to a possible embodiment, one passage (circular strip or spiral) of the laser beam 9 is partially superimposed onto a subsequent passage (circular strip or spiral) of the laser beam 9, such that the laser beam 9 passes over (at least in part) where it has

previously passed. In this case, it is possible to vary the degree of overlap between the various zones A, B and C; in particular, the annular zone A has a first degree of overlap which is greater than a second degree of overlap of the annular zone B, whilst annular zone C has a third degree of overlap between the first degree of overlap of annular zone A and the second degree of overlap of annular zone B. By way of example, the first degree of overlap of annular zone A is between 45% and 75%, the second degree of overlap of annular zone B is between 15% and 35%, and the third degree of overlap of annular zone C is between 30% and 50% (a degree of overlap of 0% corresponds to the absence of an overlap, whilst a degree of overlap of 100% corresponds to a total overlap); these values are only examples and could also be different.

It is important to underline that axially within annular zone A there are no parts of the inner surface 2 that are not cleaned, i.e., those parts of the inner surface 2 that are not cleaned are found only axially outside annular zone A. In other words, cleaning the inner surface 2 involves cleaning the entire inner surface 2 that is affected by the cleaning cycle in a differentiated way (i.e., with cleaner parts, zone A, and less clean parts, zone B) but in any case cleaning the entire area without leaving "holes" that are not clean at all.

According to a preferred embodiment, the emitter device 8 is actuated such as to continuously emit the laser beam 9 in order to achieve continuous cleaning, i.e., without interruptions, along circular bands. According to an alternative embodiment, the emitter device 8 is actuated such as to intermittently emit the laser beam 9 in order to perform intermittent cleaning ("*checkerboard*"), i.e., alternating clean areas with unclean areas, along circular bands.

The embodiments described herein can be combined therebetween without departing from the scope of protection of the present invention.

The cleaning system 1 described above has many advantages.

Firstly, the cleaning system 1 described above makes cleaning the inner surface 2 of the tyre 3 very quick; some experimental tests have shown that the cleaning system 1 described above can even be 50-60% faster than a similar known cleaning system.

Furthermore, the cleaning system 1 described above ensures optimum adhesion of the sealing agent, or of the sound-absorbing material, to the inner surface 2.

Finally, the cleaning system 1 described above is simple and inexpensive to implement insofar as, when compared to a similar known cleaning system, it essentially requires only software updates without any hardware modification (or at least with marginal hardware modifications).

List of Reference Numbers in the Figures

1	cleaning system
2	inner surface
3	tyre
4	support device
5	axis of rotation
6	position sensor
7	camera
8	emitter device
9	laser beam
10	handling device
11	support arm
12	actuator
13	control unit
A	annular zone
B	annular zone
C	annular zone

CLAIMS

1) Method for cleaning the inner surface (2) of a tyre (3) and comprising the step of emitting a laser beam (9) that is directed against the inner surface (2) by means of an emitter device (8);

the cleaning method is **characterised in that** it comprises the further steps of:

performing deeper cleaning within at least a first annular zone (A) of the inner surface (2) in applying, by means of the laser beam (9), to the first annular zone (A) a first surface energy density; and

performing less thorough cleaning within at least a second annular zone (B) of the inner surface (2) in applying, by means of the laser beam (9), to the second annular zone (B) a second surface energy density that is not zero and that is lower than the first surface energy density.

2) Cleaning method according to claim 1, wherein the second surface energy density is between 35% and 50% of the first surface energy density.

3) Cleaning method according to claim 1 or 2, wherein the first annular zone (A) is arranged in proximity to the side walls of the tyre (3) in such a way as to be at the opposite ends of the second annular zone (B).

4) Cleaning method according to claim 1, 2 or 3, wherein the second annular zone (B) is arranged at the centre of the tyre (3).

5) Cleaning method according to one of claims 1 to 4, wherein the first annular zone (A) is arranged both in proximity to the side walls of the tyre (3) and at the centre of the tyre (3).

6) Cleaning method according to one of the claims from 1 to 5 and comprising the further step of performing intermediate cleaning within at least a third annular zone (C) of the inner surface (2) in applying, by means of the laser beam (9), to the third annular zone (C) a third surface energy density that is lower than the first surface energy density and higher than the second surface energy density.

7) Cleaning method according to claim 6, wherein the third annular zone (C) is interposed between the first annular zone (A) and the second annular zone (B).

