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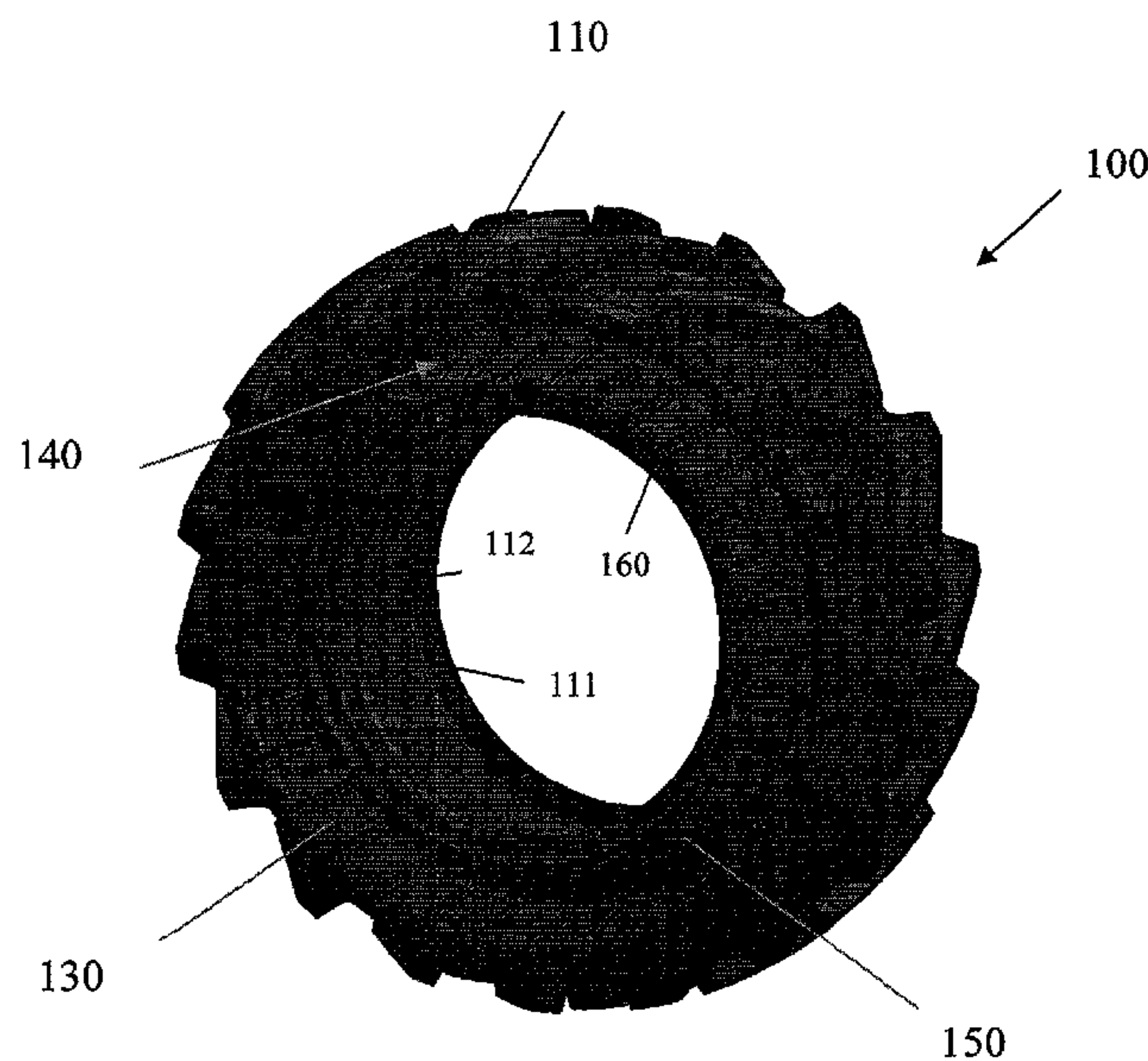


Fig. 2A

(57) **Abrégé/Abstract:**

A wheel assembly for a surface vehicle is presented. The wheel assembly comprises a tire comprising an envelope structure which by its inner surface encloses a cavity. The envelope structure comprises an outer, surface-engaging side having a circumferential surface, and opposite side walls which are integral with and extend from the surface-engaging side. The side walls by their free ends define an inner, rim-engagement side of the tire by which the tire is connectable to a wheel hub. Each of the opposite side walls comprises a surface pattern defining a suspension assembly within the side wall to thereby prevent stretching of the tire envelope towards its maximal volume when the envelope is compressed with gas, while allowing deformation of the tire envelope when loaded or depressurized such that the surface engaging side of the tire maintains a substantially constant contact with the surface.

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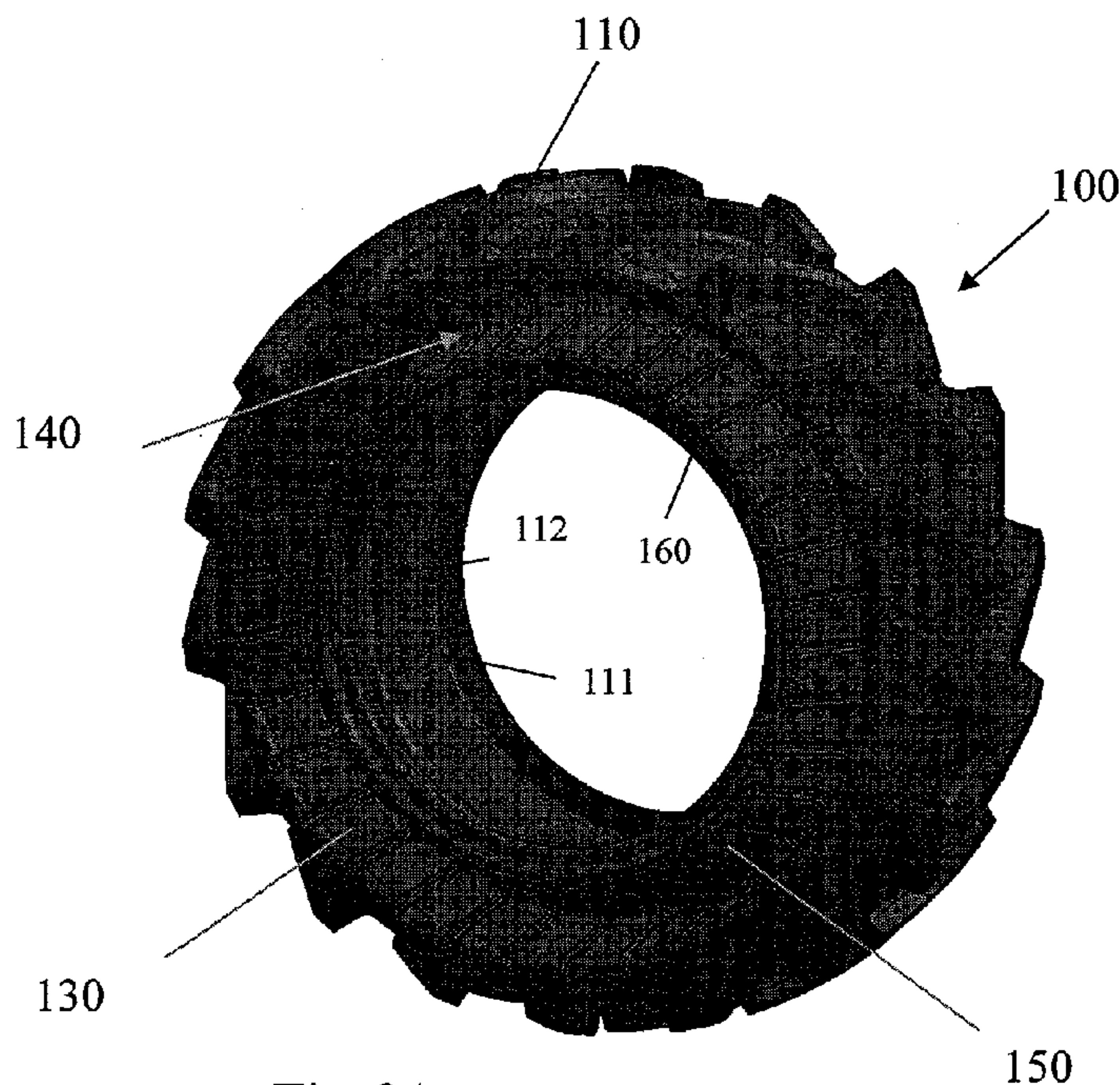


Fig. 2A

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TIRE FOR SURFACE VEHICLE

TECHNOLOGICAL FIELD AND BACKGROUND

This invention relates to a tire and/or wheel assembly for a vehicle, aimed at improving the propelling of a surface vehicle.

It is generally known that in order to provide effective maneuverability of a surface vehicle, its rim-mounted tires should be inflated to their inflation pressure, while
5 puncture of a tire envelope especially in the sidewall of such tire may cause a very rapid loss of internal inflation pressure. Known techniques aimed at solving a problem of driving the vehicle upon deflation of its tire are associated with the provision of sensors or deflation warning devices capable of earlier detection of a change in the gas pressure
10 within the tire in order to warn the user of a loss of pressure, as well as provision of various facilities for delaying effects of puncture on tires for as long as possible. For example, a tire of the conventional type may be provided thereinside with various elements, some including elastomers such as rubber polyurethanes and others, such that, in the event of puncture of the main outer tire or loss of pressure by the latter, the
15 inner structure might serve as a support for the outer tire. Devices are also known which are placed inside the tire and which, though not inflated in normal use, may reduce pressure loss in the tire in the event of puncture of the latter. Moreover in a standard tire there is a strong dependency between the pressure and the tire ability to withstand torque and lateral forces, i.e. the less internal pressure in a standard tire the less stable it
20 will be and its accurate steering ability will be reduced.

GENERAL DESCRIPTION

The present invention provides a novel locomotion assembly which can be used for carrying and propelling a surface vehicle. More specifically, the present invention
25 provides a novel approach for the configuration of a surface vehicle's tire. The tire of the invention may be configured as gas envelope, while in some embodiments the gas can be air. The configuration of the tire of the present invention is such that the

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technological procedure associated with the tire inflation may be eliminated or at least significantly reduced.

In this connection, the following should be understood. As indicated above, in order to provide effective maneuverability of a surface vehicle, its wheel assembly should be substantially flexible in order to deform, and while deforming the wheel assembly would better follow the contact surface allowing for better traction and at the same time the flexibility will allow for shock absorption that contributes both to ride comfort and general stability and safety of the vehicle. In many cases the flexibility is gained by using gas (mostly air) inflating the tire. A standard tire consists of a closed inflated flexible envelope, where the gas/air stretches the envelope substantially to its full radial dimension therefore defining substantially the largest potential volume for the given envelope, any flexibility or deformation in such tire envelope involves deflection and stretching in the surface of the envelope. The deformation generates heat and causes fatigue resulting in wear-out and energy loss. Moreover, the way that said deformation accrued, will not allow sufficient contact between the deflected area of the tire (the contact patch of the tire tread) and the surface, as will be described further below.

The present invention provides a semi-flexible envelope that by mathematical definition defines a volume that is substantially smaller than the theoretical volume which such envelope can potentially define, i.e. when compressed with gas the envelope is limited by its unique structure thus preventing stretching towards its maximum volume. Moreover, the profile of the envelope allows deformation of the tire when loaded or when depressurized in a way that the tread part of the tire maintains a good constant contact with the surface, as well as maintains its ability to deliver torque and bear side forces from the vehicle to the ground, and generates substantially less heat while doing so.

The sidewall of the tire of the present invention presents a combination of curved surfaces. To this end, a combination of curved surfaces can be described as a combined surface formed by an infinite number of points that maintain a relation between them, i.e. relative distance to one another along the surface, such that curving or folding of the surface will not change the relation between the points along the surface, and therefore will not involve stretching or deflection in the surface. In contrary, the sidewall of a standard tire can be defined as a spherical surface which can

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be described as an infinite number of points that maintain singular relation, i.e. any change in the sphere will result in a change in relation between some of the points, and will thus involve stretching and deflection, that in many cases generate heat and may cause fatigue in the surface material.

5 Thus, by one broad aspect of the invention there is provided a wheel assembly for a surface vehicle, comprising a tire envelope configured to be mountable on a wheel hub, the tire envelope by its inner surface defining a gas cavity having a certain maximal volume defined by a geometry of the envelope (namely the maximal volume achievable in the absence of structural constraints), wherein the tire envelope comprises
10 or defines a suspension assembly within its side walls (e.g. a suspension assembly embedded in side walls of the tire envelope). Consequently under gas pressure in said cavity the volume achievable through gas-pressure imposed expansion is substantially smaller than said maximal volume defined by the geometry of the envelope.

 The tire of the present invention can be filled by gas/air to better suspend a
15 vehicle, but has no such requirement for delivering torque or to withstand side forces. The tire can be designed to operate as pneumatic tire while using the gas/air as a suspension shock absorbent, however it may function safely with no gas/air, being designed as a non-pneumatic wheel and exploiting its structure to deliver torque and bear side forces. The non-pneumatic configuration is useful also in cases when gas/air
20 cannot be used or its use is undesirable, such as in a Luna vehicle for example.

 The tire has an outer, surface-engaging side (termed "tread", having a circumferential surface), and opposite side surfaces/walls which are integral with and extend from the surface-engaging side and by their free ends define an inner, rim-engagement side, of the tire by which the tire is connectable to the locomotion
25 assembly. According to the invention, each of the opposite side walls of the tire has a pattern in the form of a surface relief, which in some embodiments defines at least one groove which has a substantially V-shaped cross-section and is located between the surface-engaging side (tread) and the rim-engagement side. Such a groove with substantially V-shaped cross section is referred to below as a V-shaped groove. It can
30 also be described as if each V shape groove divides the sidewall into 2 two-dimensional curved surfaces.

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Thus, by such embodiments the side wall has a surface pattern defining one or more V-shaped grooves extending between the surface engaging side and the ring-engagement side (i.e. along the radial axis of the tire). The provision of such grooves which are made in a generally flexible/elastic tire material and which have substantially
5 round apexes provides the tire with a desired suspension assembly. This allows the tire (locomotion assembly) containing very low air pressure (even zero pressure inside) to be still able to withstand forces and rotate and drive the vehicle with sufficient maneuverability.

Generally, the required V-shape geometry of the groove may be achieved by any
10 suitable apex angle. In some embodiments, the intersecting sides of the V-shape groove are formed by a pair of opposite segments of substantially frustum-conical structures (or generally conoid structures). The general concept of using frustum-conical in locomotion assembly of a surface vehicle is described in the International (PCT) application No. PCT/IL2011/000115, which is assigned to the assignee of the present
15 application, and which is incorporated herein by reference.

