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(54) **Titre : PROCEDE POUR LA FABRICATION DE STRUCTURES DE RENFORT CREUSES SE CROISANT**
(54) **Title: METHOD FOR MANUFACTURING HOLLOW REINFORCEMENT STRUCTURES INTERSECTING ONE ANOTHER**

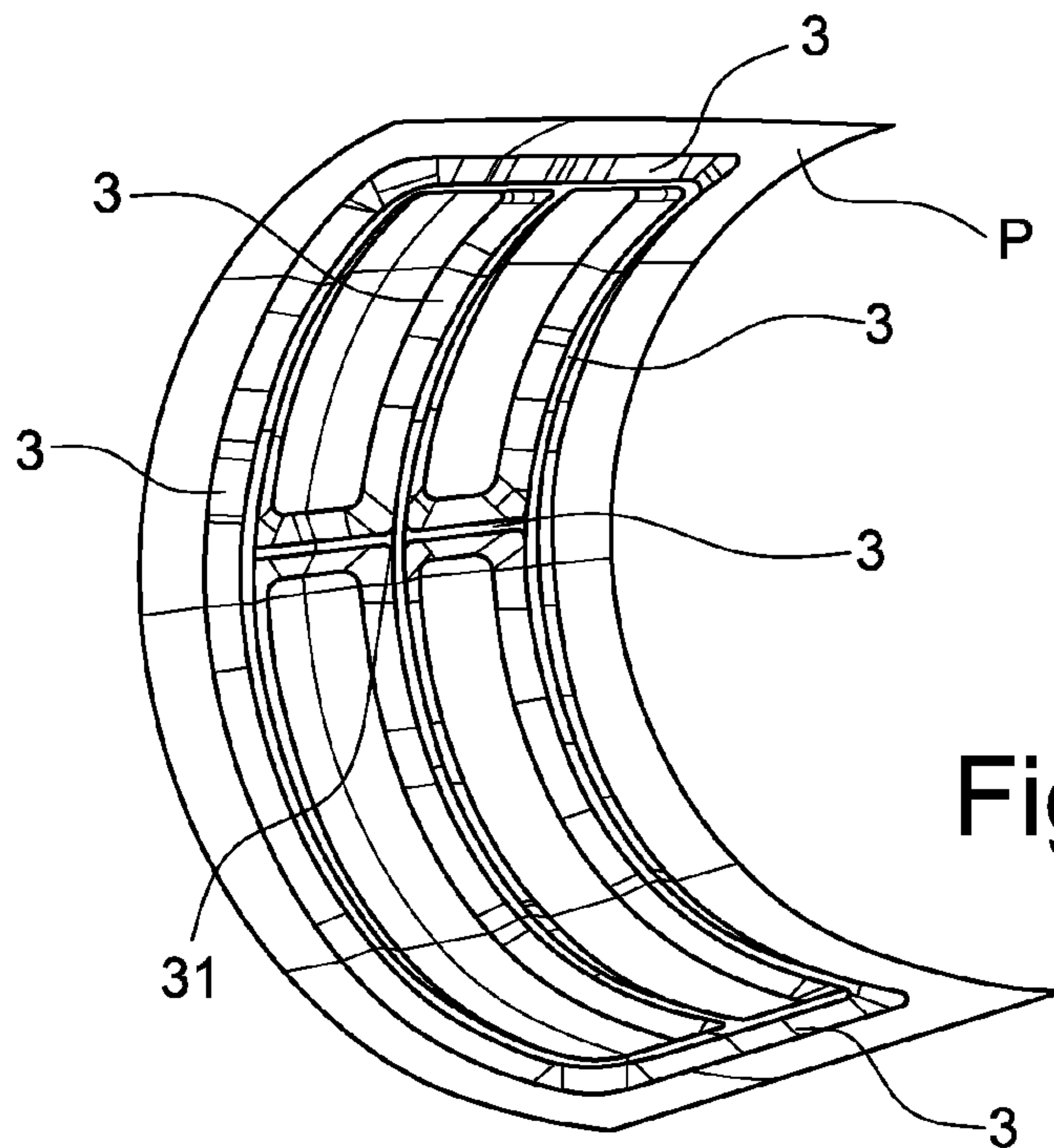


Fig. 1B

(57) **Abrégé/Abstract:**

Method to manufacture a plurality of hollow reinforcement structures (3) for panels (P) or aerostructures. The method comprises the following consecutive steps: a) positioning at least one mandrel (2) on the surface of a panel (P) in correspondence to each hollow structure (3) to be manufactured; b) laminating at least one composite material layer (4) on top of each mandrel (2); c) polymerizing said panel (P) on which said at least one composite material layer (4) is applied; d) removing said at least one mandrel (2) from the hollow structures (3). At least two of said hollow reinforcement structures (3) intersect one another a single polymerization step b) is provided for all the hollow reinforcement structures (3).



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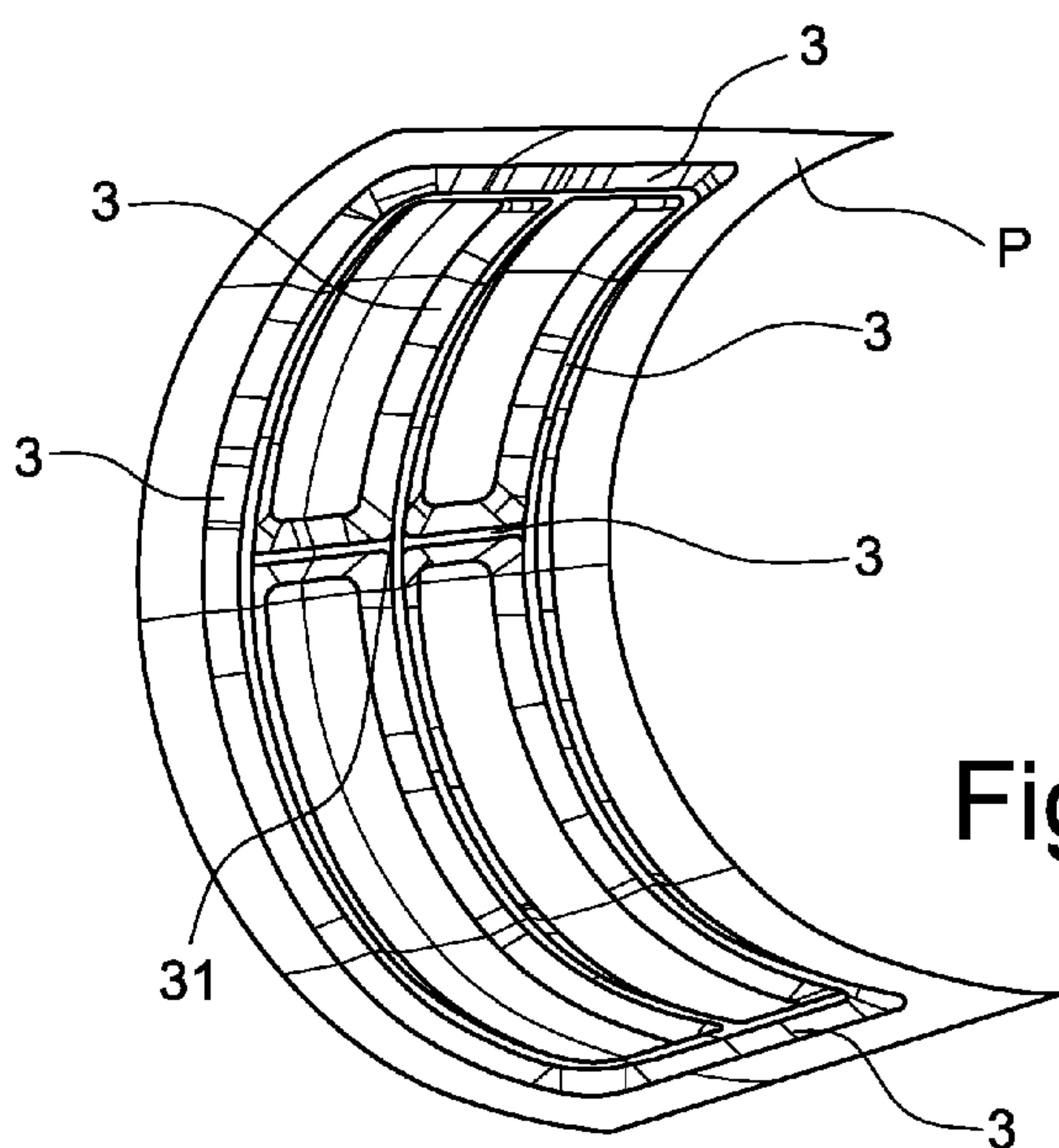
(54) Title: METHOD FOR MANUFACTURING HOLLOW REINFORCEMENT STRUCTURES INTERSECTING ONE AN-
OTHER