8) Cleaning method according to claim 6 or 7, wherein the third surface energy density is between 60% and 80% of the first surface energy density.

9) Cleaning method according to one of the claims from 1 to 8 and comprising the further steps of:

rotating, by means of a support device (4), the tyre (3) about an axis (5) of rotation;

always keeping constant the intensity of the laser beam (9), as emitted by the emitter device (8); and

increasing or decreasing the surface energy density applied to the inner surface (2) by the laser beam (9) in decreasing or increasing the rotational speed of the tyre (3).

10) Cleaning method according to one of the claims from 1 to 9, wherein, axially, within the first annular zone (A), there are no parts of the inner surface (2) that are not cleaned, i.e., those parts of the inner surface (2) that are not cleaned are only found axially outside the first annular zone (A).

11) Cleaning method according to one of the claims from 1 to 10 and comprising the further step of continuously emitting the laser beam (9) in order to achieve continuous cleaning, i.e., without interruptions, along circular bands.

12) Cleaning method according to one of the claims from 1 to 10 and comprising the further step of emitting the laser beam (9) intermittently in order to perform intermittent cleaning, i.e., alternating clean areas with non-clean areas, along circular bands.

13) Cleaning method according to one of the preceding claims from 1 to 12 and comprising the further steps of:

partially overlapping one passage of the laser beam (9) with the next passage of the laser beam (9); and

varying the degree of overlap between the first annular zone (A) and the second annular zone (B).

14) Cleaning method according to claim 13, wherein the first annular zone (A) has a first degree of overlap which is higher than a second degree of overlap of the second annular zone (B).

15) System (1) for cleaning the inner surface (2) of a tyre (3) and comprising: an emitter device (8) that is configured such as to emit a laser beam (9) that is directed against the inner surface (2), and a control unit (13);

the cleaning system (1) is **characterised in that** the control unit (13) is configured such as to:

perform deeper cleaning within at least a first annular zone (A) of the inner surface (2) in applying, by means of the laser beam (9), to the first annular zone (A) a first surface energy density; and

perform less thorough cleaning within at least a second annular zone (B) of the inner surface (2) in applying, by means of the laser beam (9), to the second annular zone (B) a second surface energy density that is not zero and that is lower than the first surface energy density.