According to the present invention, the tire constitutes a wheel-tire unit which may be constituted just by the above described envelope structure of elastomeric material composition (or semi elastomeric materials) enclosing a cavity/lumen which may or may not be filled by gas medium. The tire is preferably configured to have
20 desired rigidity and flexibility distribution along and across its sides. To this end, rigidity and flexibility may be different at different regions of the side wall, i.e. the side walls might have a certain rigidity/flexibility pattern at least along the radial axis (radial pattern) of the tire and in some embodiments a further rigidity/flexibility pattern along the circumference of the side wall (circumferential pattern). These different levels of
25 rigidity and flexibility can be achieved by several ways, which may include implantable/embedded rigid material such as plastics, steel, spring etc., the rigidity may be gained by forming a 'beam' structure using combination of non streaking elements such as cables, or cords such as textile cords nylon, Kevlar, etc. and/or relatively hard/stiff elastomers such as hard rubber, as will be described more specifically further
30 below.

In case the envelope is filled with compressed gas/air, the structure has to eliminate the gas from bulging the envelope to define the biggest possible volume it

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can. Therefore a certain restrain has to be set in order to keep the desired shape of the envelope. The inner part of the groove (closer to the rim/hub engagement side of the tire) tends to increase its diameter. Therefore, constructing the inner side of the groove with un-stretchable elements will support the envelope structure, preventing the inner
5 side from 'bulging' out.

Moreover, in order for the inner and outer sides of the groove to withstand the gas/air pressure, both the inner and outer sides of the groove are sufficiently rigid along the radial axis of the tire. In some embodiments of the invention, it is desirable to maintain the radial rigidity of the groove sides but at the same time to gain
10 circumferential flexibility, therefore the groove structure might be strengthened in an uneven way so it may contain relatively rigid elements only along the radial axis, or it may be designed in a way that an array of pattern elements (slots, projections, thinner regions) is provided which are arranged in a spaced-apart relationship circumferentially around the groove side(s) thereby weakening the circumferential structure while
15 keeping the radial rigidity. A similar principle may be applied where an array of bulges extend circumferentially around the groove side(s) providing similar results.

Thus, the tire may have a certain rigidity pattern across its side walls, i.e. between the surface-engaging and rim-engagement sides. This pattern is defined by that the apex of the groove and its corners at opposite sides of the groove are sufficiently
20 elastic (e.g. achieved by making the tire with smaller thickness within these regions) as compared to the tire regions between them. As a result, the two parts of the groove function as two beams that can be bended but not deformed. The general shape of such grooved tire is maintained and any change is reversible. On the other hand, the tire should have sufficient flexibility to absorb the forces falling on it while not breaking
25 down. Additionally, the inner side of the groove might have a relatively higher rigidity, with respect to both "radial" and "circumferential" rigidities, in order to maintain the generally wheel-like shape of the tire, and the outer part of the groove (closer to the surface-engaging side of the tire) might be of relatively lower rigidities.

Thus, the desired combination of rigidity and flexibility can be achieved by the
30 provision of appropriate rigidity pattern in the generally flexible material of the tire, i.e. higher radial and circumferential rigidity at the inner part of the groove than that of the outer part, while securing three flexing points along the radial direction, i.e. at the apex

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and corners at opposite sides of the V-shaped groove. As indicated above, a second rigidity pattern can be provided as a circumferential pattern along the circumferential direction of the inner and outer parts of the groove. This may be achieved by an array of spaced-apart slots (e.g. regions with implanted material of different rigidity than in spaces between the slots and/or uneven wall thickness) arranged along the groove with the slots' orientation being substantially perpendicular to the tire plane (across the groove). Thus, the tire with such groove extending along its circumference has a first rigidity pattern in a radial direction of the tire (across the groove) and possibly also a second rigidity pattern in a circumferential direction.

Thus, according to another broad aspect of the invention, there is provided a tire envelope for a surface vehicle, comprising a surface pattern in its side walls extending between a surface-engaging side and a rim-engagement side of the tire, said surface pattern configured as a suspension assembly embedded in the side walls to thereby prevent stretching of the tire envelope towards its maximal volume when the envelope is compressed with gas, while allowing deformation of the tire envelope when loaded or depressurized such that the surface engaging side of the tire maintains a substantially constant contact with the surface.

According to yet another broad aspect of the invention, there is provided a tire for a surface vehicle, the tire comprising an envelope structure which by its inner surface encloses a cavity, said envelope structure comprising an outer, surface-engaging side having a circumferential surface, opposite side walls which are integral with and extend from said surface engaging side, the side walls by their free ends defining an inner, rim-engagement side of the tire by which the tire is connectable to a locomotion assembly, wherein each of the opposite side walls comprises a surface pattern extending between the surface-engaging side and the rim-engagement side and defining a surface relief in the form of at least one groove having substantially V-shaped cross section, and wherein each of the side walls is configured with a predetermined rigidity pattern across the side wall.

The rigidity pattern may comprise relatively small rigidity and thus relatively high flexibility of regions of the tire at apex of the V-shaped groove and corners defined by connection between the groove with respectively the surface engaging side and the rim engagement side of the tire.

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The rigidity pattern may comprises different rigidities of the tire within respectively an outer side of the groove closer to the surface engaging side and an inner side of the groove closer to the rim engagement side of the tire. For example, the inner side of the groove comprises an array of support elements embedded therein and
5 extending along at least one of radial and circumferential axes of the tire.

The surface engaging side is configured to have predetermined rigidity along a circumferential axis of the tire. To this end, the surface engaging side may comprise an array of support elements embedded therein.

Alternatively or additionally, the rigidity pattern may be formed by varying
10 thickness of at least one of the outer and inner sides of the groove.

Generally speaking the grooved side walls of the tire and appropriate rigidity/flexibility distribution of the tire material within the tire creates an optimal suspension assembly allowing the effective operation of a locomotion assembly using such tire with practically no limitations to the lack/reduction of pressure in the tire
15 cavity.

As indicated above, the tire regions at the apexes of the grooves (and outer corners) are relatively flexible. It has been realized in accordance with an embodiment of this invention that in a deformable wheel the flexible portions of the side walls (particularly at said apexes), considerable strains may develop. The present invention
20 offers a solution to reduce such strains by providing a specifically designed load-bearing arrangement.

The present invention thus in its yet further aspect provides a deformable wheel assembly with an inflatable enclosure defined by the above described tire, and a load-bearing arrangement formed by a plurality of support elements, comprising a first array
25 of spaced-apart elements and a second array of spaced-apart elements, the elements in each of the arrays defining together a substantially frustum-conical structure (i.e. the lines that link defined points at distal ends of the elements together define a frustum-cone), the two frustum-conical structures intersecting one another with the elements of one dove-tailing those of the other structure.

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BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in
5 which:

Fig. 1A illustrates the typical behavior of a traditional tire when being loaded, as compared to that utilizing the tire of the invention having grooved side walls;

Figs. 1B and 1C illustrate the footprint of the locomotion assembly utilizing the tire of the present invention in respectively loaded and unloaded state of the tire;

10 **Fig. 2A** illustrates an example of the tire of the present invention;

Figs. 2B and 2C show more specifically an example of the pattern provided in the side walls of tire of the present invention;

Fig. 3 illustrates an example of the geometrical and rigidity patterns provided in the tire of the present invention;

15 **Figs 4A and 4B** illustrate specific but not limiting example of the configuration of a support assembly embedded in the tire to provide the desired rigidity pattern;

Fig. 4C exemplifies an additional rigidity pattern that can be used in the tire of the invention;

20 **Figs. 5A and 5B** show another possible support assembly embedded in the tire to provide a desired rigidity and flexibility pattern, and

Figs. 6A and 6B illustrate advantageous operational features of the tire of the present invention.

Fig. 7 is a perspective view of a deformable wheel, according to an embodiment of the invention;

25 **Fig. 8** is a perspective cross-sectional view of the wheel of Fig. 7;

Fig. 9 shows a large cross-sectional view of a portion of the wheel with the internal load-bearing structure contained within the tire; and

Fig. 10 is a cross-sectional perspective view of a portion of the tire illustrating the manner of association of a reinforcing element with side walls of the tire.

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DETAILED DESCRIPTION OF EMBODIMENTS

In order to better understand the features of the tire configured according to the present invention, utilizing the V-shape groove structure described above, reference is made to **Figs. 1A to 1C** describing the physical reason that is behind the typical behavior of a traditional tire (regardless of its size or cross section) as compared to the tire of the present invention. **Fig. 1A** shows a tire in its loaded and unloaded states. In the figure, a circle **C₁** in the middle with diameter **620** constitutes a rim, a circle **C₂** is the unloaded tire, and lines **L₁** and **L₂** between the rim **C₁** and the outer circumference of the unloaded tire **C₂** indicate the line of the tire sidewall in a normal tire. The sidewall in the fully inflated tire defines the maximal distance between the outer circumference and the rim, i.e. the outer circumference under any condition cannot breach the outer diameter of the tire. Curve **R₁** corresponds to a condition of a conventional tire when deflated, while curve **R₂** corresponds to that of a tire in accordance of the present invention when deflated.

When air is discharged from the tire, the tire will collapse (under the vehicle weight) and the rubber will have to be displaced somewhere. Since the circumferential dimension cannot increase the original diameter (lines **L₁** and **L₂**), the rubber will shrink and compress a little bit and will increase the footprint a bit. If the tire is further deflated, it will have to collapse, and since it cannot collapse outside, it will collapse inside as shown by curve **R₁**. When the same occurs with the tire of the present invention, the outer circumference will be pushed away (under the load), and, since it has no limitation (the sidewall here is actually the "wall of the cup" and is almost horizontal, and it can 'get away' from the rim), it will deform to absorb and receive the shape of the ground, as by curve **R₂**.

Figs. 1B and 1C show the footprint of the tire of the present invention in respectively, inflated and deflated states thereof. As can be seen, a 200% increase in footprint is achieved.

Reference is now made to **Figs. 2A to 2C**, illustrating tires configured according to the invention. **Fig. 2A** shows the tire **100** which is configured as an envelope structure whose inner surface **111** encloses a cavity **112**. The latter may be filled by gas,

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e.g. air. Generally, the tire may or may not be inflatable. The tire envelope **100** has an outer, surface engaging side **110** (tread, having a circumferential surface), and opposite side walls **120A** and **120B** which are integral with the surface engaging side **110** and extend therefrom. The side walls by their free ends **160** are connectable to a rim of a locomotion assembly (not shown) and thus actually define a rim engagement side. According to the invention, each of the opposite side walls **120A** and **120B** has a surface pattern defining at least one substantially V-shaped groove **140** between the surface engaging side **110** and the rim engagement side **160**. In the present not limiting example, a single-groove pattern is provided in each side wall.

The groove **140** has inner and outer sides **150** and **130** intersecting at the groove apex **180**. As better seen in **Fig. 2B**, the outer side **130** of the groove is connected to the surface engaging side **110** via a corner region **170** of the tire envelope **100**, and the inner side **150** of the groove is connected to the rim engagement side **160** via another corner region **190** of the envelope **100**. The configuration is such that these corner and apex regions **170**, **180** and **190** have lower rigidity and higher flexibility/elasticity than the inner and outer sides of the groove. Thus, each of the side walls **120A**, **120B**, has a surface pattern forming at least one V-shaped groove, and also has a rigidity pattern extending across the side wall (i.e. along radial axis) of the tire. As also shown in the figure, the tire at its rim engagement side **160** is typically formed with non-stretchable circumferential member (bead) that secure the tire to the rim and in most cases is constructed from steel cords.

Preferably, the side walls **120A** and **120B** have additional rigidity pattern defined by different rigidities of the inner and outer sides **150** and **130** of the groove **140**. More specifically, the inner side **150** of the groove **140**, by which it is connected to rim engagement side **160** of the tire **100** has higher rigidity than the outer side **130** of the groove connected to the surface engaging side **110** of the tire. The inner side **150** has higher rigidity than the outer side **130** along both radial and circumferential axes.

Fig. 3 shows more specifically the surface and rigidity patterns. As shown, these patterns extend along a path **310**, i.e. across the side wall **120A**, which can generally be defined as “radial axis” of the tire **100**. One of the patterns is in the form of a surface relief defined by the provision of at least one groove **140**, and the other pattern is the rigidity pattern along the path **310** (e.g. material composition). The rigidity pattern is

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formed at least by providing lower rigidity at the corners **170**, **190** and apex **180**, and possibly also by different rigidities of the outer and inner sides **130** and **150** of the groove.

Generally, the rigidity pattern across the side wall may be achieved by using
5 different materials or the same material, such as rubber, that has undergone different degrees of hardening processes and/or has different thicknesses. The rigidity pattern may be produced by embedding a support structure within the tire. The support structure is typically in the form predetermined arrangement of support elements, such as cables, fabrics, cords, textile, micro fibers. The support elements are oriented with
10 respect to circumferential and radial axes in order to provide the desired rigidity and flexibility distribution in the tire, which provide for securing the circumferential length all along the cross section of the tire defined by path **310** from the rim engagement side (bead) **160** to the surface engaging side (tread) **110**, as well as maintain circumferential flexibility along the same cross section. Also, the rigidity and flexibility distribution
15 should be selected to maintain radial rigidity over the inner and outer sides (cones) **150** and **130** while keeping the sufficiently flexing points at the corner regions, i.e. region **190** between the groove and bead, region **180** between the inner and outer sides (i.e. the groove apex region), and region **170** (so-called “shoulder”) between the groove and tread.

Reference is made to **Figs. 4A and 4B** showing a specific but not limiting
20 example of the tire **100** of the present invention. As shown in the figures, the sides of the groove as well as the surface engaging side are provided with the support elements. The support elements include a so-called shoulder belts extending along the surface engaging side close to the shoulder (**170** in **Fig. 3**), inner cone plies and outer cone plies
25 oriented with certain angular relation between them and with respect to the radial and circumferential axes.

As shown in the specific example of **Fig. 4A**, the rigidity pattern can be achieved by providing cables **410** and **420** embedded in the tire envelope, in the surface engaging side **110** and the outer and inner sides of the groove in the side wall **120A**.
30 **Fig. 4B** shows the same configuration of **Fig. 4A** from a different angle. It should be noted that the cables **410** are used to secure the circumferential length of the tire at the surface engaging side **110**, close to the corner **170**.