Fig. 1B

(57) Abstract: Method to manufacture a plurality of
hollow reinforcement structures (3) for panels (P) or
aerostructures. The method comprises the following
consecutive steps: a) positioning at least one mandrel
(2) on the surface of a panel (P) in correspondence to
each hollow structure (3) to be manufactured; b) lam-
inating at least one composite material layer (4) on top
of each mandrel (2); c) polymerizing said panel (P) on
which said at least one composite material layer (4) is
applied; d) removing said at least one mandrel (2)
from the hollow structures (3). At least two of said
hollow reinforcement structures (3) intersect one an-
other a single polymerization step b) is provided for
all the hollow reinforcement structures (3).

TITLE: METHOD FOR MANUFACTURING HOLLOW REINFORCEMENT
STRUCTURES INTERSECTING ONE ANOTHER

The present invention relates to a method to
5 manufacture reinforcement structures, for example designed
to stiffen a panel or a structure, preferably in the
aeronautical field. Reinforcement structures according to
the present invention are made of a composite material and
are hollow on the inside. Reinforcement structures
10 according to the present invention are especially suitable
for panels or aerostructures, which are made of a composite
material, as well. The method according to the present
invention allows the manufacturing of structures
intersecting one another, so as to obtain desired stiffness
15 features in said panel or aerostructure.

Panels or structures in general in the aeronautical
field require a high structural efficiency. The need to
reduce weights and, at the same time, ensure high-quality
mechanical features of the panels or aerostructures over
20 the course of time has led to the development and use of
materials and configurations that are more and more
optimized.

Sandwich panels are known, which comprise two thin
outer laminate face sheets, which are made of a composite
25 material and are spaced apart by a core made of light
material, such as for example honeycomb structures or foam
materials, etc..

Aerostructures can typically be represented as an
assembly of skins or laminates made of a composite
30 material. The use of composite materials to manufacture
panels allows constructors to obtain high performances,

especially to bear the loads to which the panels are subject.

Furthermore, panels or structures are known, which are made of a composite material and do not use an intermediate
5 layer made of a light material. The necessary stiffness for this type of panel or aerostructure is obtained by means of local and discrete reinforcements. These reinforcements are made of a composite material consisting of skins and stiffeners obtained by means of a polymerization process,
10 in particular co-curing or simultaneous polymerization process, to which the composite material of all the components that are part of the panel or structure are subject. This has brought to the attention of constructors some hard limits of the technology available for
15 manufacturing these reinforcements. Reinforcements are normally arranged along one single direction, namely longitudinal or transverse, for example relative to a plane defined by the panel or aerostructure.

Reinforcements are known, which are manufactured by
20 means of hollow structures made of a composite material.

The processes carried out to manufacture these hollow structures use lamination mandrels. These mandrels are arranged on the panel or structure so as to be covered by laminates, normally made of carbon, which determine the
25 stiffness of the panel or structure. After the polymerization step performed to stiffen the hollow structure, the mandrel must be removed.

Normally, the methods used to manufacture hollow reinforcement structures comprise the step of manufacturing
30 said hollow structures along directions that are parallel to one another.

Reinforcement or stiffening structures intersecting one another can be manufactured with a method in which, during a first step, the hollow structures arranged along a particular direction are manufactured and then cured or
5 polymerized; after the first step, hollow structures normally arranged in a direction that is perpendicular to the first one are manufactured and, subsequently, a second polymerization step is performed, during which the structures are cured so as to stiffen the new hollow
10 structures.

The manufacturing method implemented by the prior art can scarcely be automated due to the impossibility to simultaneously manufacture hollow reinforcement or stiffening structures along directions that are different
15 form one another, in particular converging and/or intersecting.

Said hollow structures have a cross section that can have a different shape depending on the shape of the mandrel.

20 The shape of the mandrel itself can increase or reduce the possibility to manufacture hollow reinforcement or stiffening structures intersecting one another. It is widely known that the intersection of hollow reinforcement or stiffening structures with a trapezoidal or “Ω”-shaped
25 cross section turns out to very hard to manufacture, since it requires a further manufacturing effort, for example to laminate intersection points. This manufacturing effort leads to an increase in manufacturing costs.

A further technical problem arising from the solutions
30 suggested by the prior art relates to the possibility of removing, for example extracting, the mandrel after the

hollow structure has been manufactured, in particular after the polymerization step. The presence of hollow reinforcement or stiffening structures manufactured after other hollow structures, for example reinforcement or stiffening structures, have been manufactured makes it difficult for the mandrel to be extracted following the polymerization step.

The object of the present invention is to solve the problems mentioned above by implementing a new method to manufacture hollow reinforcement or stiffening structures that are not parallel to one another and, for example, intersect one another.

One aspect of the present invention relates to a method to manufacture hollow reinforcement or stiffening structures having the features set forth in appended claim 1.

Further accessory features are set forth in the appended dependent claims.

A further aspect of the present invention relates to a panel according to claim 10, on which hollow reinforcement structures are manufactured.

The features and advantages of the method to manufacture hollow reinforcement or stiffening structures will be best understood upon perusal of the following detailed description with reference to the accompanying drawings, which show what follows:

- figures 1A and 1B show a panel or aerostructure on which hollow reinforcement structures can be manufactured; in particular, figure 1A shows only the panel in a specific embodiment that is not flat, but curved, without reinforcement structures, whereas figure 1B shows

the panel of figure 1A with reinforcement structures, which, by way of example, are arranged so as to be perpendicular to one another;

• figure 2 shows a detail of a point of intersection of two hollow reinforcement structures that are arranged perpendicular to one another and shown in figure 1B;

• figures 3A and 3B show cross sections of the panel comprising hollow reinforcement structures; in particular, figures 3A shows a hollow reinforcement structure and figure 3B shows a point of intersection between two hollow reinforcement structures;

• figure 4 shows an embodiment of the mandrel used in the method according to the present invention;

• figures 5A and 5B show a view from above of different panel embodiments, for example flat panels in which the reinforcement structures intersect one another at different angles.