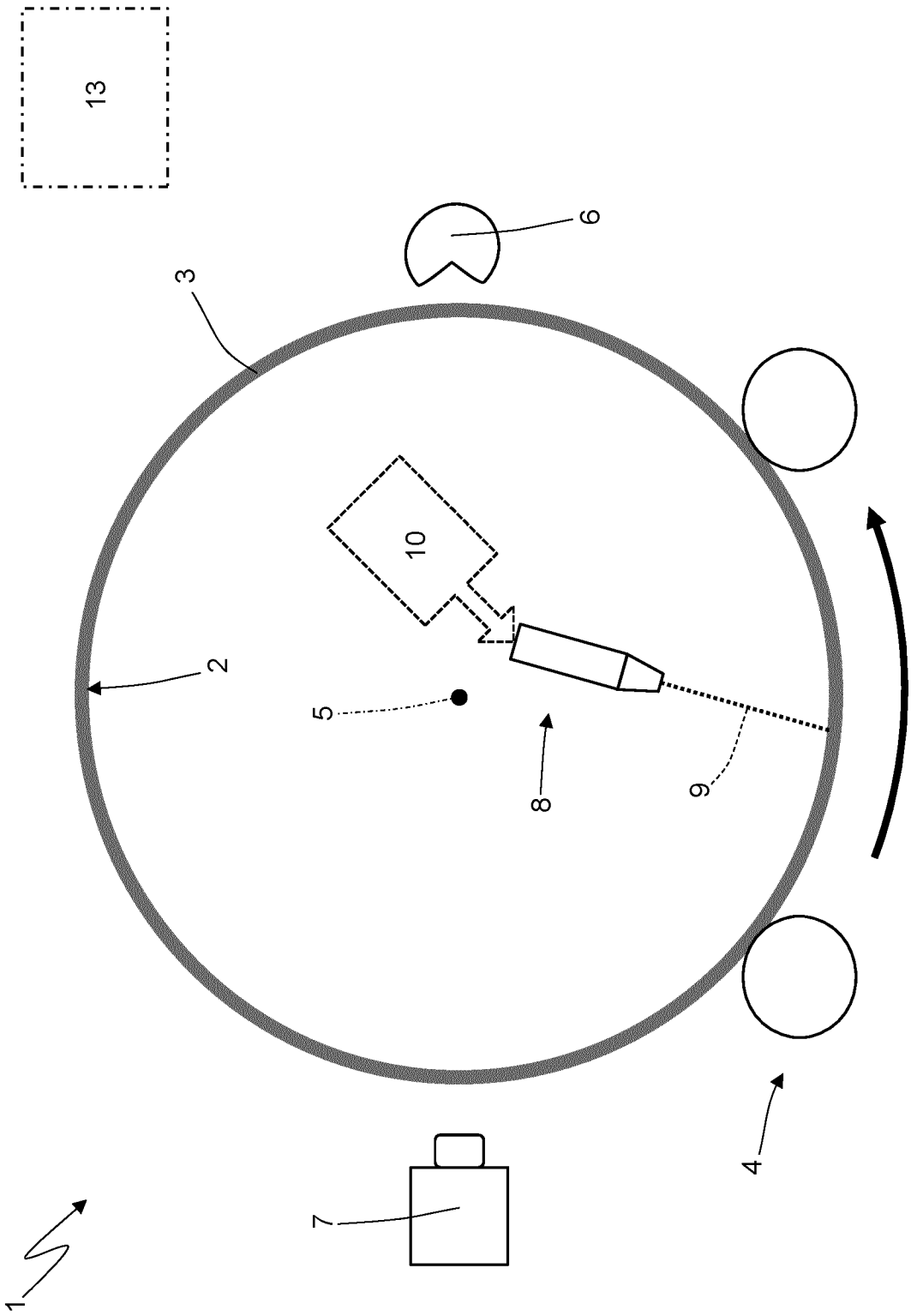


Fig. 1

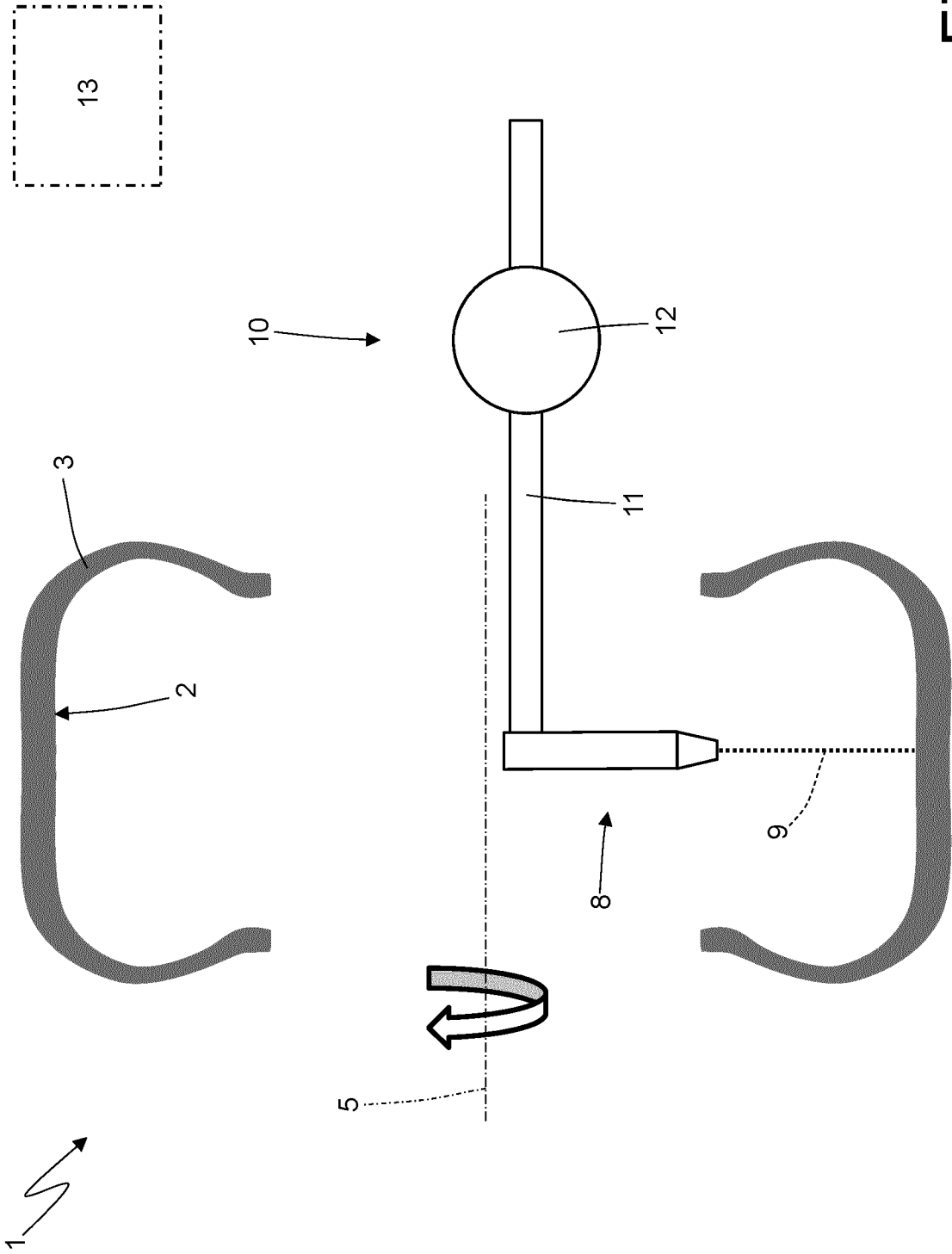


Fig. 2

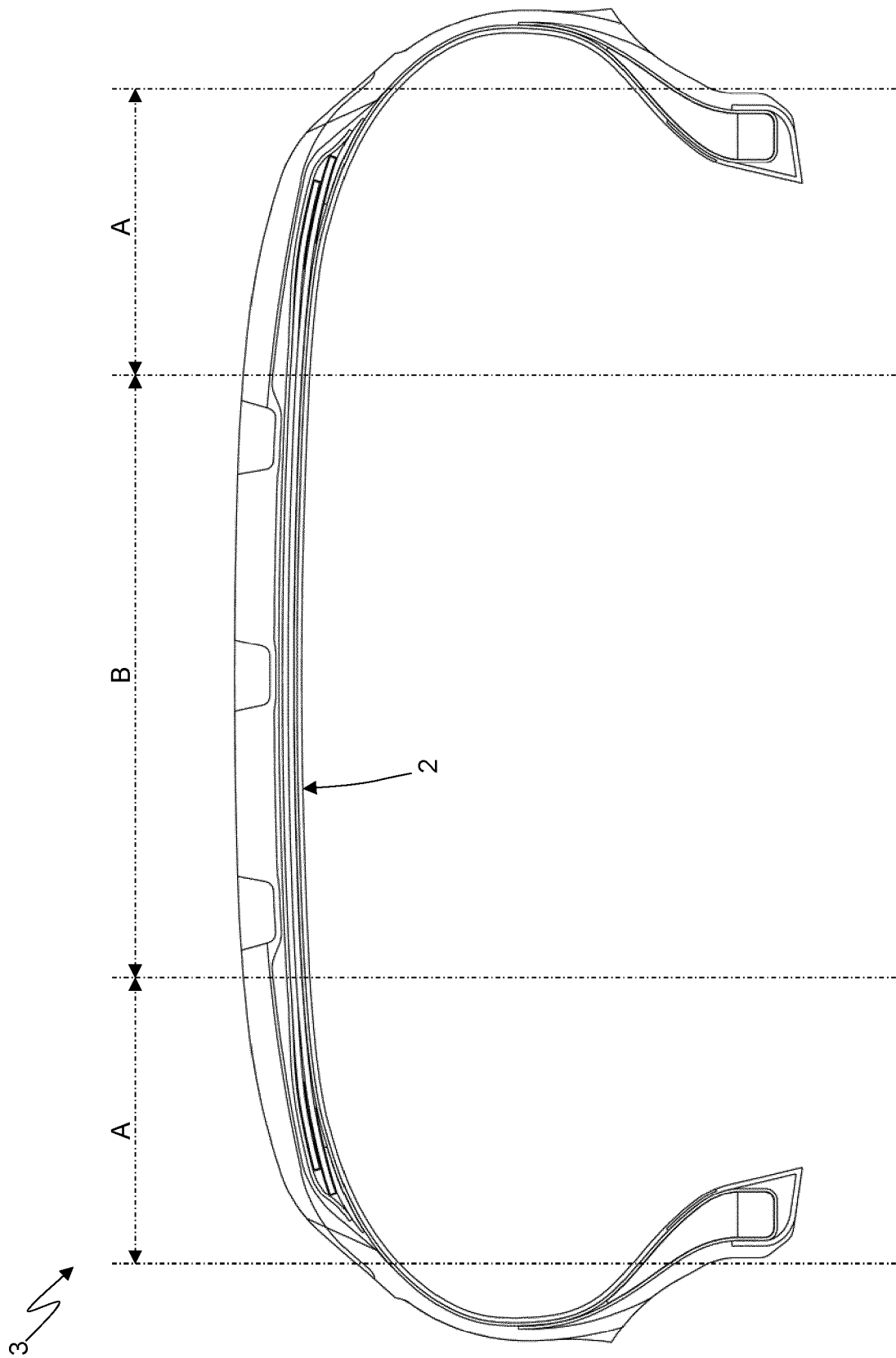


Fig. 3

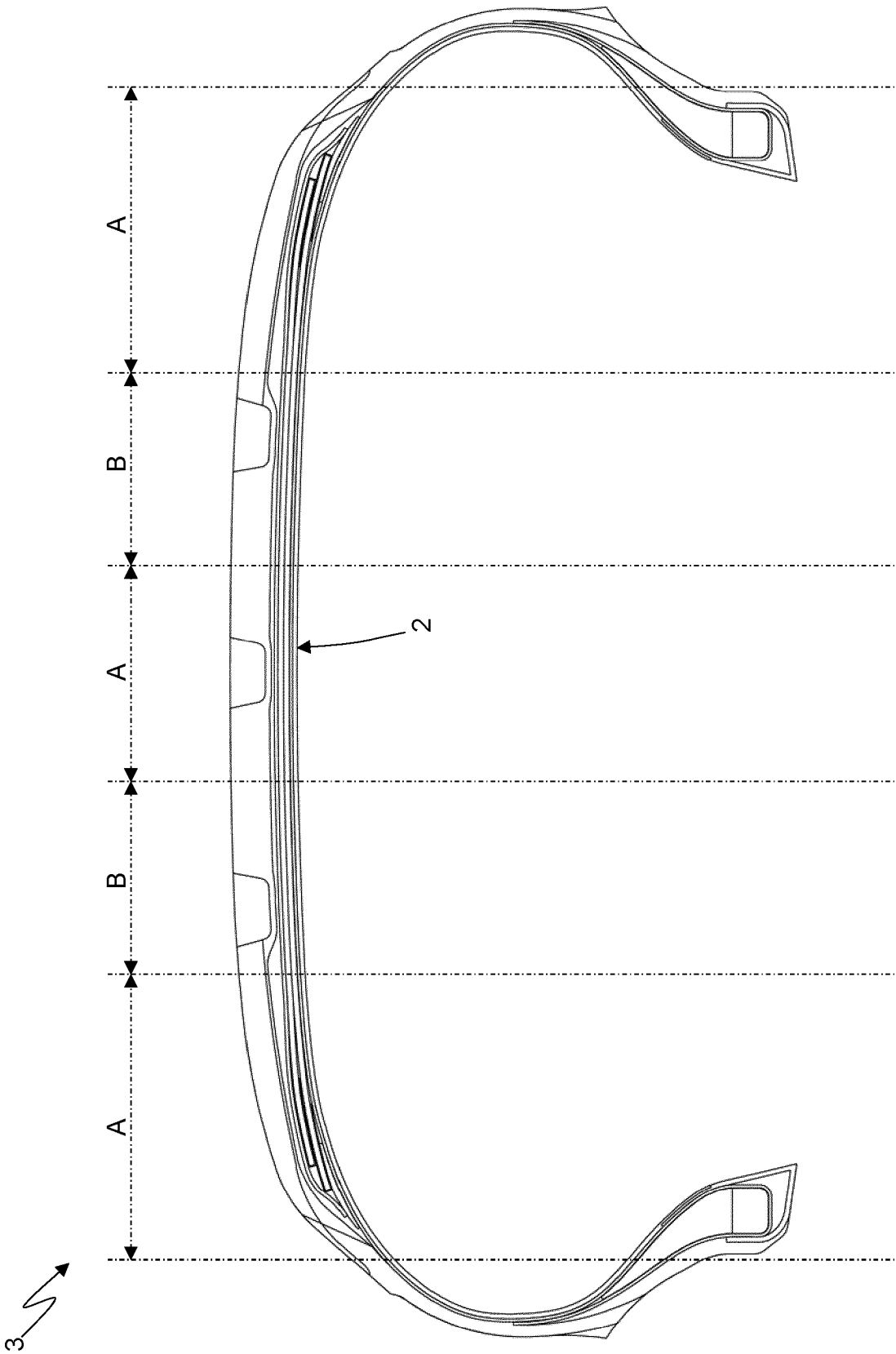


Fig. 4