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Reference is now made to **Fig. 4C** that illustrates another feature of the invention, which can additionally be used in any of the above-described examples. In some embodiments of the invention, the tire has additional rigidity pattern extending along the circumferential axes of at least one of the outer and inner sides of the groove **140** made in the side wall **120A**. As can be seen in this specific not limiting example, the outer and inner sides **130** and **150** of the groove **140** have a varying thickness defining the rigidity pattern. The varying thickness is formed by an array of spaced apart of relatively thick regions **450** spaced by thinner flexing regions **460**, where the array extends along the circumferential axis of the respective side of the groove, and the regions area aligned substantially perpendicular to the tire plane (i.e. across the groove side). This configuration allows for achieving a desired circumferential rigidity pattern by, *inter alia*, appropriately selecting the pattern features, i.e. the thickness of different regions **450** and **460**, and a distance between the locally adjacent thick regions **450** (i.e. the length of the thin flexing zones **460**).

It should be noted, although not specifically illustrated, that the desired rigidity may be obtained by replacing the projecting (thicker) regions **450** by slots thus forming thinner regions spaced by thicker regions of the tire. In a different embodiment, such varying rigidity (rigidity/flexibility pattern) along the groove side may be achieved by forming the groove side with spaced-apart recesses/grooves and attaching/embedding there desirably rigid elements.

As already described above, the tire of the present invention should be rigid along its radial direction. In some embodiments of the invention, it is desirable to maintain the radial rigidity of the tire while at the same time keep circumferential flexibility. Therefore, the V-shaped groove might be strengthened in an uneven way. This can be achieved by providing/embedding in the tire a support structure which adds rigidity to the tire along the radial axis but at the same time enabling the tire to be sufficiently flexible in its circumferential direction.

An example of obtaining this is by using a spring-like support structure as exemplified in **Figs. 5A and 5B**. **Fig. 5A** illustrates one possible not limiting example of such spring-like support, in the form of a continuous spring **510** embedded in the outer and inner sides **150** and **130** of the groove **140**. The continuous spring **510** extends across the entire groove **140**, from the outer side **150** of the groove to its inner side **130**

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while passing through the apex **180**. This configuration gives the groove and the whole tire the desired rigidity in the radial and circumferential directions while the rigidity in the circumferential direction is significantly lower than that in the radial direction, by this achieving the desired flexibility along the circumferential axis.

5 **Fig. 5B** exemplifies a somewhat different configuration of the support structure which is formed by separate spring-like support members, the first one **520A** is embedded in the outer side **150** of the groove, and the second one is embedded within the inner side **130**. In addition, a belt **530** is embedded in each of the inner and outer sides of the groove, closer to the groove apex **180**. It should be noted that the
10 configuration in **Fig. 5A** is probably more rigid in the radial axis than the configuration shown in **Fig. 5B**, enabling the design of different tires with different rigidities as may be required in specific situations.

It should be noted that the above exemplified springs may be substituted by any other suitable support elements made of substantially stiff material such as polymers,
15 composite materials, and other alloys.

Reference is now made to **Figs. 6A and 6B** illustrating some advantageous operational features of the tire **100** of the present invention. The tire is shown while being subject to pressure caused by inflation (filling gas in the cavity **112**). In order for the tire **100** to hold the air pressure that exerts forces on the side walls **120A** and **120B**
20 and pushes the outer side **130** and inner side **150** of the groove outside as exemplified by their positions **130'** and **150'** respectively, it is necessary to provide the side walls **120A** and **120B** with sufficient radial stiffness, otherwise the side walls may fold, collapse and bulge out.

As described above, the side walls have rigidity patterns that give the outer and
25 inner sides of the groove the required rigidity to withstand the gas (air) pressure and prevent the side walls from collapsing, i.e. bulging out. One possible occurrence is exemplified in **Fig. 6B** in which the relatively flexible apex **180'** bulges outside due to high pressure, whereas the rigidity applied to the outer and inner sides of the groove keep the tire from bursting and or collapsing.

30 As indicated above, the above described tire (i.e. with V-shaped grooves across its side walls and with a specific rigidity pattern/profile along the groove) may by itself

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present a vehicle's wheel assembly, or such tire may be mounted on a load-bearing arrangement to form together a wheel assembly. The wheel assembly may have two configurations: a rounded, non-deformed configuration in which a surface-engaging side of the tire is substantially circular and a deformed configuration in which the surface-engaging side of the tire is non-circular and has an extended portion that engages the surface. As also indicated above, the wheel assembly of the present invention in some embodiments thereof presents an improvement of the locomotion assembly of the kind disclosed in a co-owned international application No. PCT/IL2011/000115, which is incorporated herein by reference.

As also indicated above, the tire regions at the apexes **180** of the grooves **140**, as well as corner regions **170** and **190** at opposite sides of the groove are relatively flexible. In a deformable wheel assembly utilizing such tire the flexible portions of the side walls (particularly at said apexes), considerable strains may develop. Such strains can be reduced by providing a specifically designed load-bearing arrangement. The load-bearing arrangement may be formed of discrete, dove-tailing elements, which are arranged in a manner to define two oppositely oriented substantially frustum-conical structures. The side walls of the tire- enclosure trace the frustum-conical surfaces and have thus an overall V-like cross-sectional shape with the apexes of the V-shapes of the two side walls facing one another. Such a locomotion/wheel assembly is at times referred to herein as "deformable wheel".

Fig. 7 illustrates a deformable wheel generally designated **200** with a tire **100** formed around a wheel hub **104** (sometimes known as "rim") arranged about an axis **A**, which in use coincides with the wheel's axle. The tire **100** has a surface engaging side/member **110** (tread, having a circumferential surface) with an appropriate surface relief for firm gripping of the surface and has side walls **120A** and **120B**.

As can be seen in **Figs. 8 and 9**, the side walls **120A**, **120B** have respective peripheral portions **114A**, **114B** defining a groove **140** with a generally V-shaped cross-section, ending with more central, respective, skirt portions **190**, which are configured to form a gas-tight seal with the hub **104** (manner of forming gas-tight seal best seen in **Fig. 2**). The tire may be reinforced by metal, e.g. steel, fibers or cables, two of which: **113A** and **113B**, **115A** and **115B**, which are circumferential fibers embedded within the rubberized matrix of the tire, are illustrated in **Fig. 9**.

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The surface engaging side **110**, side walls **120A**, **120B**, and hub **104** generally define an enclosure **100** for holding pressurized gas, e.g. air. As described above, by change in gas pressure within the enclosure **100**, the wheel can change its configuration from a generally circular one to a deformed configuration, in which an extended portion
5 of the surface engaging member engages a surface.

As exemplified in the embodiment of **Fig. 9**, included within the tire is a load-bearing arrangement generally designated **540**, which is formed by a plurality of support elements comprising elements **132** arranged in a first array in a spaced-apart manner; and a second array of elements **134** arranged in a second spaced-apart manner. The
10 support elements provide desired rigidity pattern/profile along the V-shaped groove.

In this embodiment, elements **132** and **134** are identical and the arrays are substantially, slightly axially-shifted (shifted by about half of the angular displacement between adjacent elements in an array) mirror images of one another. Each array of elements define substantially frustum-conical structures that intersect one another at an
15 intersection zone **550**, whereby the elements **132** and **134** are arranged in a dovetailing manner with each of elements **132** and **134**, being flanked by two elements **134** and **132**, respectively.

As can be seen in **Fig. 9** and also in **Fig. 10** (the latter representing in isolation element **132** to illustrate its structure and manner of association with the rubberized
20 portion of the tire), each of elements **132**, **134** has a generally curved side elevation. To facilitate easier reading, the description of the structure of each element will focus on element **132**, which is substantially identical to that of element **134**.

As can be seen in **Figs. 9 and 10**, element **132** has a generally curved side profile and includes a metal rib **142** embedded in a rubberized matrix **144**. The overall
25 curved structure defines a first segment **132A** and a second segment **132B**, defined on two opposing sides of the point of intersection **550**, and an intermediate section **132C**. The metal rib thus has corresponding segments **142A**, **142B** and **142C**. Segments **142A** and **142B** are located in parallel and spaced apart planes.

Upon deformation of a portion of the wheel, the first array of elements **132** and
30 the second array of elements **134** pivot one against the other, in the direction of arrows **X₁** and **X₂**. As a result, segment **134A** of element **134** comes into closer elevation

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proximity to segment **132A** of element **132**; and the same applies with respect to segments **132A** and **134B**. Side wall portions **114A**, **114B** have respective first regions defining outer sides **130** of the groove, which trace the frustum-conical surface defined by segments **134A**, **132A** (and thus by themselves define a substantially frustum-conical surface); and similarly have regions **150** that also trace a frustum-conical surface defined by segments **132B**, **134B**, with intermediate regions **180** at the apex of the V-shaped cross-section.

Pivotal movement, as illustrated by arrows **X₁** and **X₂**, also puts a strain on the rubberized portions of the tires, particularly at regions **180**. However, in the arrangement shown herein, where the segments on each side of a point of intersection **550** are situated in different spaced apart parallel (slanted) planes, the strain is considerably reduced as compared to what would occur in the case of a substantially straight element of the load-bearing structure. Each of elements **132**, **134**, defined between substantially parallel opposite side faces, has surface contours permitting tight association with corresponding portions of regions **130**, **150**, **180**, as is clearly illustrated in Figs. 9 and 10.

In the embodiment illustrated in these figures, the elements are fixed to the side faces **120A**, **120B** through gluing or welding. By other embodiments of the invention, the association may be less tight, permitting some movement tolerance between opposite faces of the elements and the side walls.

Thus, the present invention provides a novel configuration of a surface vehicle tire/wheel, which incorporates a different approach for providing a desired suspension assembly within the tire formed by the tire geometry and material characteristics. The suspension assembly is achieved by provision of substantially V-shaped grooves (in cross section) in the side walls of the tire envelope and desired rigidity and flexibility parameters of different regions/sides of the groove, and possible also of the surface engaging side of the tire.

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CLAIMS:

1. A wheel assembly for a surface vehicle, the wheel assembly comprising a tire comprising an envelope structure which by its inner surface encloses a cavity, said envelope structure comprising an outer, surface-engaging side having a circumferential surface, opposite side walls which are integral with and extend from said surface-engaging side, the sides walls by their free ends defining an inner, rim-engagement side of the tire by which the tire is connectable to a wheel hub, wherein each of the opposite side walls comprises a surface pattern extending between the surface-engaging side and the rim-engagement side and defining a surface relief in the form of at least one groove having a substantially V-shaped cross section, and wherein each of the side walls is configured with a predetermined rigidity pattern across the side wall.
2. The wheel assembly of claim 1, wherein the rigidity pattern comprises relatively small rigidity and thus relatively high flexibility of regions of the tire at apex of the V-shaped groove and corners defined by connection between the groove with respectively the surface engaging side and the rim engagement side of the tire.
3. The wheel assembly of claim 1 or 2, wherein said rigidity pattern comprises different rigidities of the tire within respectively an outer side of the groove closer to at the surface engaging side and an inner side of the groove closer to the rim engagement side of the tire.
4. The wheel assembly of any one of the preceding claims, wherein at least one of the inner and outer sides of the groove comprises a support structure configured to provide desired rigidity to said at least one side.
5. The wheel assembly of claim 4, wherein said support structure comprises an array of support elements embedded in said at least one side of the groove and extending along at least one of radial and circumferential axes of the tire.
6. The wheel assembly of any one of the preceding claims, wherein the surface-engaging side is configured to have predetermined rigidity along a circumferential axis of the tire.
7. The wheel assembly of claim 6, wherein said surface-engaging side comprises an array of support elements embedded therein.

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8. The wheel assembly of any one of the preceding claims, wherein said rigidity pattern comprises a pattern formed by varying thickness of at least one of an outer side of the groove closer to the surface-engaging side and an inner side of the groove closer to the rim-engagement side.

5 9. The wheel assembly of any one of the preceding claims, wherein said tire is supported on a load-bearing arrangement formed by a plurality of support elements, comprising a first array of spaced-apart elements and a second array of spaced-apart elements, the elements in each of the arrays defining together a frustum-conical structure, the two frustum-conical structures intersecting one another at a region of
10 intersection with the elements of one dove-tailing those of the other structure.

10. The wheel assembly of claim 9, wherein the elements of the first array and those of the second array are substantially the same.

11. The wheel assembly of claim 9 or 10, wherein the load-bearing arrangement carries the surface-engaging side of the tire and the two frustum-conical structures are
15 associated with the two opposite side walls of the tire.

12. The wheel assembly of any one of claims 9 to 11, wherein a region of intersection of two arrays of elements define for each of the elements, a first segment, extending from the region of intersection towards the surface-engaging side of the tire and a second segment extending substantially in the opposite direction, the elements'
20 first segments being associated with the tire and the elements' second portions being associated with a wheel hub.

13. The wheel assembly of any one of claims 9 to 12, wherein said elements are configured to have a curved side profile.

14. The wheel assembly of any one of claims 9 to 13, wherein a first segment of
25 each element defined for each element on one side of the region of intersection and a second segment defined on the other side are located in substantially parallel spaced-apart planes.

15. The wheel assembly of claim 14, wherein the first and second segments of each element are connected by an intermediated segment which is angled with respect to the
30 first and second segments.

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16. The wheel assembly of any one of claims 9 to 15, wherein the side walls end with a rigid skirt portions that is configured for forming a gas-tight seal with a wheel hub.

17. The wheel assembly of any one of claims 9 to 16, wherein one side of each of
5 the elements bears directly on the wheel's hub.