With reference to the figures mentioned above, the method to manufacture a plurality of hollow reinforcement structures 3 for panels "P" or aerostructures comprises the following, preferably consecutive, steps:

a) positioning at least one mandrel 2 on the surface of a panel "P" in correspondence to each hollow structure 3 to be manufactured;

b) laminating at least one composite material layer 4 on top of each mandrel 2;

c) polymerizing said panel "P" on which said at least one composite material layer 4 is applied;

d) removing said at least one mandrel 2 from the hollow structures 3.

The arrangement and/or shape of said at least one mandrel 2 is such that at least two of said hollow reinforcement structures 3 are not parallel to one another and, for example, are convergent, preferably intersecting.

5 For the purpose of the present invention, the term panel "P" means a structure or aerostructure, for example the skin, under the hollow structures 3 according to the present invention. Said panel "P" is an element on itself, on which the hollow structures 3 according to the present
10 invention are manufactured. Figure 1A shows an explanatory embodiment of panel "P".

The intersection of at least two hollow reinforcement structures 3 defines an intersection point 31.

In an explanatory and non-limiting embodiment, at
15 least two hollow structures 3 intersect one another in a perpendicular manner, as shown by way of example in figure 1B.

Figures 5A and 5B show equivalent embodiments of reinforcement structures 3, in which two or more structures
20 3 intersect one another in intersection point 31 in a non perpendicular manner. In particular, said hollow structures 3 have different intersection angles. The selection of the angle of intersection between two or more hollow structures 3 depends on the reinforcement and stiffening conditions
25 requested for specific panel "P" or aerostructure.

Panel "P" or aerostructure normally comprises an outer surface, which is substantially visible when the panel or aerostructure is positioned, for example, on an aircraft or a portion thereof; and an inner surface, which is not
30 visible when said panel or aerostructure is positioned, for example, on an aircraft or a portion thereof. Panel "P" can

be associated with a plurality of hollow reinforcement structures 3 according to the present invention.

Panel "P" or aerostructure can be flat, as shown for example in figures 5A and 5B, or curved, as shown for
5 example in figures 1A and 1B.

To manufacture the hollow structures 3 intersecting one another on said panel "P", the method according to the present invention comprises a single step b) of polymerizing said panel "P", to polymerize all the hollow
10 reinforcement or stiffening structures 3, preferably for all the hollow structures 3 arranged on each panel "P" or aerostructure.

The hollow structures 3 manufactured on a panel "P" can be manufactured by means of a plurality of mandrels 2,
15 which are properly arranged so as to manufactures hollow structures 3 intersecting one another. In an alternative embodiment, the hollow structures 3 manufactured on a panel "P" can be manufactured by means of single mandrel 2, which is shaped so as to manufactures more than one hollow
20 structures 3 intersecting one another. In the latter embodiment, mandrel 2 is shaped so as to create more than one hollow structures 3, for example all the hollow structures 3 that have to be manufactured on said panel "P" or aerostructure, for example on a single panel "P" or
25 aerostructure. Figure 1B shows a panel on which there are manufactured hollow reinforcement structures 3 intersecting one another, in particular three hollow structures arranged horizontally and three hollow structures arranged vertically, the latter hollow structures being arranged so
30 as to be perpendicular to the former three hollow structures. The hollow structures 3, shown for example in

figures 1B, 5A and 5B, can be manufactured by means of a plurality of mandrels 2 or by means of a single mandrel 2.

Furthermore, mandrel 2 determines the shape of the cross section of the hollow structure 3.

5 The hollow structures 3 have a cross section defining an opening 30.

The cross section of mandrel 2 allows the hollow structure 3 to be manufactured with an opening 30 having the desired shape.

10 In an explanatory and non-limiting embodiment, the cross section of said hollow structure 3 defines an opening with a trapezoidal shape. In order to manufacture hollow structures 3 with a trapezoidal opening 30, a mandrel 2 is used, which has a cross section with a substantially
15 trapezoidal shape, as well.

In general, the section of the hollow structure 3 that defines opening 30 has a shape depending on the shape of the mandrel used. One can use mandrels 2 with a circular section or with a polygonal section.

20 If one examines more in detail the steps to be performed to manufacture the hollow structure 3, the step a) of positioning at least one mandrel 2 on the surface of a panel "P" precisely consists in positioning one or more mandrels 2 on the surface of a panel "P".

25 Preferably, said mandrels 2 are positioned on the surface of the inner face of panel "P" or aerostructure.

The number of mandrels 2 used depends on the number and shape of hollow structures 3 to be manufactured. For example, in case of small-sized panels "P" or
30 aerostructures, if necessary having a small number of

intersection points 31, one can manufacture the desired shape with a single mandrel 2.

Said at least one mandrel 2 is positioned on the panel "P" in the point where the hollow structures 3 having an opening 30 have to be manufactured. In particular, said at least one mandrel 2 is positioned in the points where the panel "P" or aerostructure needs a structural reinforcement.

After said at least one mandrel 2 has been positioned in the positions in which the hollow structure 3 has to be manufactured, one can move on to the following step b) of laminating at least one composite material layer 4 on top of each mandrel 2.

The composite material layer is laid on top of mandrel 2, also in contact with panel "P", and is laminated so as to obtain a surface that is as linear as possible.

The lamination continues until the desired thickness is reached and/or all mandrels 2 used to manufacture the hollow structures 3 are covered.

For the purpose of the present description, the term "linear surface" means a surface, even a curved one, which does not have undesired wrinkles.

At the end of the lamination, a panel is obtained, which contains adjusted mandrels that guide its geometries.

After having positioned one or more composite material layers 4, so as to cover said at least one mandrel 2 and panel "P" where a reinforcement of the panel itself is needed, one can move on to the following step c) of polymerizing said panel "P".

The polymerization takes place by means of a curing process, for example by heating panel "P" where said at least one composite material layer 4 has been laid.

5 More preferably, the polymerization step c) is performed by means of a co-curing process, preferably in autoclave.

Panel "P" or aerostructure is preferably polymerized by means of a specific thermobaric cycle of the matrix of the composite material used. Said thermobaric cycle is
10 preferably carried out by using an autoclave, so that said at least one composite material layer 4 correctly adheres to panel "P" and stiffens.

If necessary, during said step c), mandrel 2 can expand before the heating stiffens the composite material
15 layer 4, so as to widen the size of opening 30 of the hollow structure 3, anyway maintaining the dimensions indicated in the manufacturing data sheets. The possible expansion of mandrel 2 is limited by the stiffening of the laminated composite material layers 4, thus determining the
20 dimensions of openings 30 of the hollow structures 3.

Advantageously, a subsequent intermediate cooling step is provided, which takes place after the polymerization step c) and causes the shrinkage of said mandrel 2.

At the end of the polymerization step c) one can move
25 on to the step d) of removing said at least one mandrel 2 from the hollow structures 3.