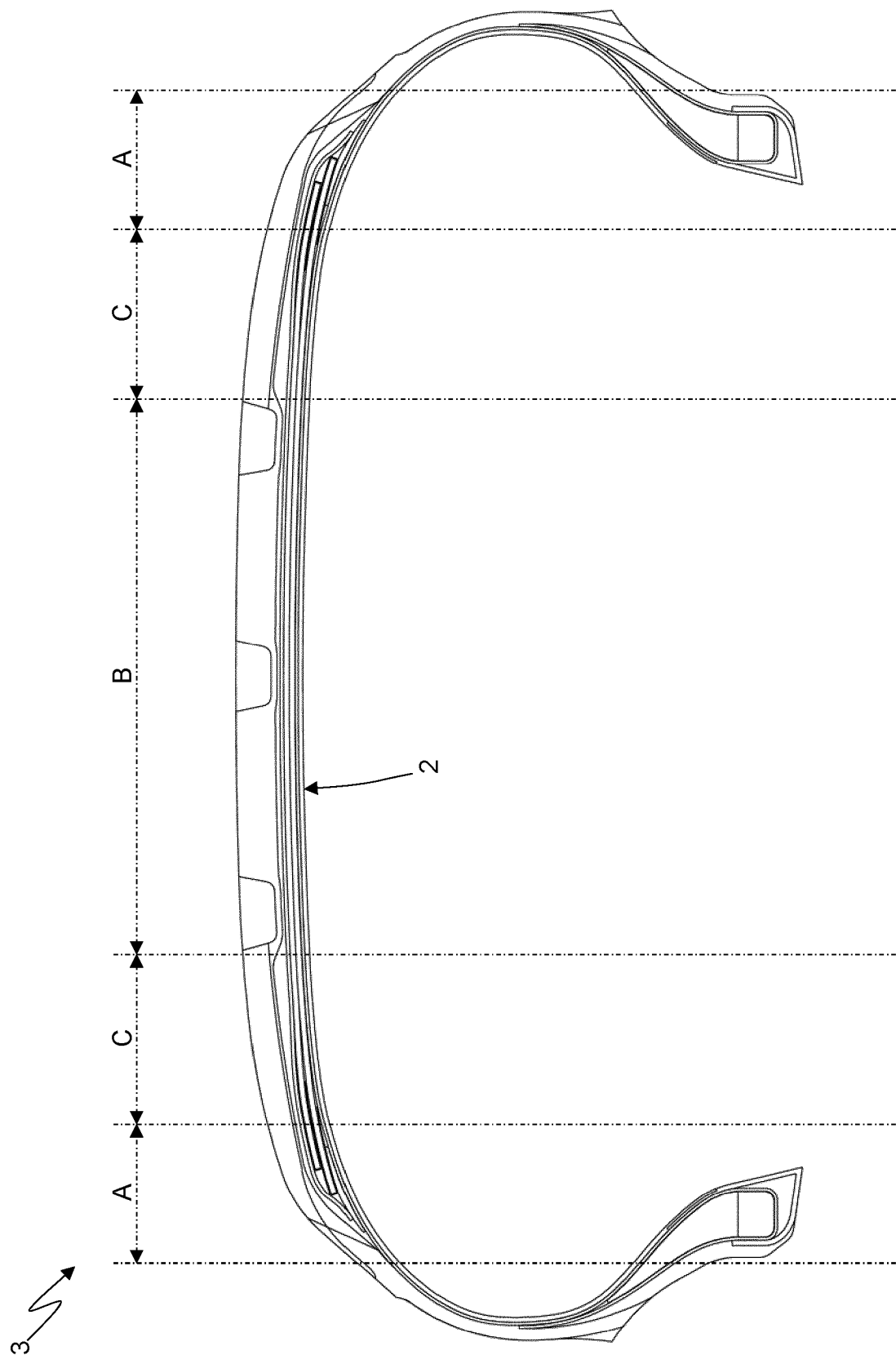


Fig. 5

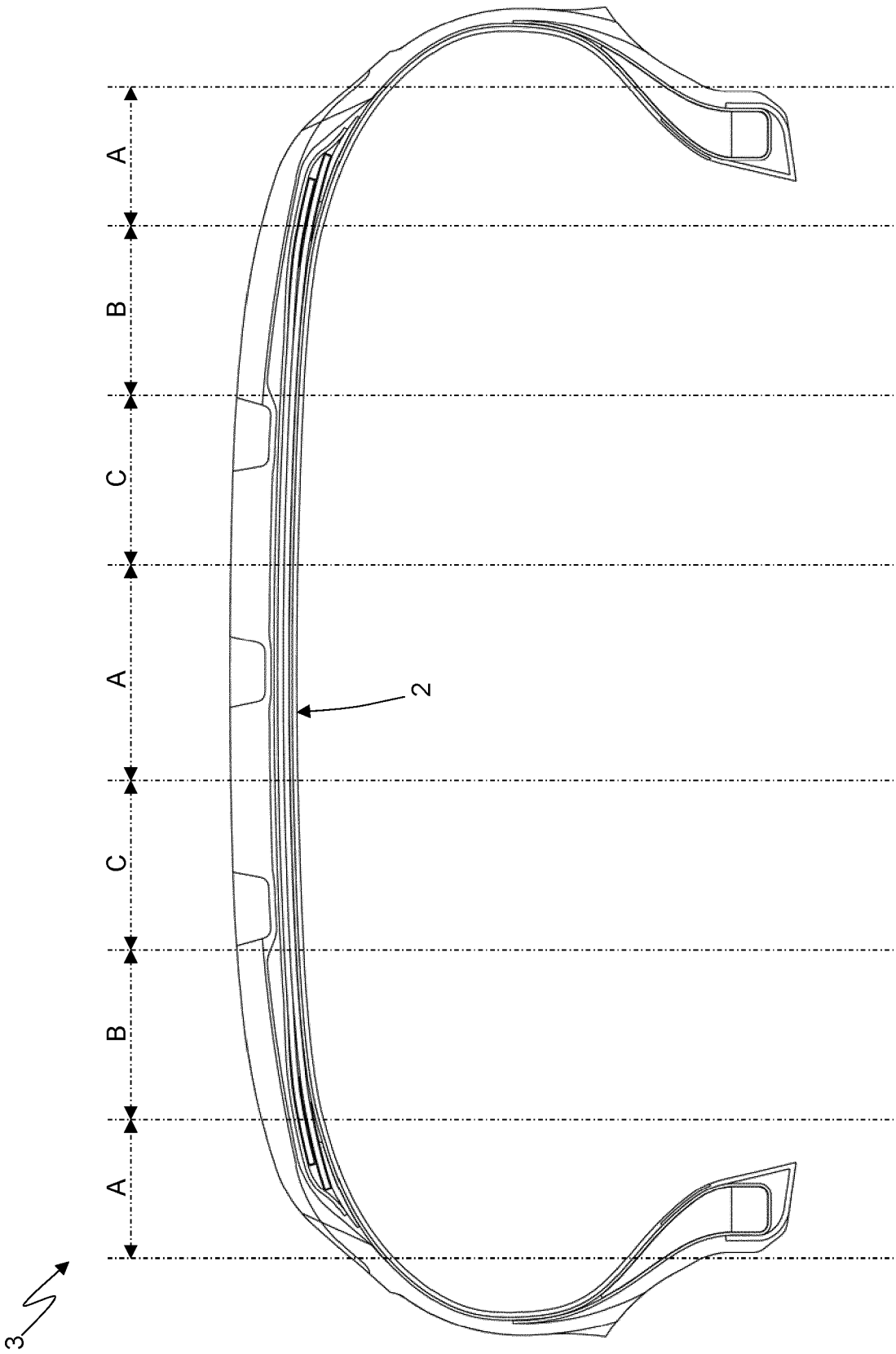


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/061058

A. CLASSIFICATION OF SUBJECT MATTER INV. B29D30/00 B29D30/06 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) B29D		
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) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2019/248084 A1 (STRAITIFF DONALD GRAHAM [US] ET AL) 15 August 2019 (2019-08-15) paragraphs [0005] - [0007], [0044] - [0046], [0059] - [0063]; figure 3D -----	1-15
A	EP 3 677 416 A1 (BRIDGESTONE CORP [JP]) 8 July 2020 (2020-07-08) paragraph [0010] -----	1-15
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search		Date of mailing of the international search report
17 August 2022		09/09/2022
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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