18. The wheel assembly of claim 17, wherein one side of each of the elements bear onto said skirt region.

19. A vehicle comprising the wheel assembly of any one of the preceding claims.

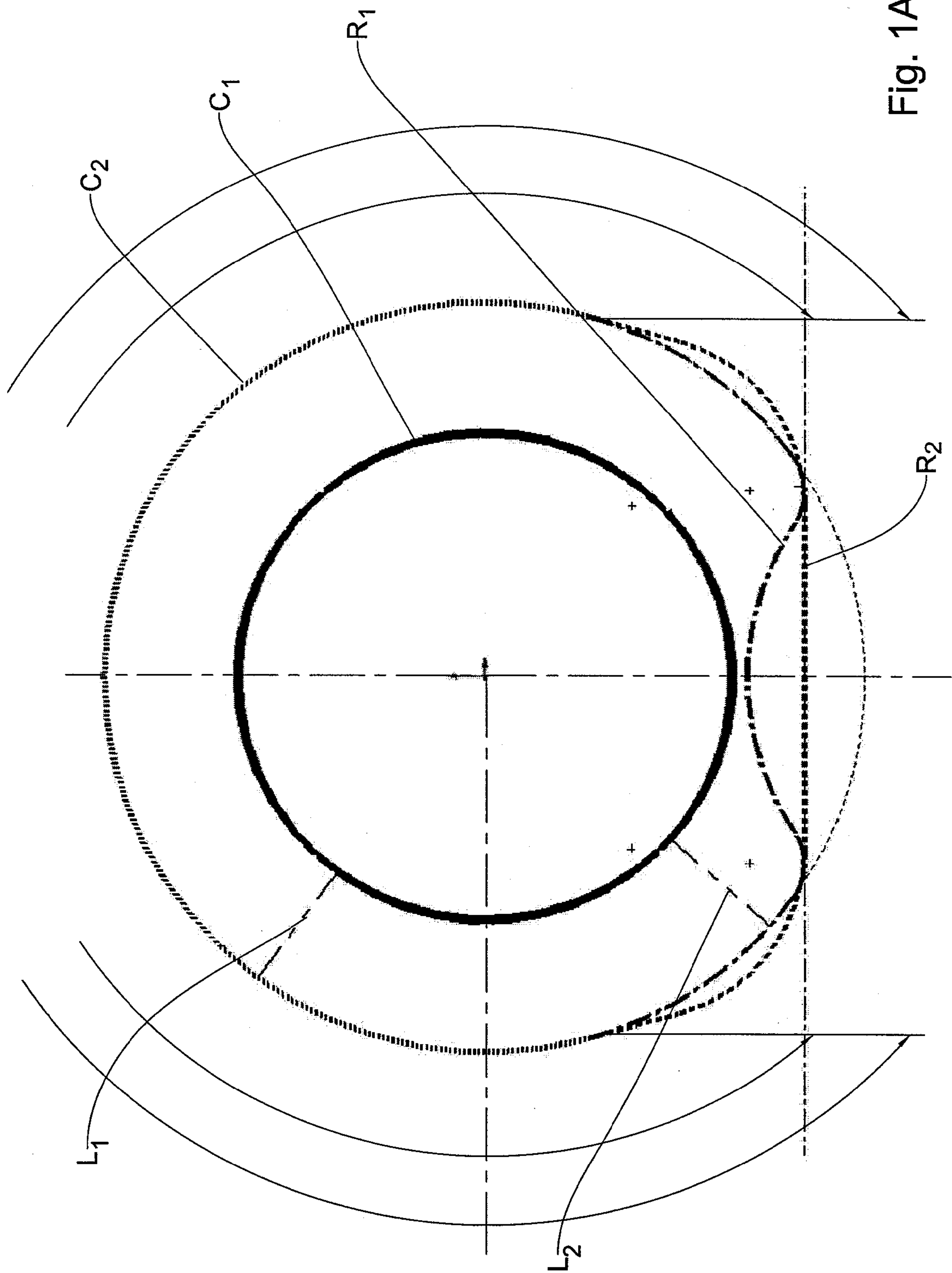
20. A tire envelope for a surface vehicle, comprising a surface pattern in its side walls
10 extending between a surface-engaging side and a rim-engagement side of the tire, said surface pattern configured as a suspension assembly embedded in the side walls to thereby prevent stretching of the tire envelope towards its maximal volume when the envelope is compressed with gas, while allowing deformation of the tire envelope when loaded or depressurized such that the surface engaging side of the tire maintains a
15 substantially constant contact with the surface.

21. The tire envelope of claim 20, wherein said surface pattern comprises a surface relief in the form of at least one groove having a substantially V-shaped cross section.

22. The tire envelope of claim 20 or 21, wherein said surface pattern comprises a predetermined rigidity pattern across the side wall.

23. A wheel assembly for a surface vehicle, comprising a tire envelope configured to
20 be mountable on a wheel hub, the tire envelope by its inner surface defining a gas cavity having a certain maximal volume defined by a geometry of the envelope, wherein the tire envelope comprises or defines a suspension assembly within its side walls, such that under gas pressure in said cavity the volume achievable through gas-pressure imposed
25 expansion is substantially smaller than said maximal volume defined by the geometry of the envelope.

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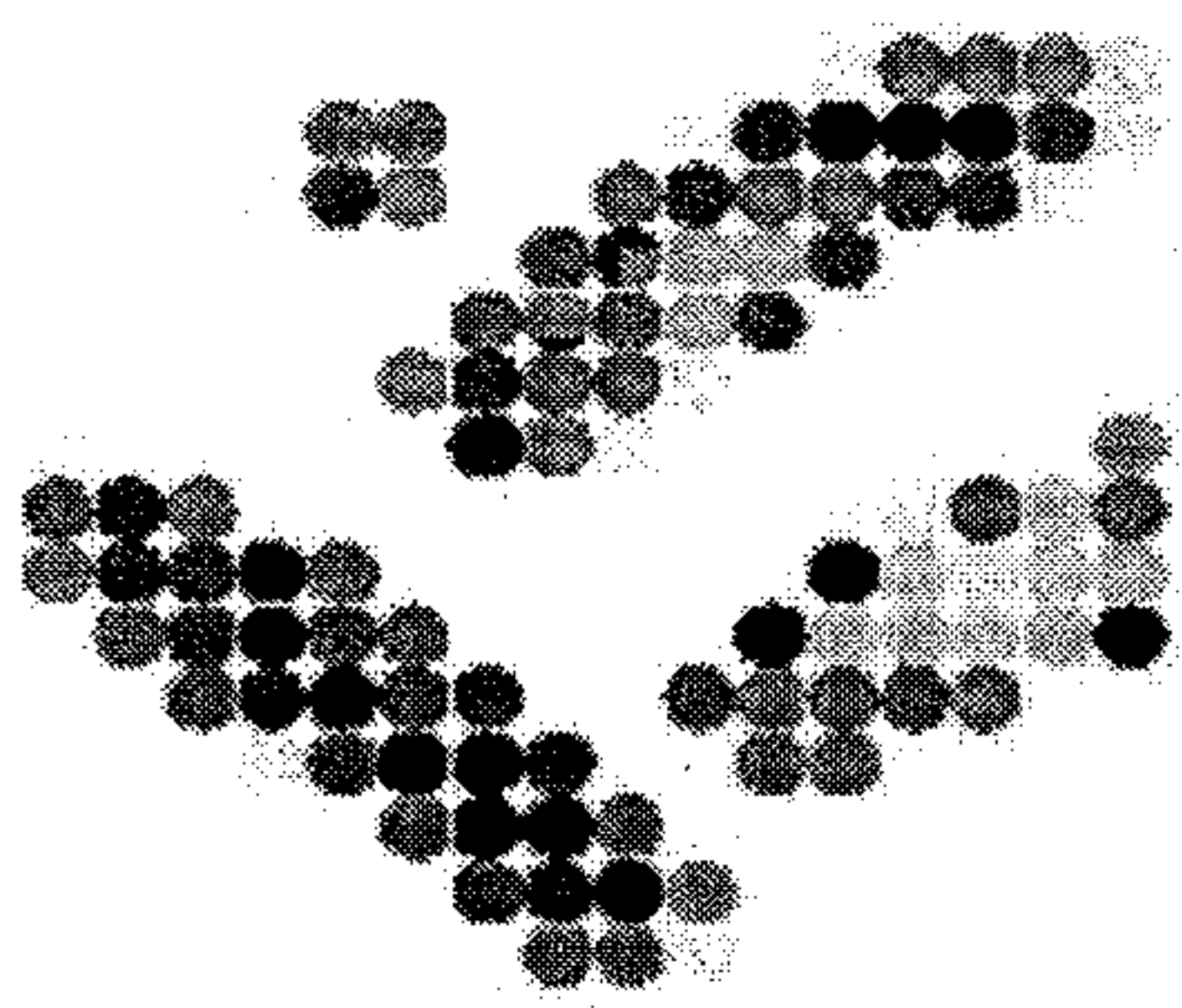


FIG. 1B

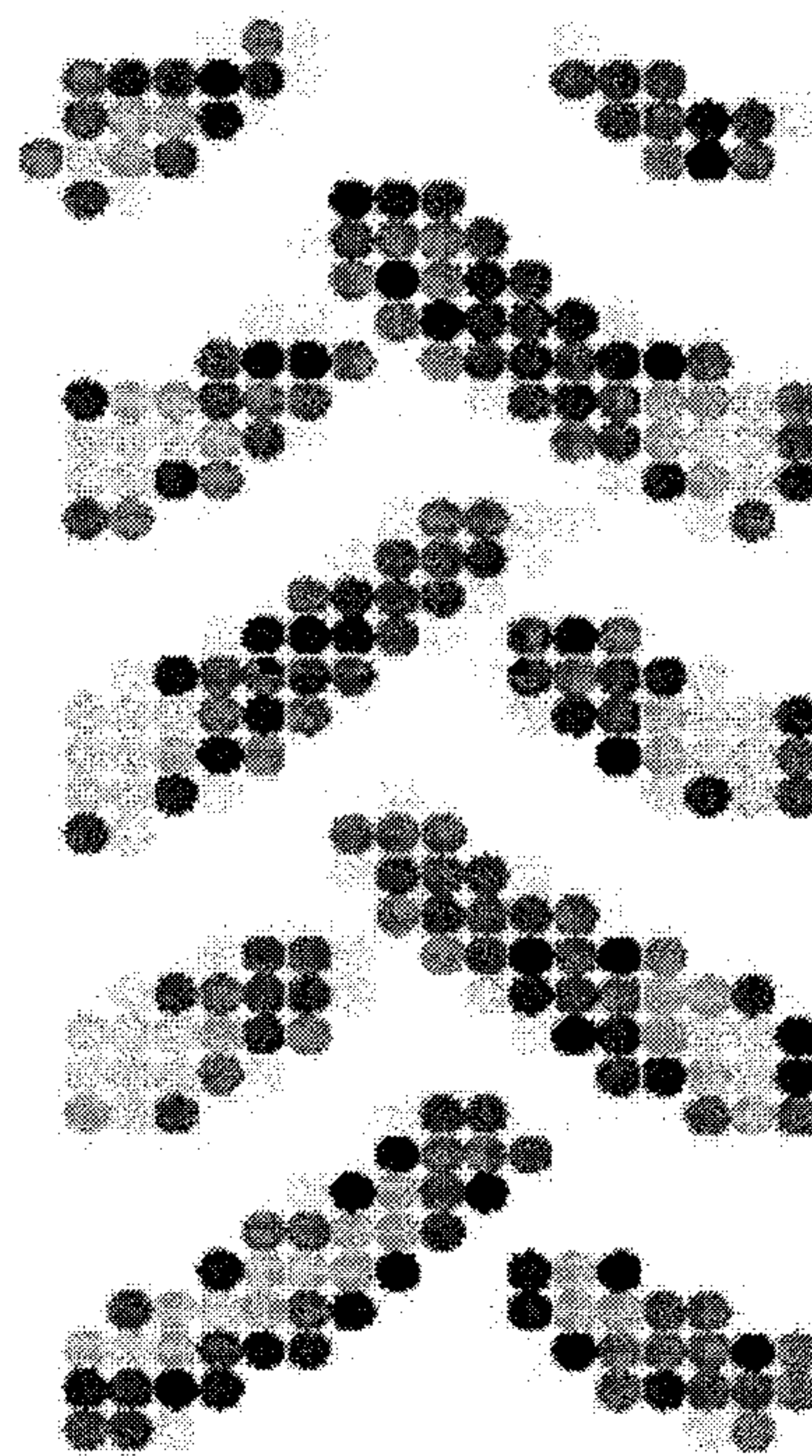
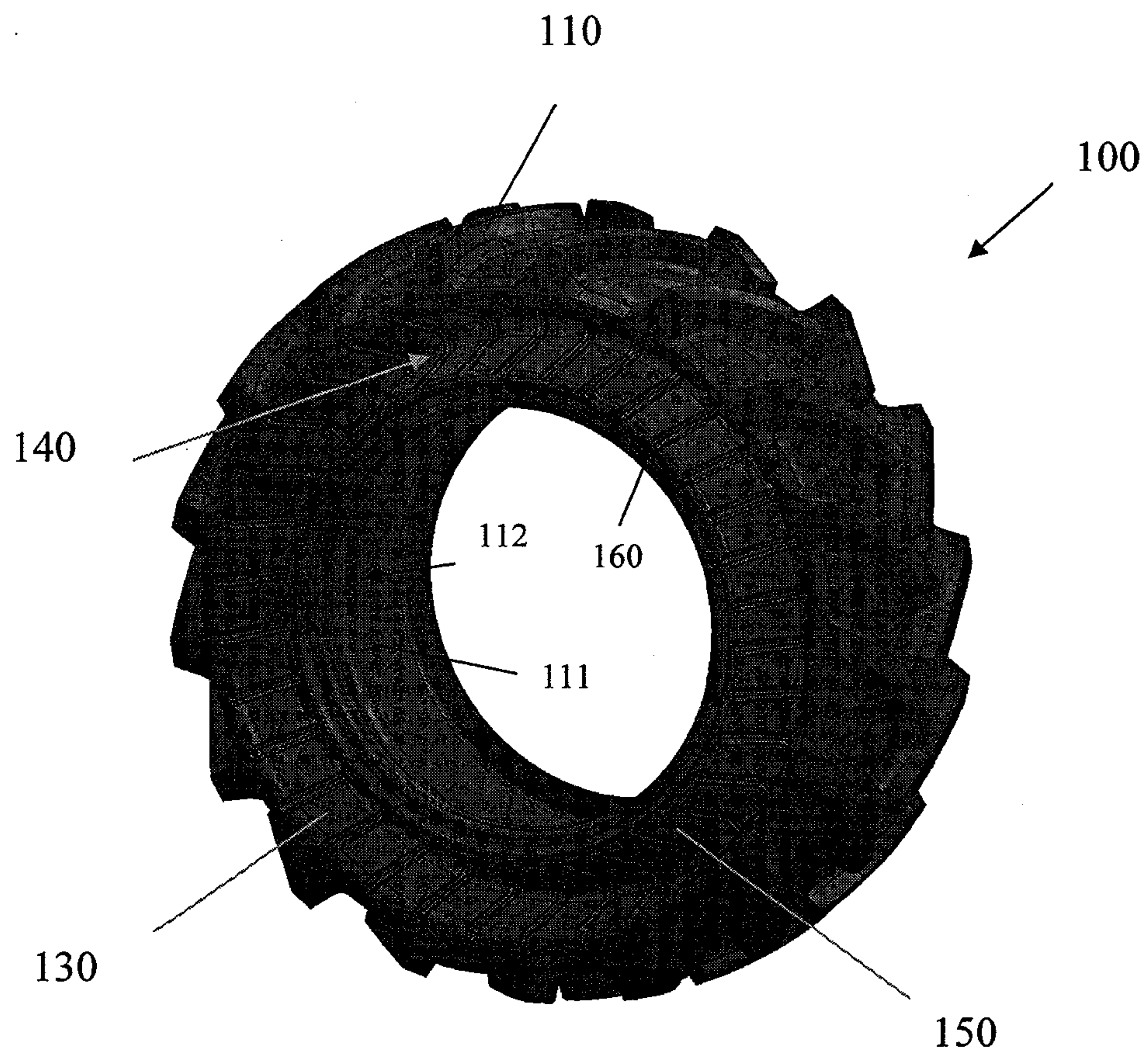
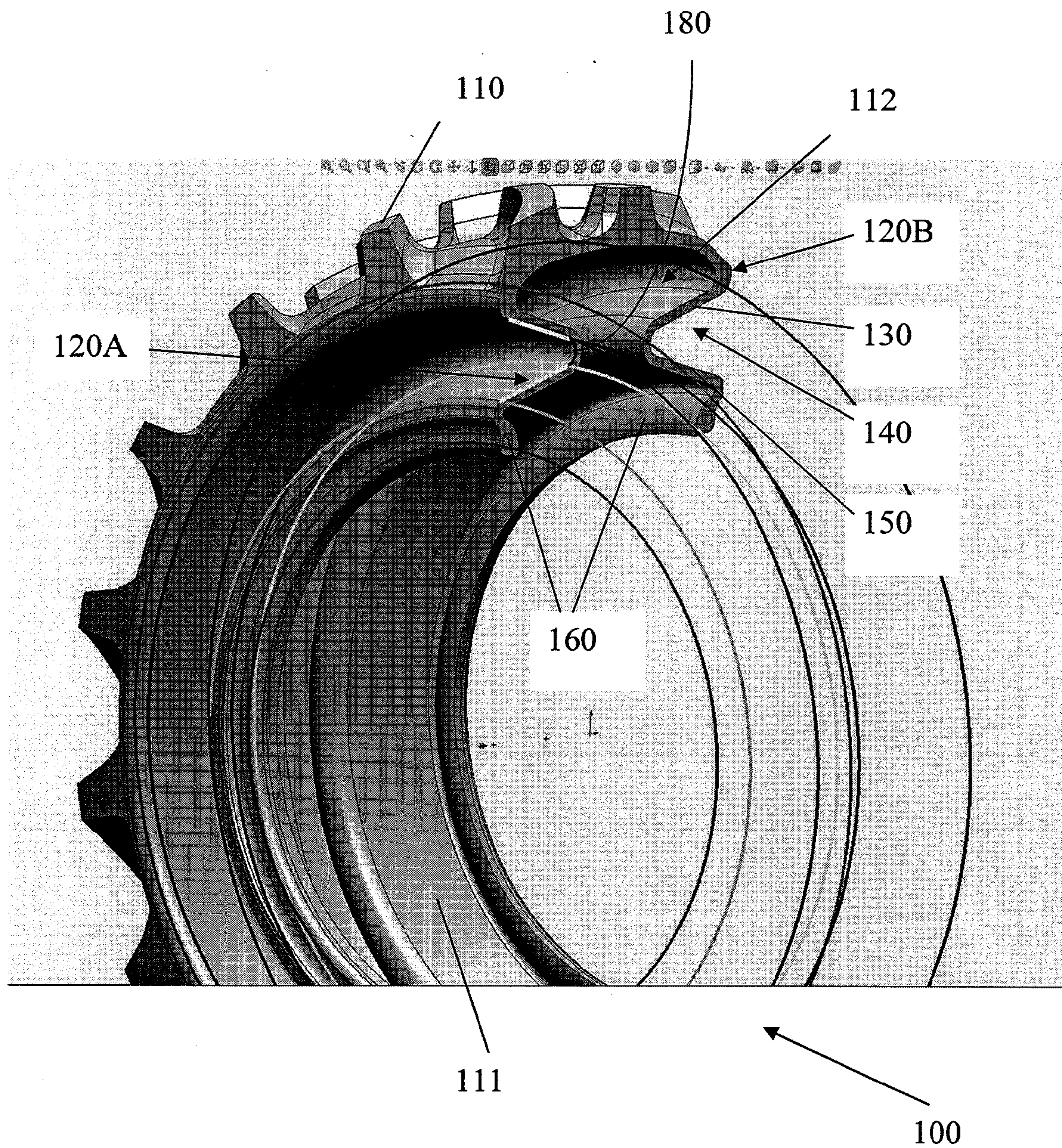