In general, the method according to the present invention uses mandrels 2 that are water-soluble. These water-soluble mandrels are able not to undergo structural
30 variations during the polymerization step. Said mandrels 2,

for example, are made of an inert material, preferably a powder with a water-soluble binder.

In general, irrespective of the technical features mentioned above, the use of said at least one mandrel 2 made of a water-soluble material helps implement the method to manufacture hollow structures, for example intersecting one another, by means of a single polymerization step b), preferably for all the hollow structures 3 intersecting one another.

In the preferred embodiment of the method, prior to the step d) of removing mandrel 2, there is a further step d0) of perforating the hollow reinforcement structure 3. With said perforation step d0) one can manufacture an opening that is such as to allow mandrel 2 to be removed or extracted in case there is no outlet hole.

The use of water-soluble mandrels 2 allows constructors to manufacture holes with a diameter that is much smaller than the initial diameter of mandrel 2. Through these holes in the hollow structure 3 the dissolved mandrel can be removed, for example poured and/or spilled in suitable storing containers.

After the removal step d), the method comprises a further step in which panel "P" or aerostructure is properly trimmed. After the trimming step, the panel is provided with gaskets, so as to allow panel "P" or aerostructure to be positioned, for example on an aircraft.

The present method to manufacture hollow reinforcement structures 3 is stable to be carried out and, furthermore, is particularly simple, since it does not require the use of further devices compared to the method implemented in the prior art.

The method to manufacture hollow structures 3 intersecting one another can be implemented with any type of panel "P" or aerostructure provided with any shape, both flat and curved, for example comprising inflexion points or saddle points.

Furthermore, the method according to the present invention allows manufacturers to reduce production costs, as all the hollow structures are manufactured in one single step, thus reducing the lamination and polymerization steps and eliminating the cleaning of the hollow structure 3 and the removal of the mandrel.

In detail, the method according to the present invention is able to manufacture all the hollow reinforcement structures 3 of a panel "P" by performing one single lamination step b) and one single polymerization step c).

The method according to the present invention can be implemented in an automatic manner by means of automatic systems. For example, by means of systems used to position said at least one mandrel 2 on panel "P" and by means of automatic systems to lay and laminate composite material layers 4.

The method can be largely automated thanks to the possibility to manufacture the hollow structures 3 intersecting one another by means of a single step of the process, in particular by means of a single polymerization step c). The method according to the present invention allows all the hollow structures 3 that have to be manufactured on a panel "P" or aerostructure to be manufactured in one single manufacturing step, without the repetition of steps of the method.

The automation of the method, for example, is implemented by means of an automated fiber placement system, also called AFP system, to place composite materials on a lamination mold. On said lamination mold
5 there are installed one or more mandrels 2, preferably water-soluble. Said mandrels 2 are dedicated, as they have geometries and consistencies that are such as to allow composite material layers 4 to be laid on them in an automated manner. The automatic lamination of layers 4
10 continues until a predetermined thickness is reached and/or all the mandrels available are covered.

At the end of the lamination, a panel is obtained, which contains adjusted mandrels guiding its geometries and is ready for the single cycle in autoclave.

15 After the simultaneous polymerization of all the hollow structures 3 available on panel "P" or aerostructure, the panel is perforated by means of a machine tool and the mandrels are removed. The removal of mandrels 2, in the preferred embodiment, takes place
20 through their dissolution.

Again, panel "P" or aerostructure is properly trimmed and the gaskets are applied, so as to allow panel "P" or aerostructure to be positioned, for example on an aircraft.

Furthermore, the use of water-soluble mandrels 2 to
25 manufacture the hollow structures 3 allows mandrels 2 to be manufactured in the desired shapes. The use of prior art mandrels to manufacture intersecting hollow structures 3 would lead to the impossibility for operators to remove the mandrels from the hollow structures in an easy manner.

The method according to the present invention is particularly suitable for the production of hollow reinforcement structures for panels for aircrafts.

5 This integrated reinforcement geometry can also be used in panels for nacelles or panels for aircraft that require stiffening.

The method according to the present invention allows constructors to manufacture stiffened panels in a particularly efficient manner. In particular, the
10 configuration described in this document was conceived to fulfill the needs of the aeronautical field.

NUMERICAL REFERENCES:

	Panel	P
15	Mandrel	2
	Hollow structure	3
	Opening	30
	Intersection point	31
	Composite material layer	4

CLAIMS:

1. Method to manufacture a plurality of hollow reinforcement structures (3) for panels (P) or aerostructures in which at least two of said hollow reinforcement structures (3) intersect one another;
5 the method comprises the following consecutive steps:
a) positioning one or more mandrels (2) on the surface of a panel (P) in correspondence to each hollow structure (3) to be manufactured;
10 b) laminating at least one composite material layer (4) on top of each mandrel (2);
c) polymerizing said panel (P) on which said at least one composite material layer (4) is applied, in a single step of polymerization for all the hollow reinforcement
15 structures (3);
d) removing said one or more mandrels (2) from the hollow structures (3);
characterized in that:
- said step of positioning said one or more mandrels is
20 such that a single mandrel (2) is provided, which is shaped so as to manufacture hollow structures (3) that intersect one another;
 - said step of removing said one or more mandrels (2) from the hollow structures (3) take place through their
25 dissolution, being said one or more mandrels (2) water-soluble mandrels.
2. Method according to claim 1, wherein, prior to the step d) of removing the mandrel (2), there is a step d0) of perforating the hollow reinforcement structure (3).
- 30 3. Method according to claim 1, wherein a single lamination step b) is provided.

4. Method according to claim 1, wherein the method is implemented in an automatic manner by means of automatic systems.

5. Method according to claim 1, wherein the
5 polymerization step is performed by means of a co-curing process in autoclave.

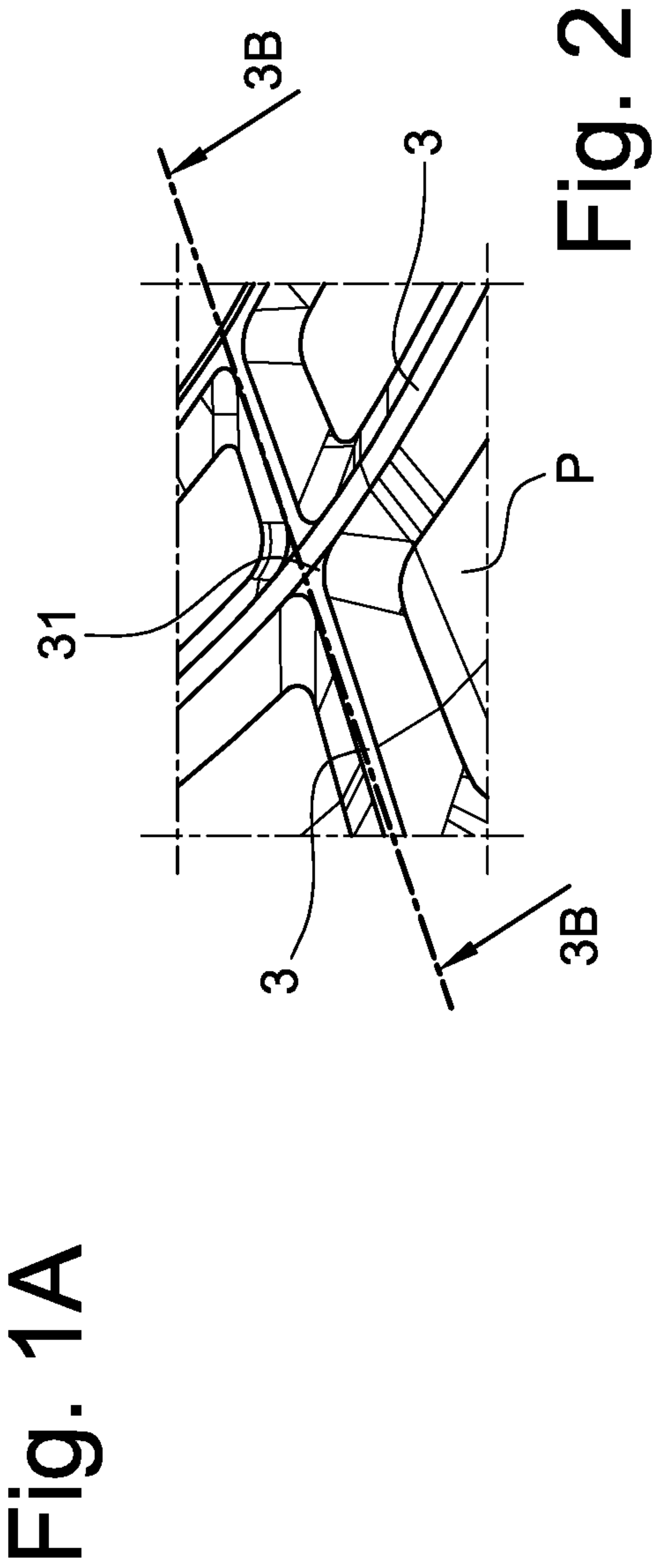
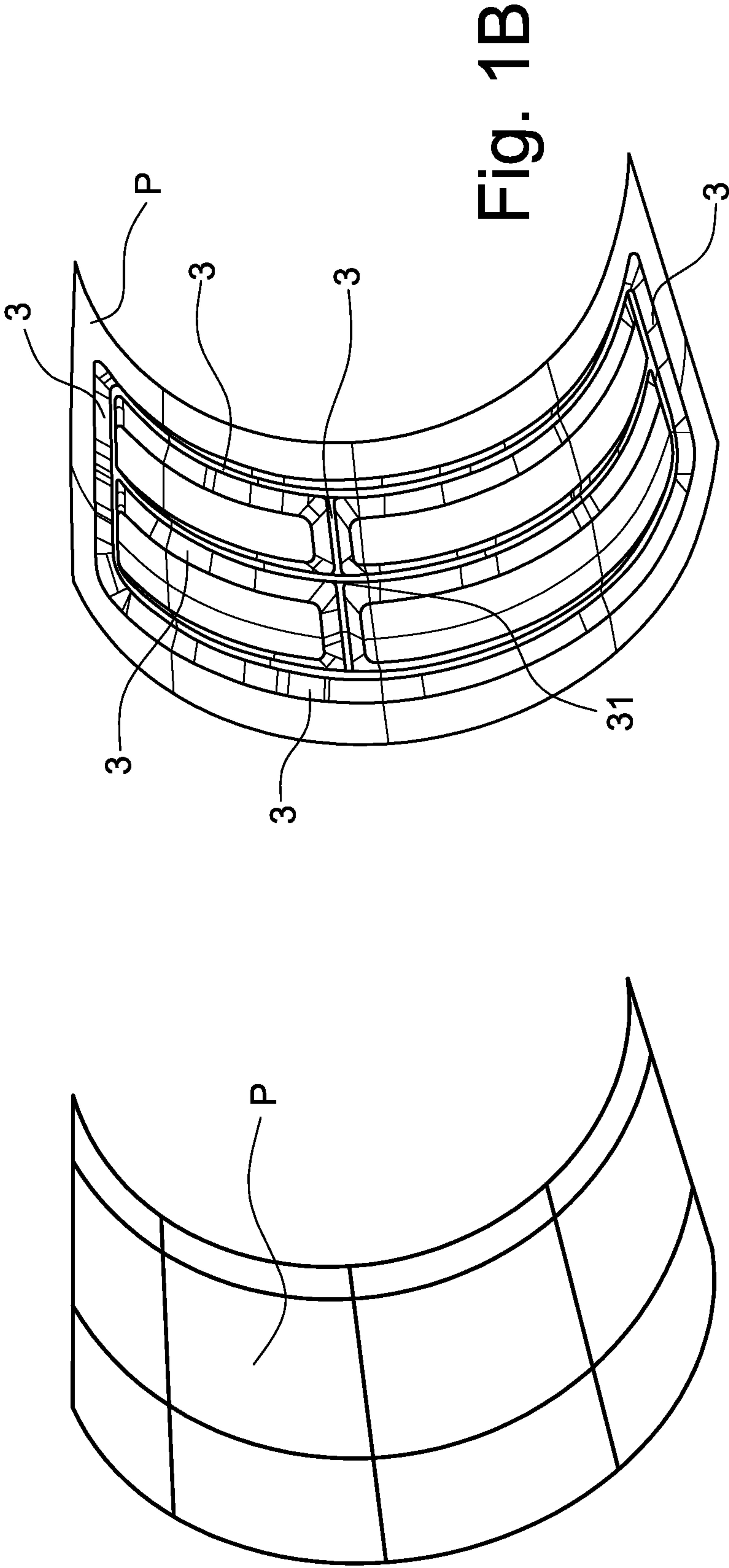
6. Method according to claim 1, wherein the hollow structures (3) have a cross section that defines an opening (30) with a shape that depends on the shape of the mandrel
10 (2) used.

7. Method according to claim 2, wherein a subsequent intermediate cooling step is provided, which takes place after the polymerization step c) and causes the shrinkage of said mandrel (2).

15 8. Panel or aerostructure (P) comprising:

- an outer surface, which is visible when the panel or aerostructure is positioned, for example, on an aircraft;
and

- an inner surface, which is not visible when said panel or
20 aerostructure is positioned, for example, on an aircraft;
said panel (P) is associated with a plurality of hollow reinforcement structures (3), which are manufactured according to the method of claims 1-7.