FIG. 1C

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**Fig. 2A**

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**Fig. 2B**

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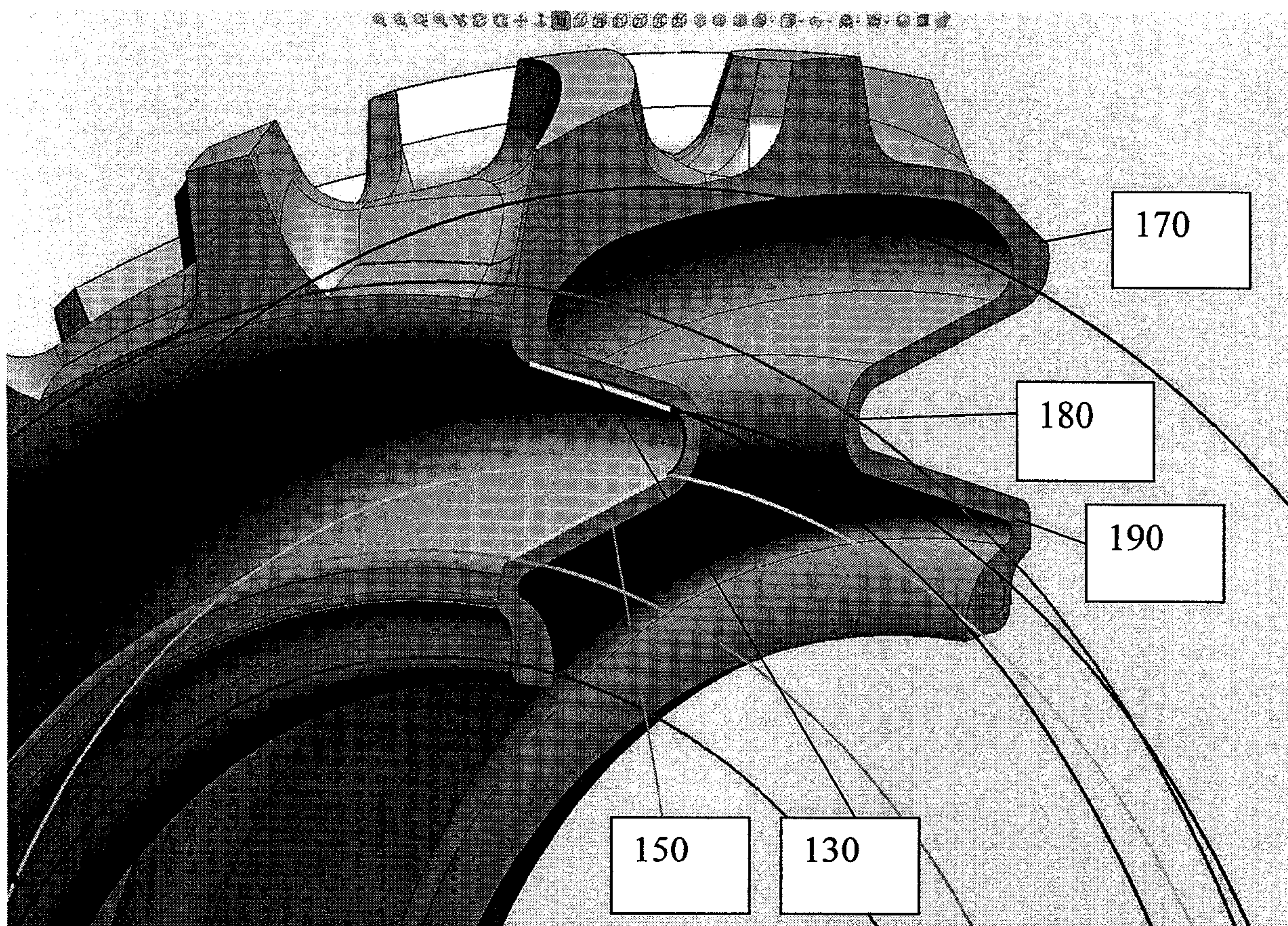
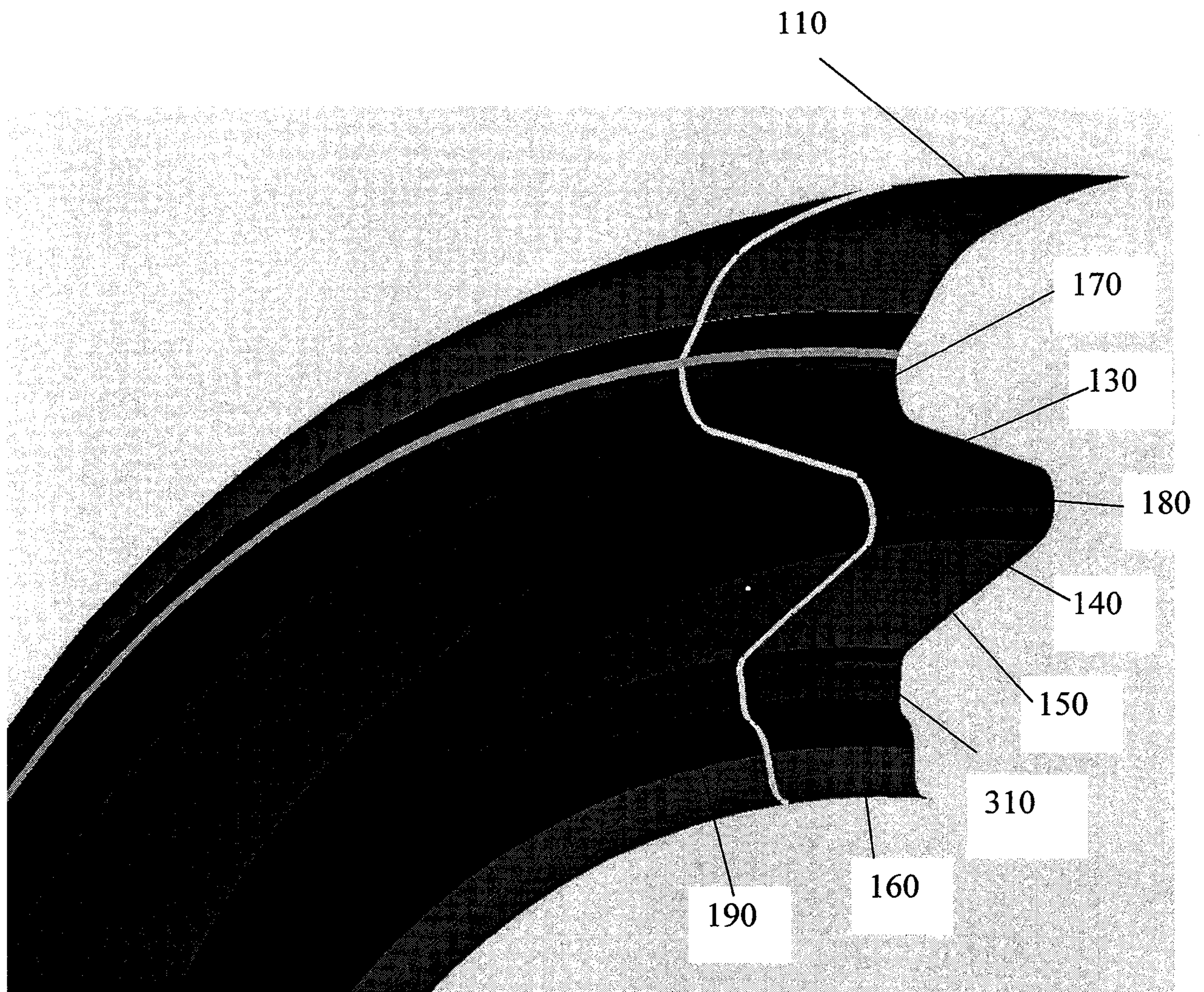
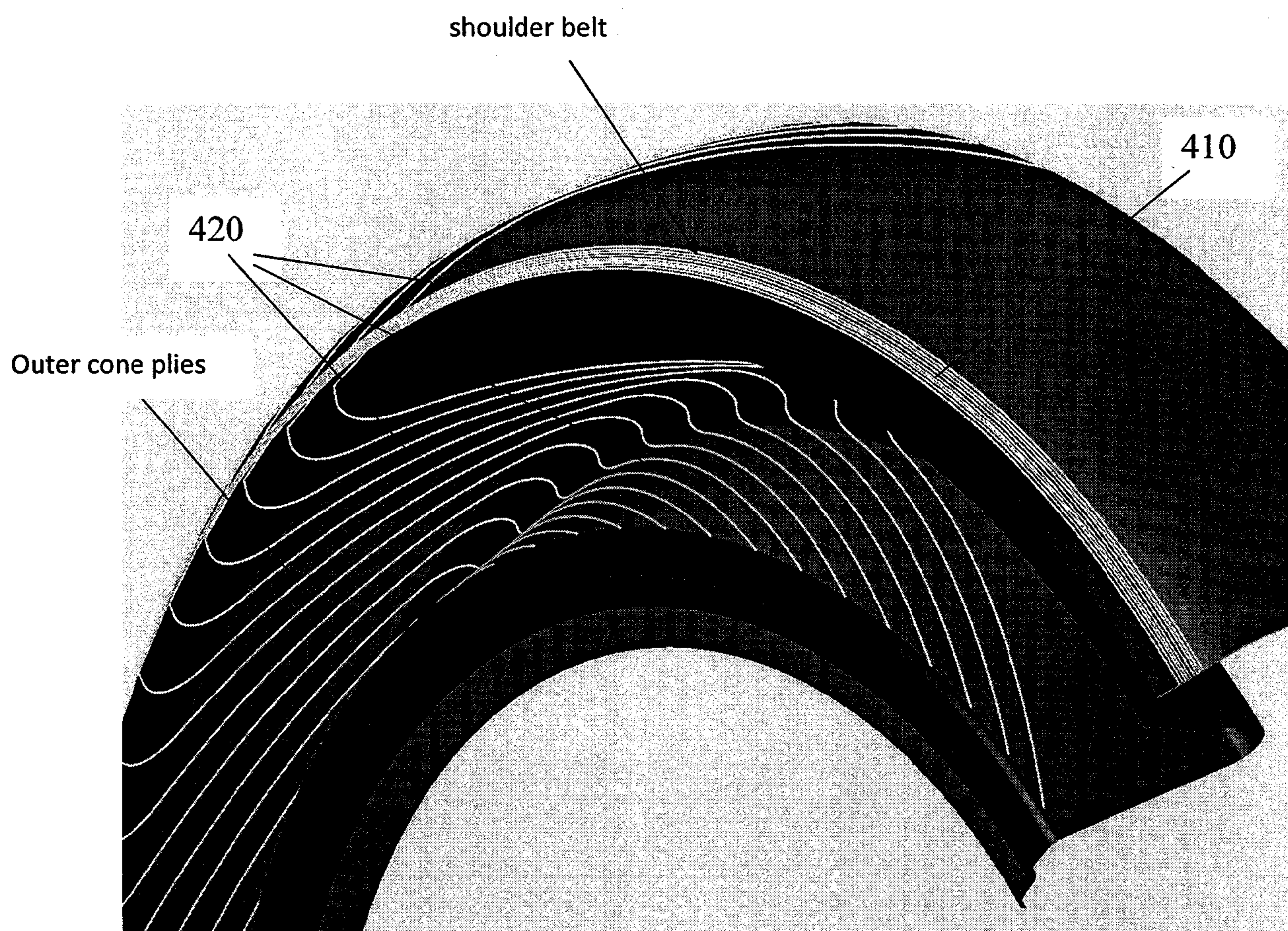