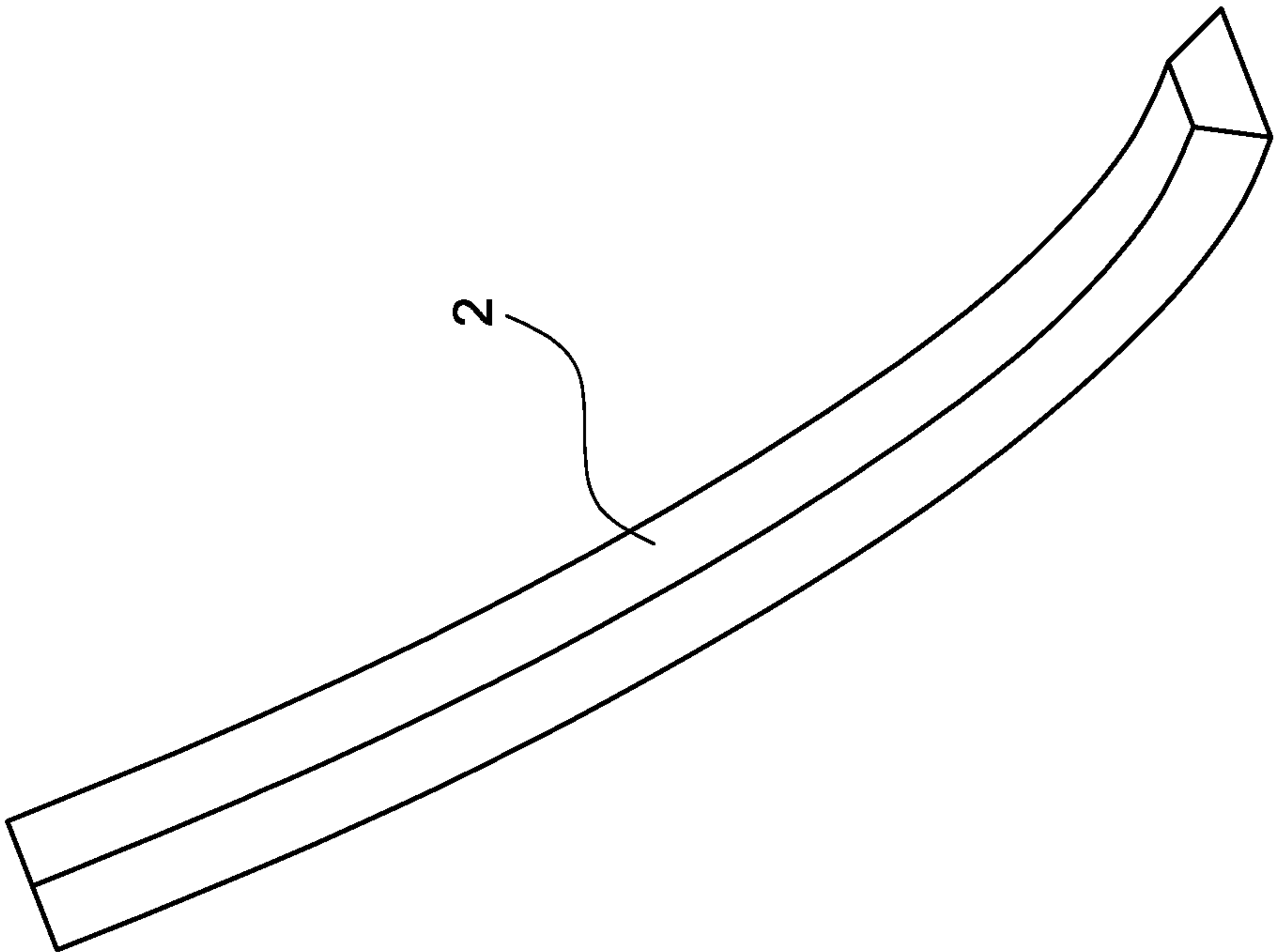


Fig. 4

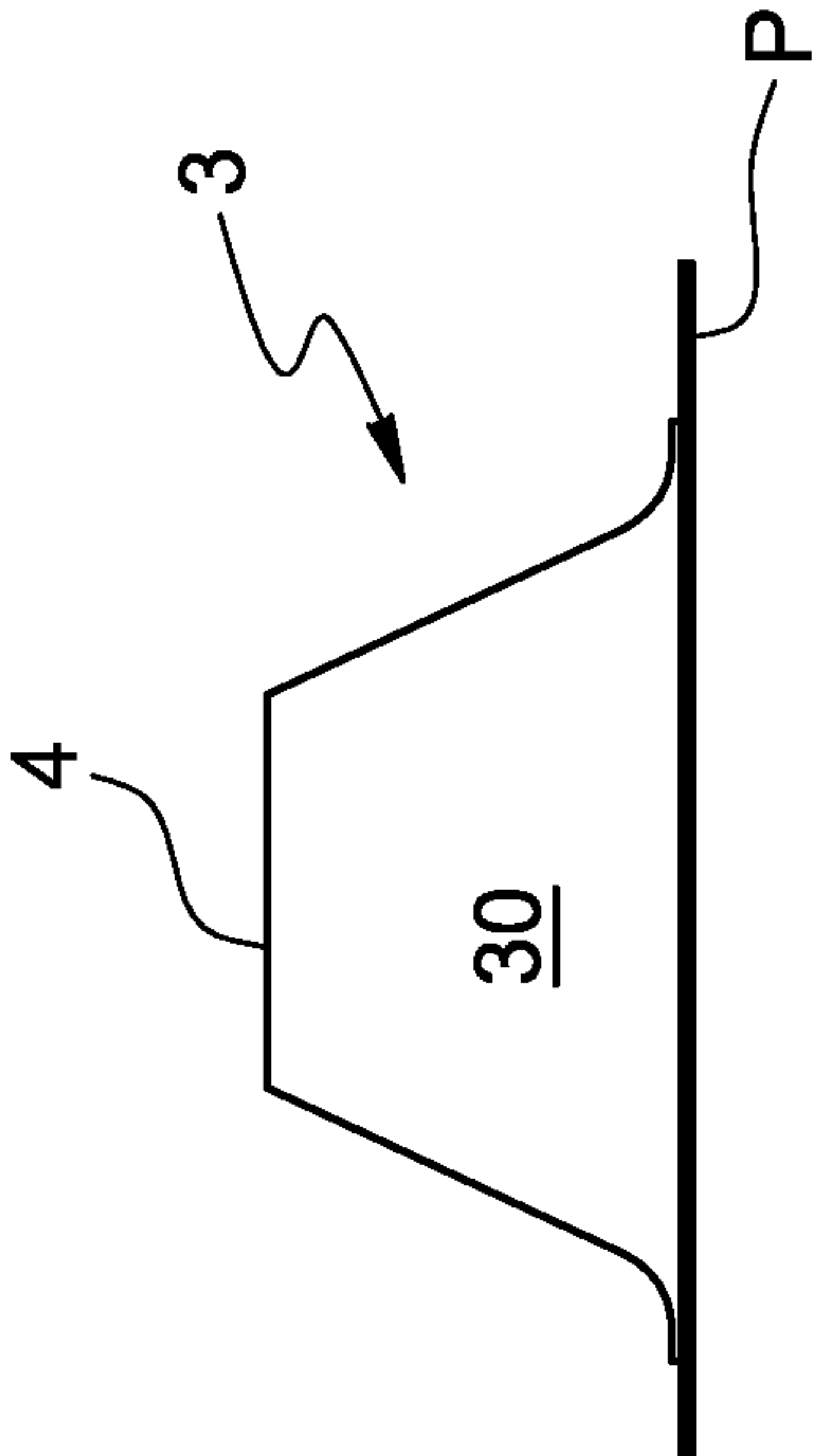


Fig. 3A