Fig. 2C

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**Fig. 3**

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**Fig. 4A**

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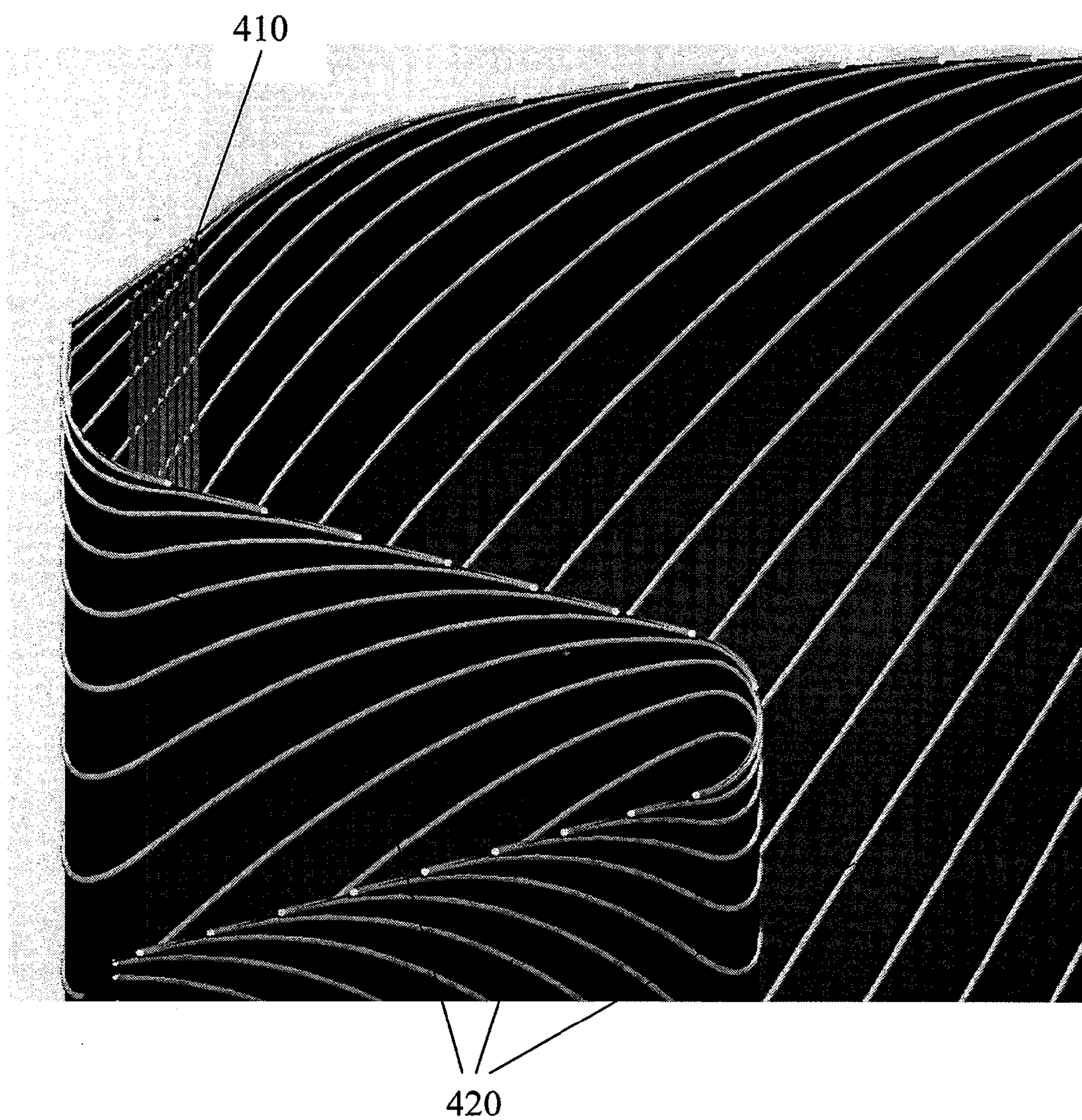
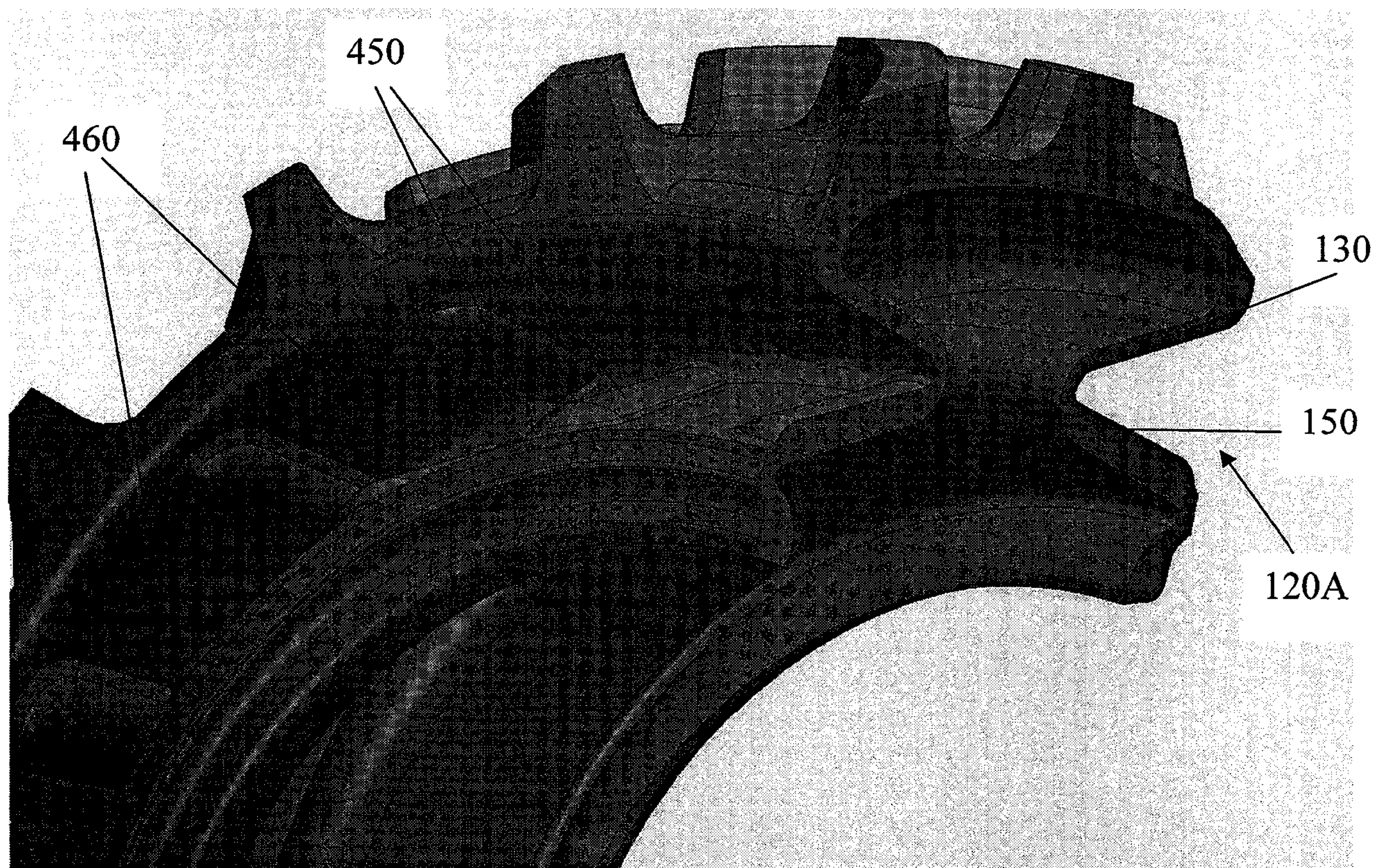


Fig. 4B

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**Fig. 4C**

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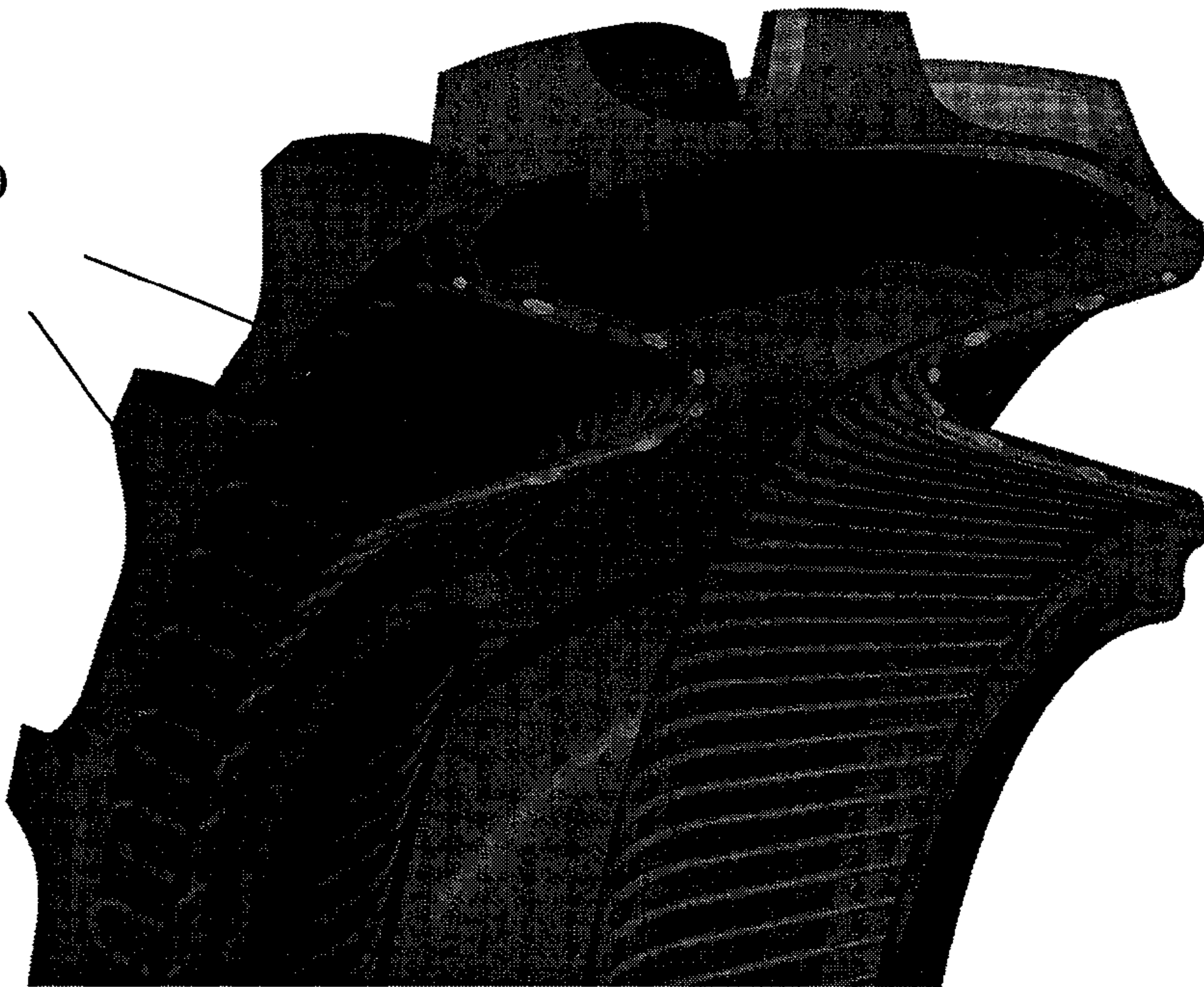