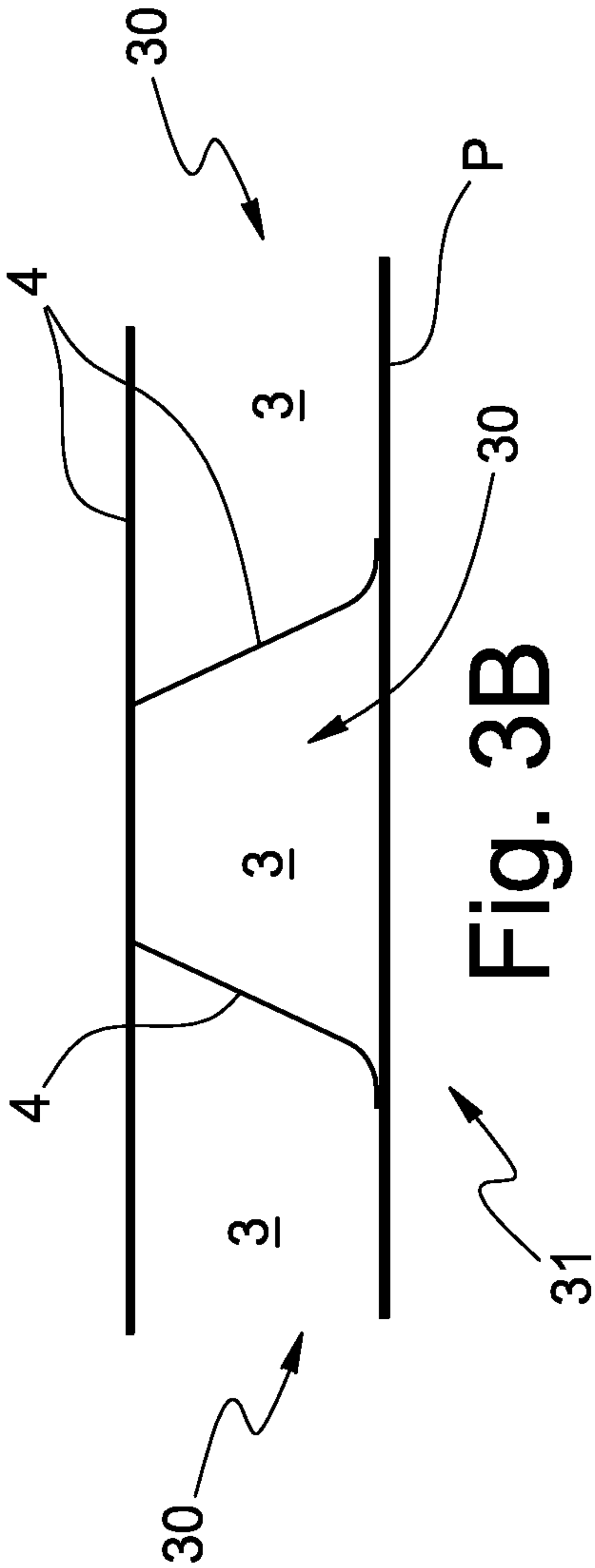


Fig. 3B

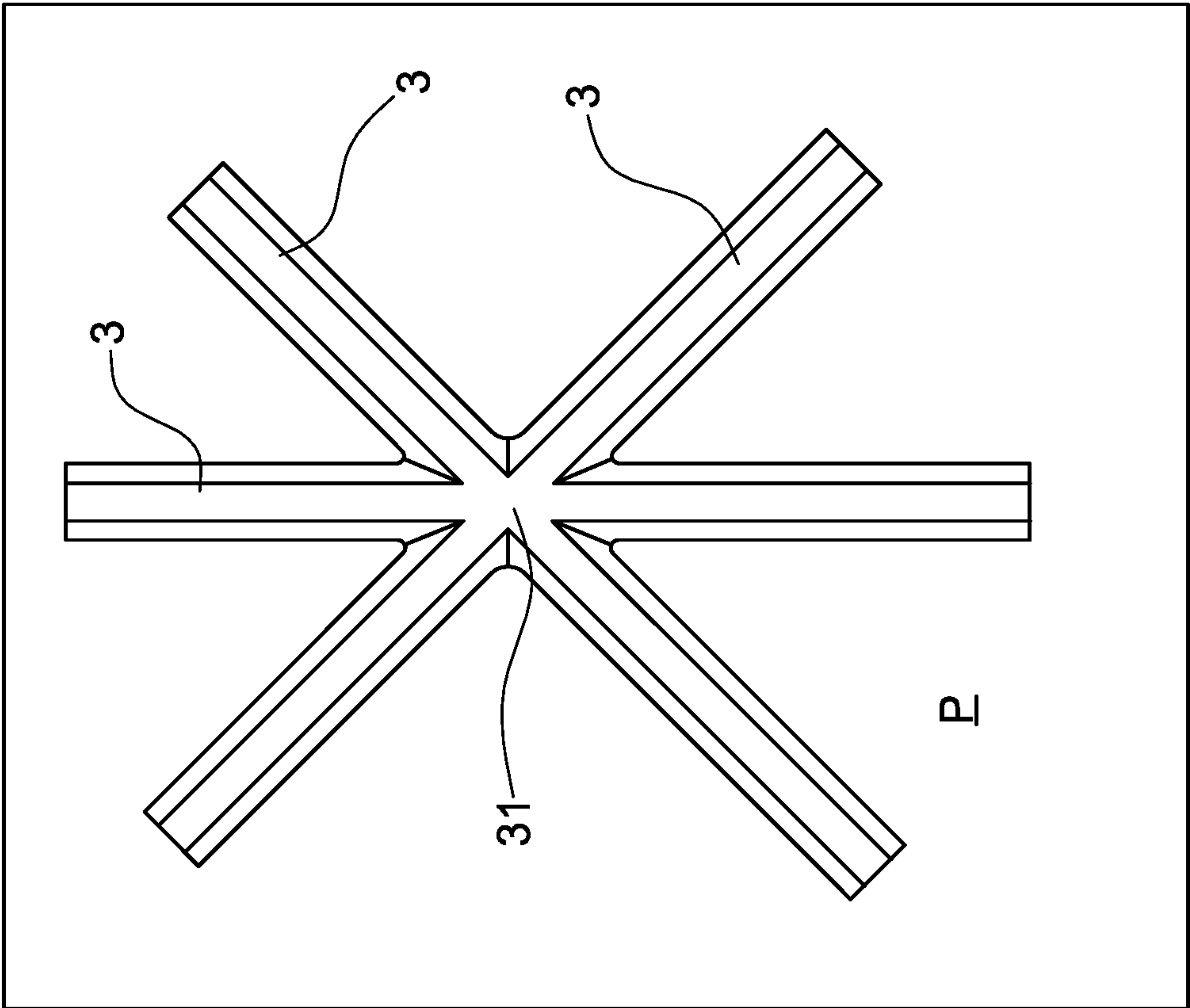


Fig. 5B