Fig. 5A

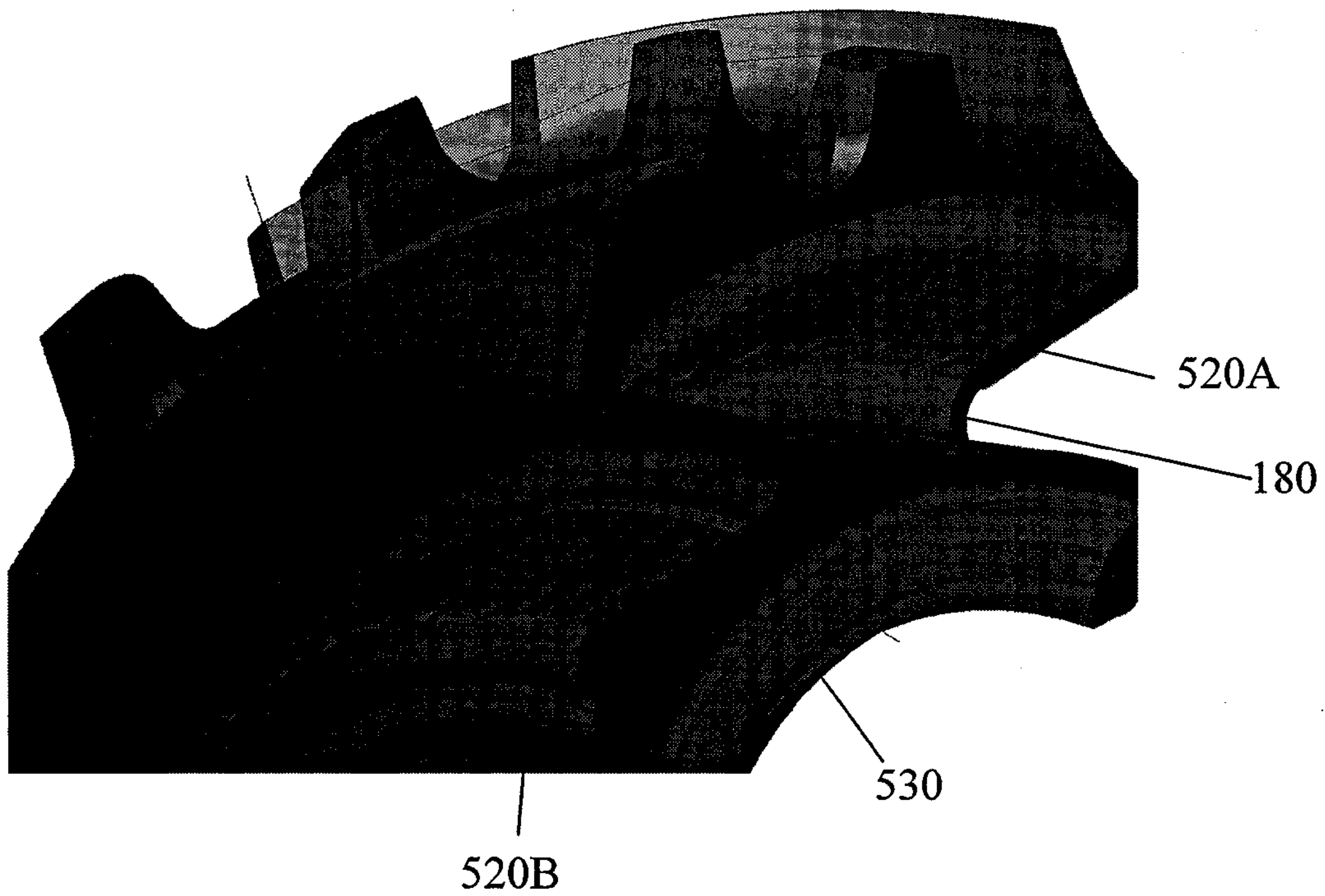


Fig. 5B

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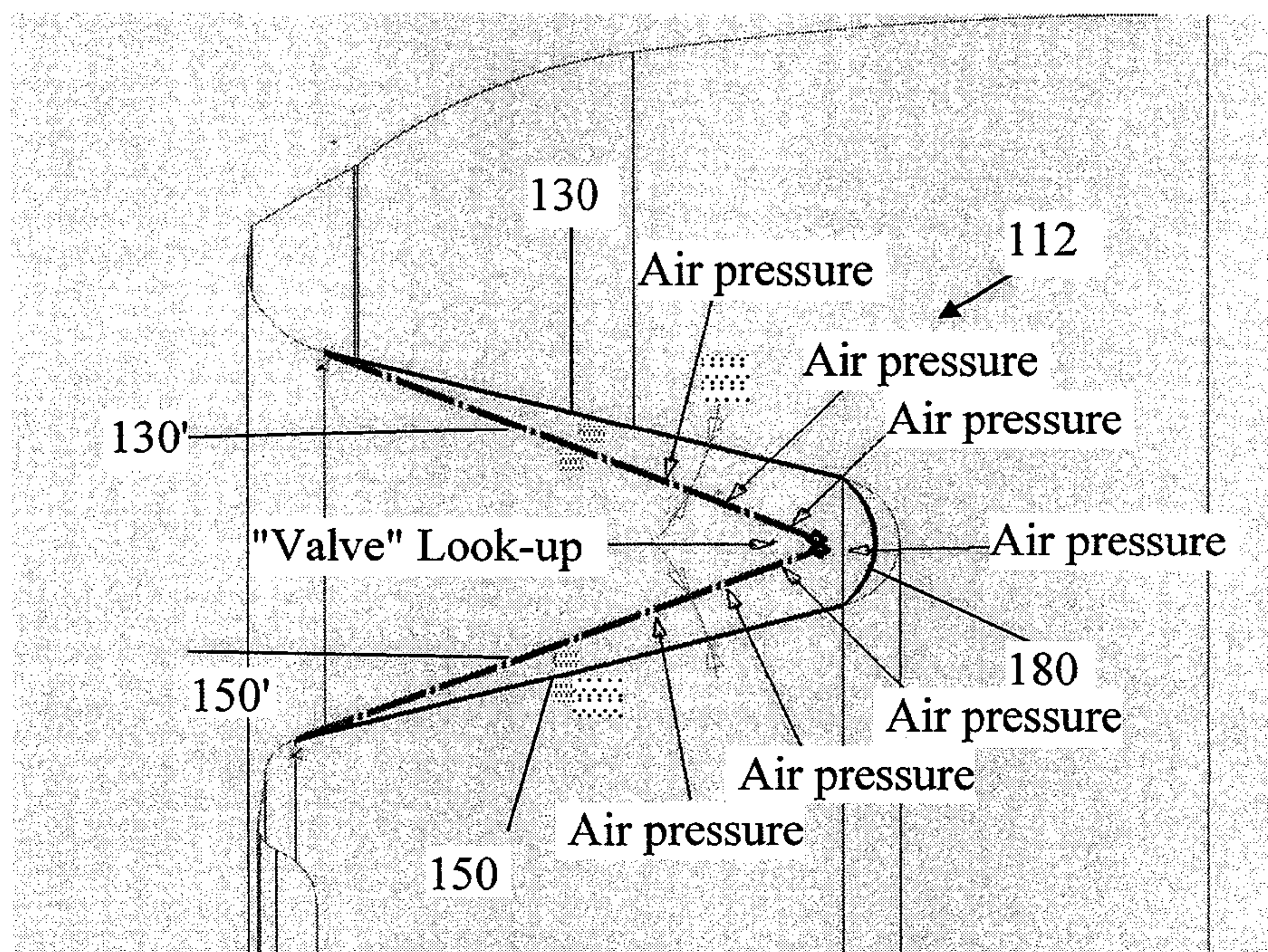


Fig. 6A

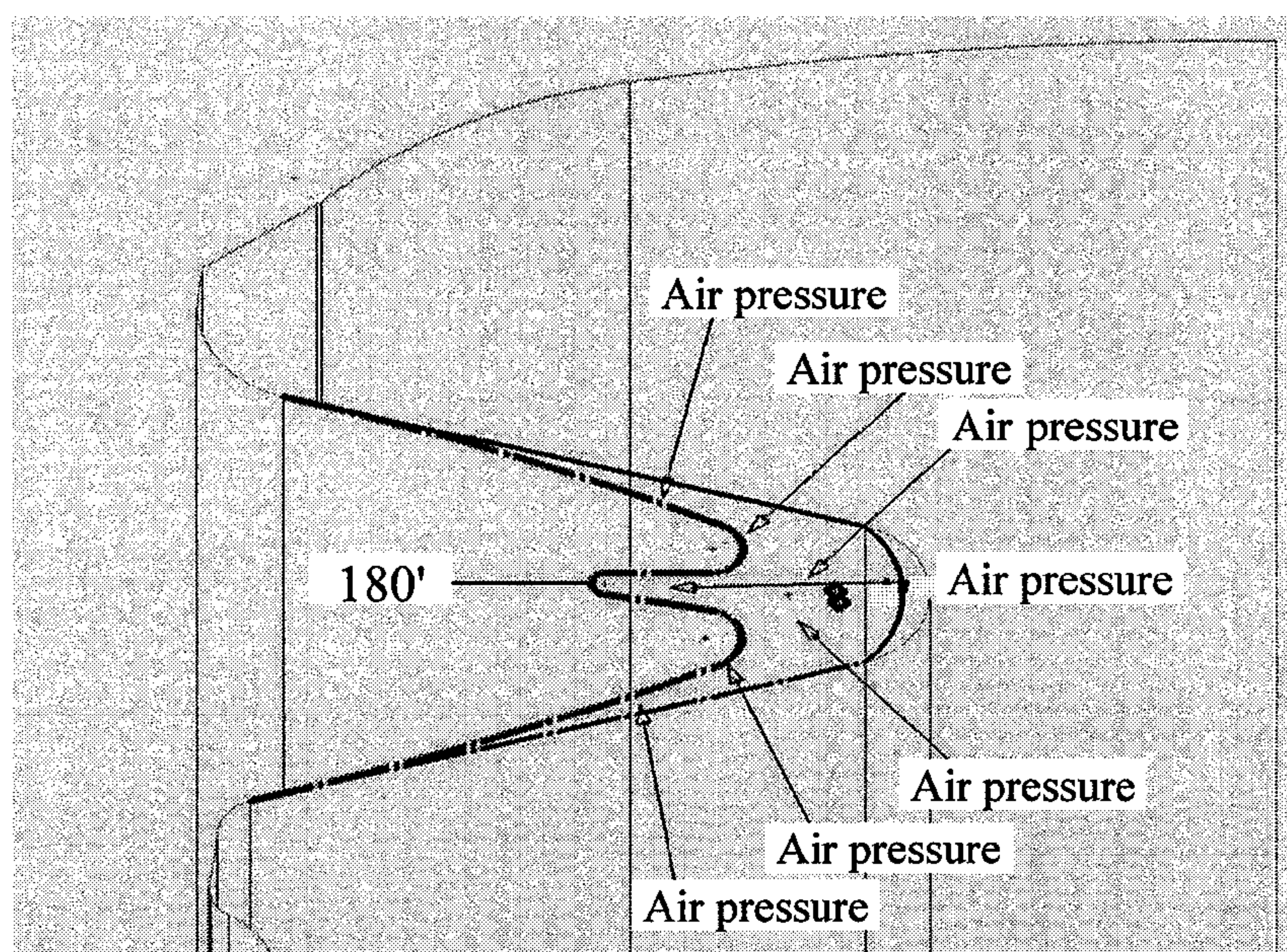


Fig. 6B

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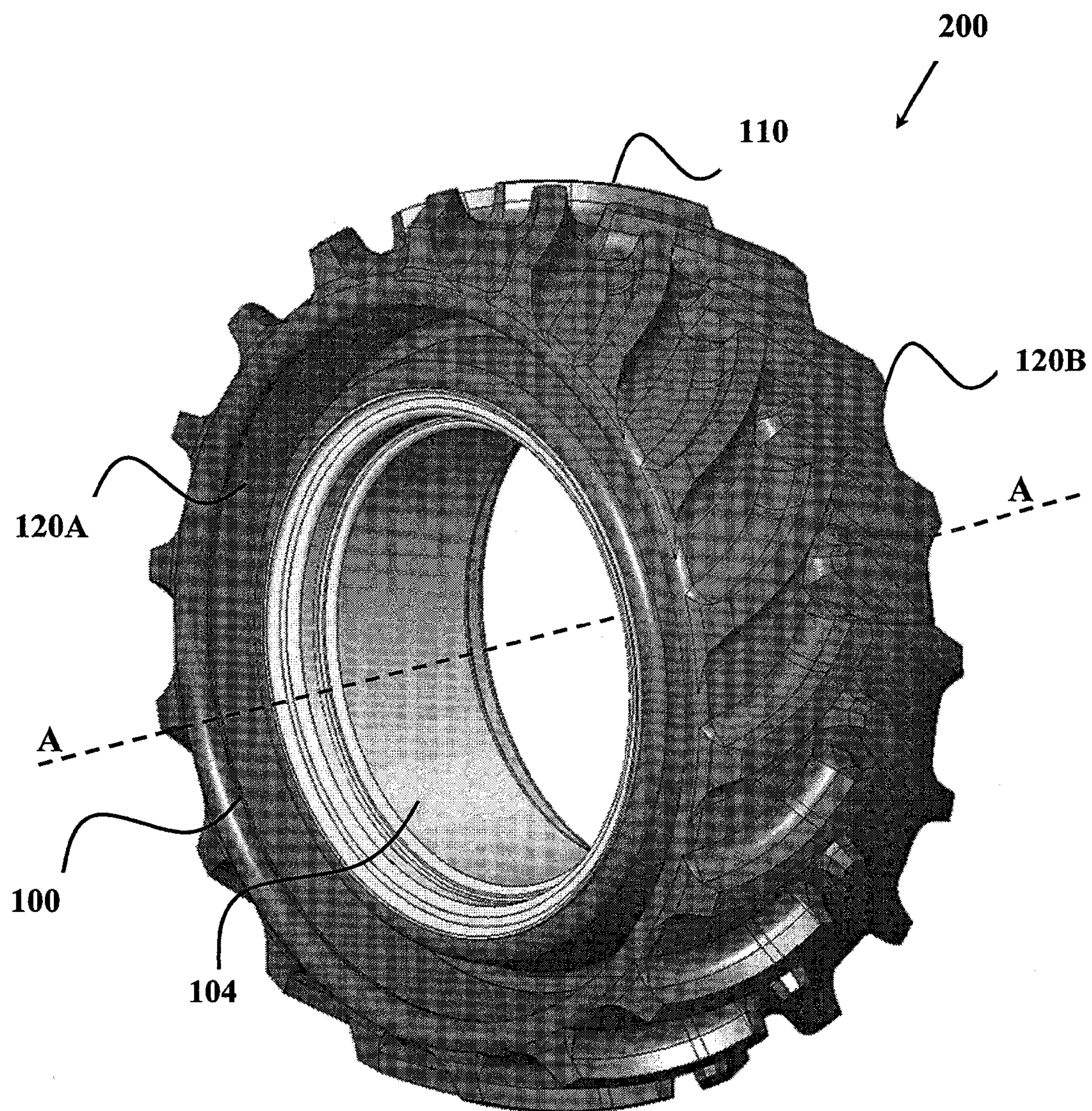


FIG. 7

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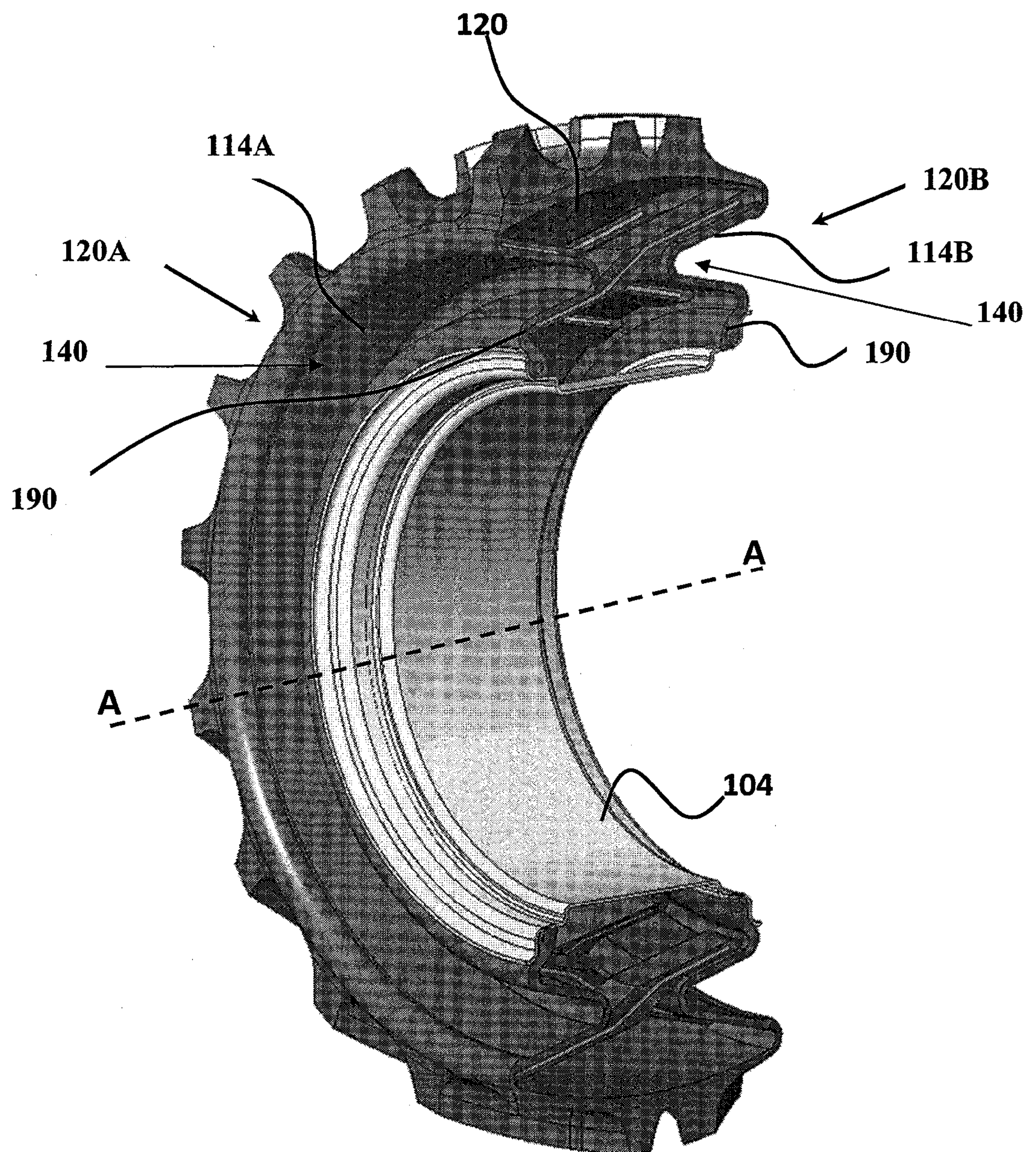


FIG. 8

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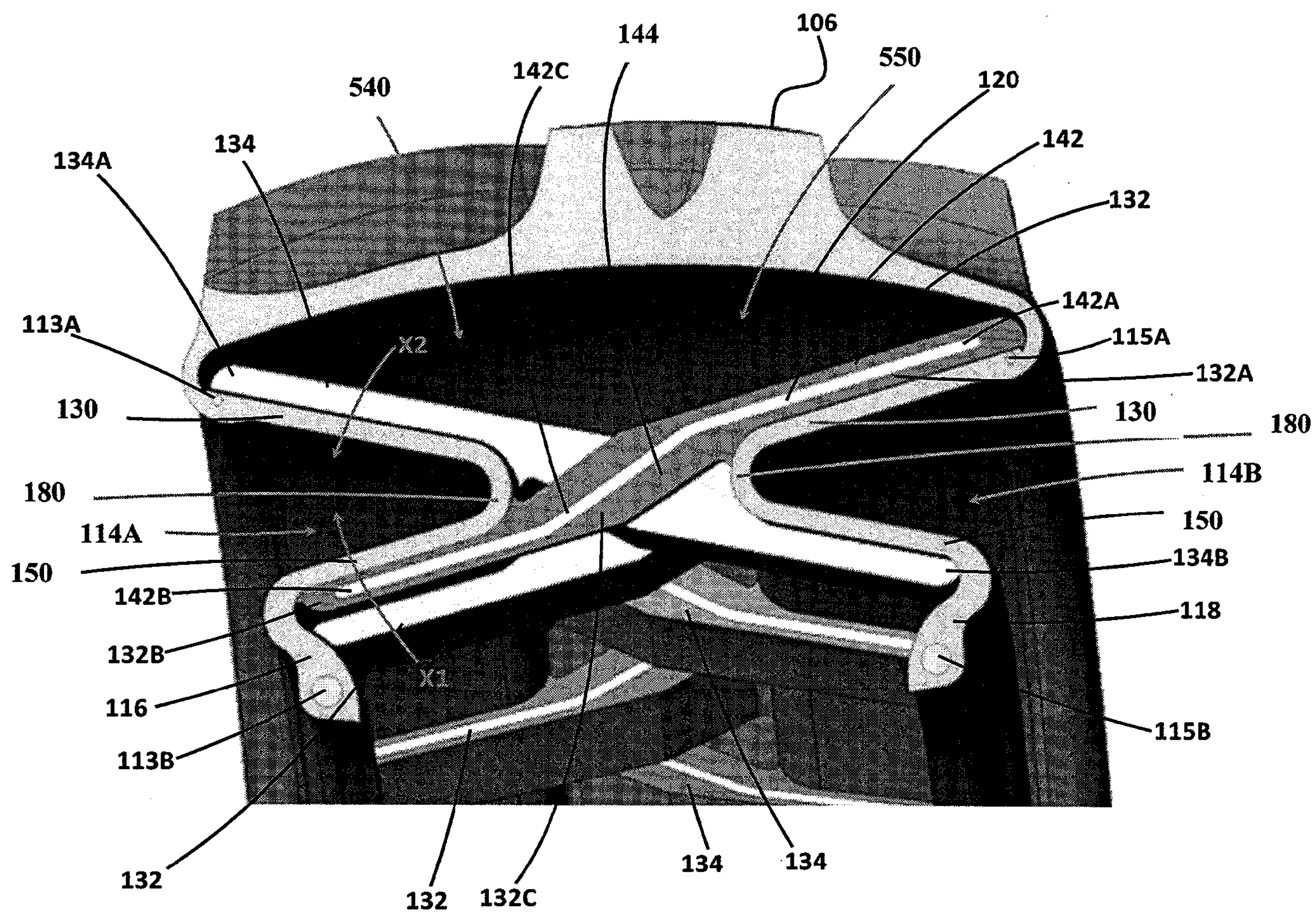


FIG. 9

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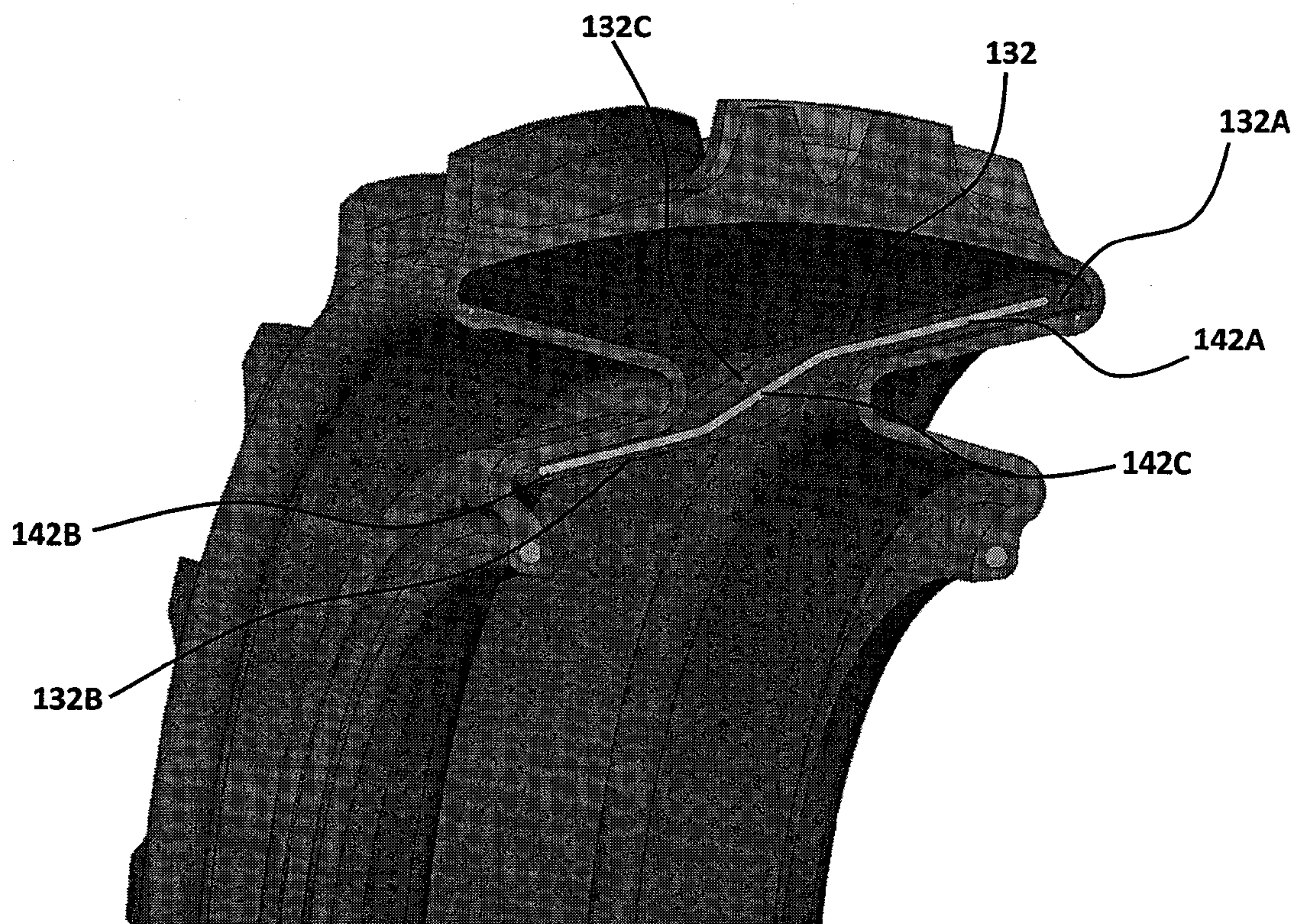


FIG. 10

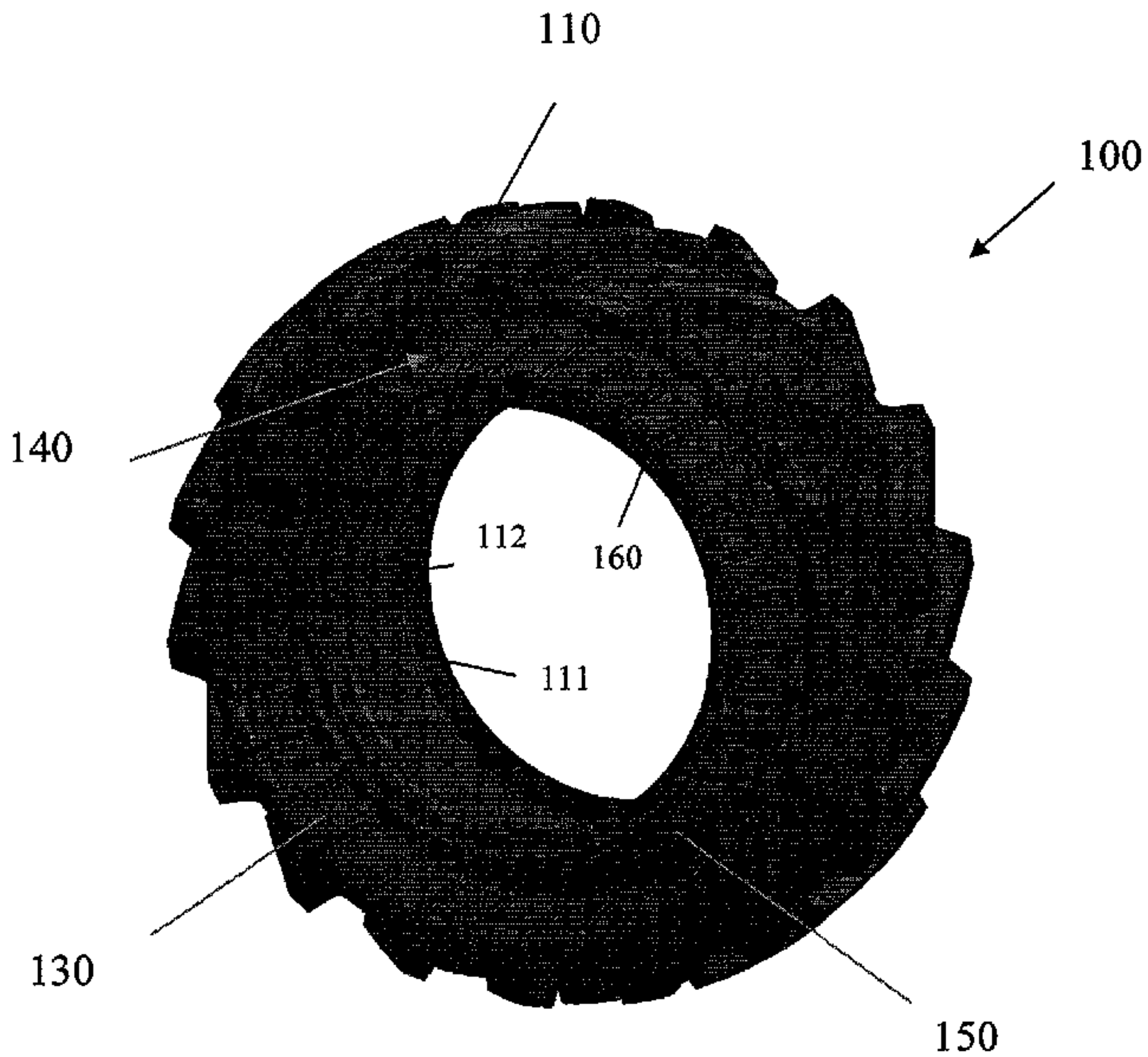


Fig. 2A