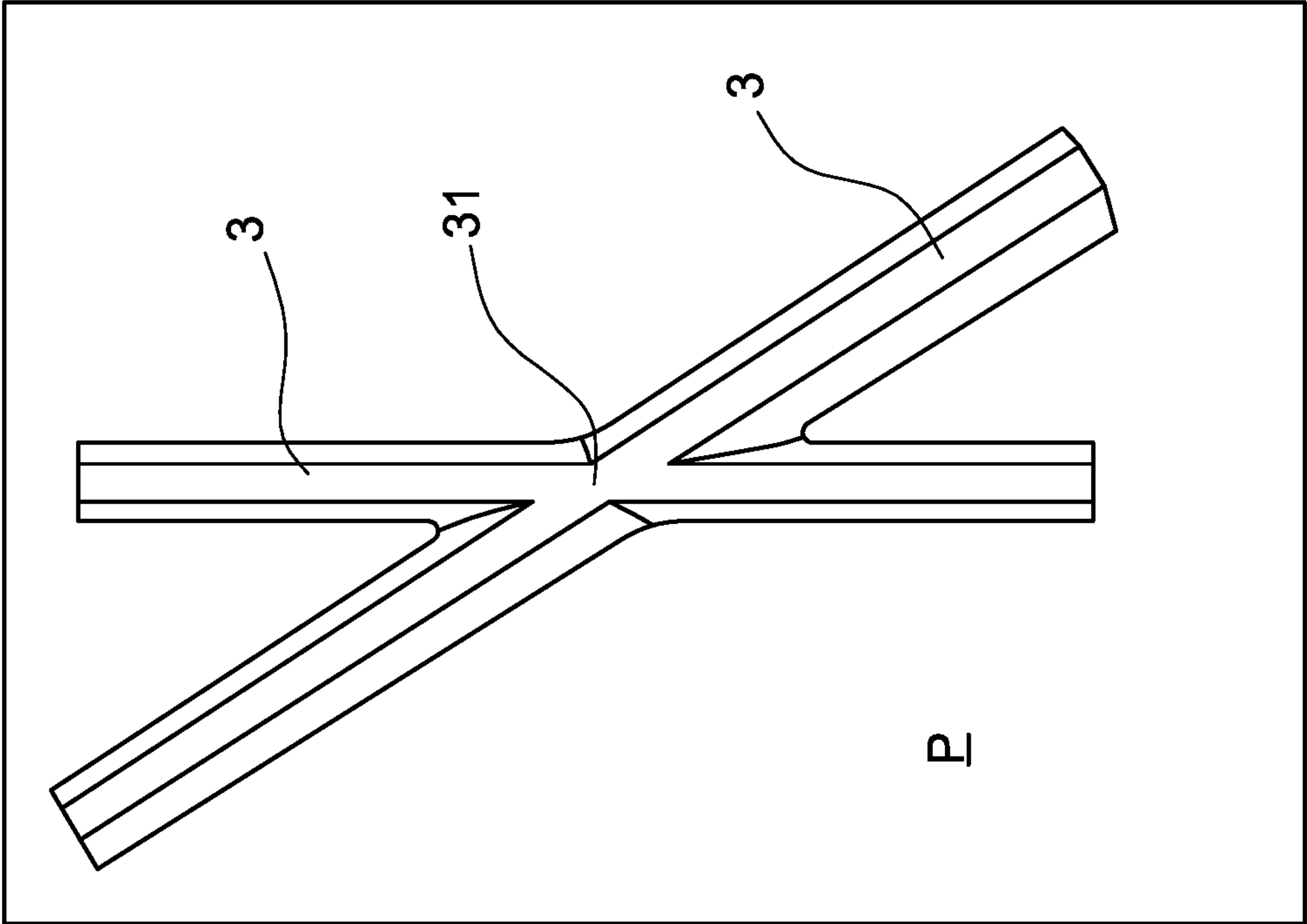


Fig. 5A

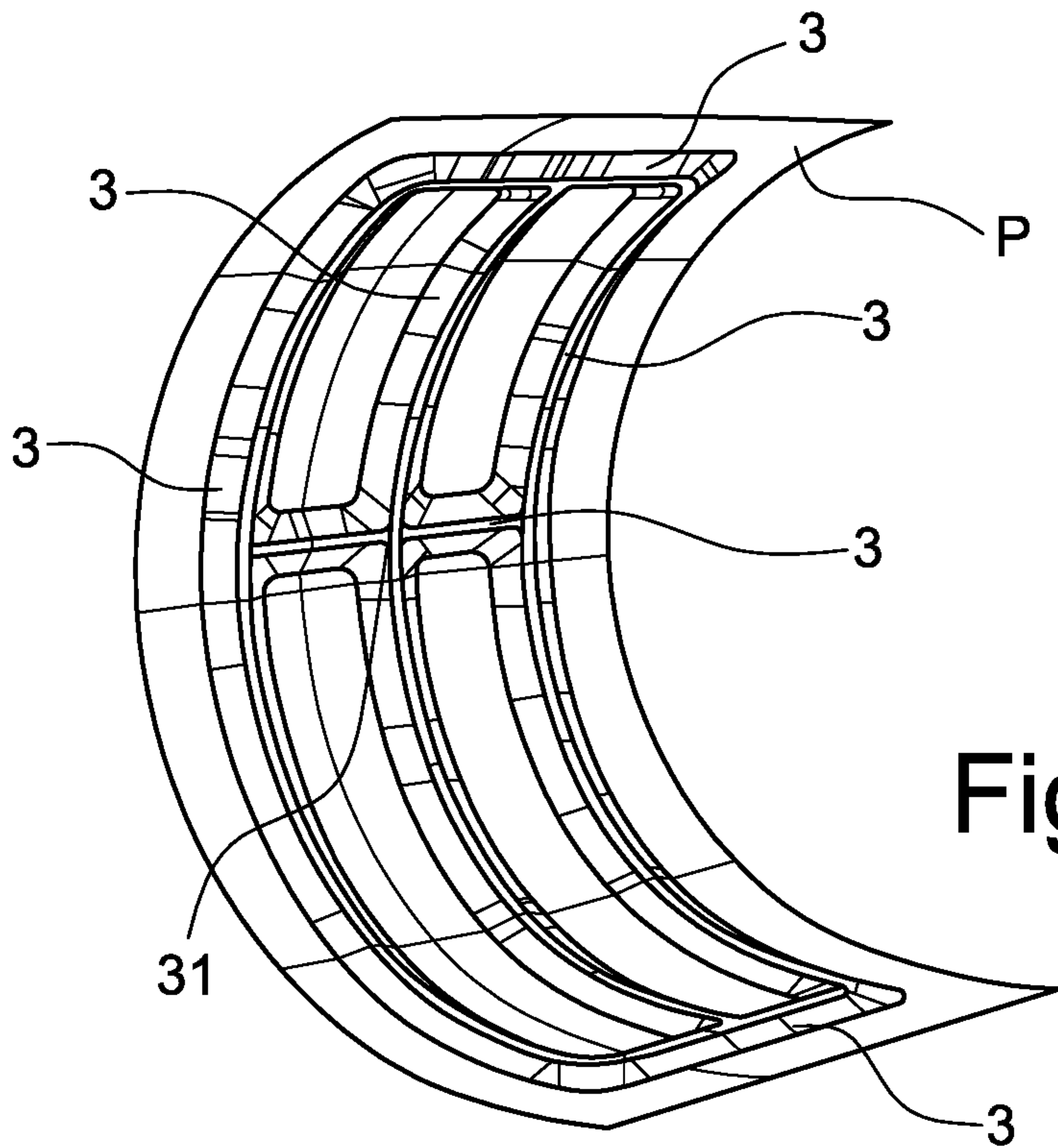


Fig. 1B