Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2732714 A1 2011/08/26

(21) 2 732 714

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2011/02/28

(41) Mise à la disp. pub./Open to Public Insp.: 2011/08/26

(30) Priorités/Priorities: 2010/02/26 (DE102010009566.4); 2011/02/04 (EP11153316.2)

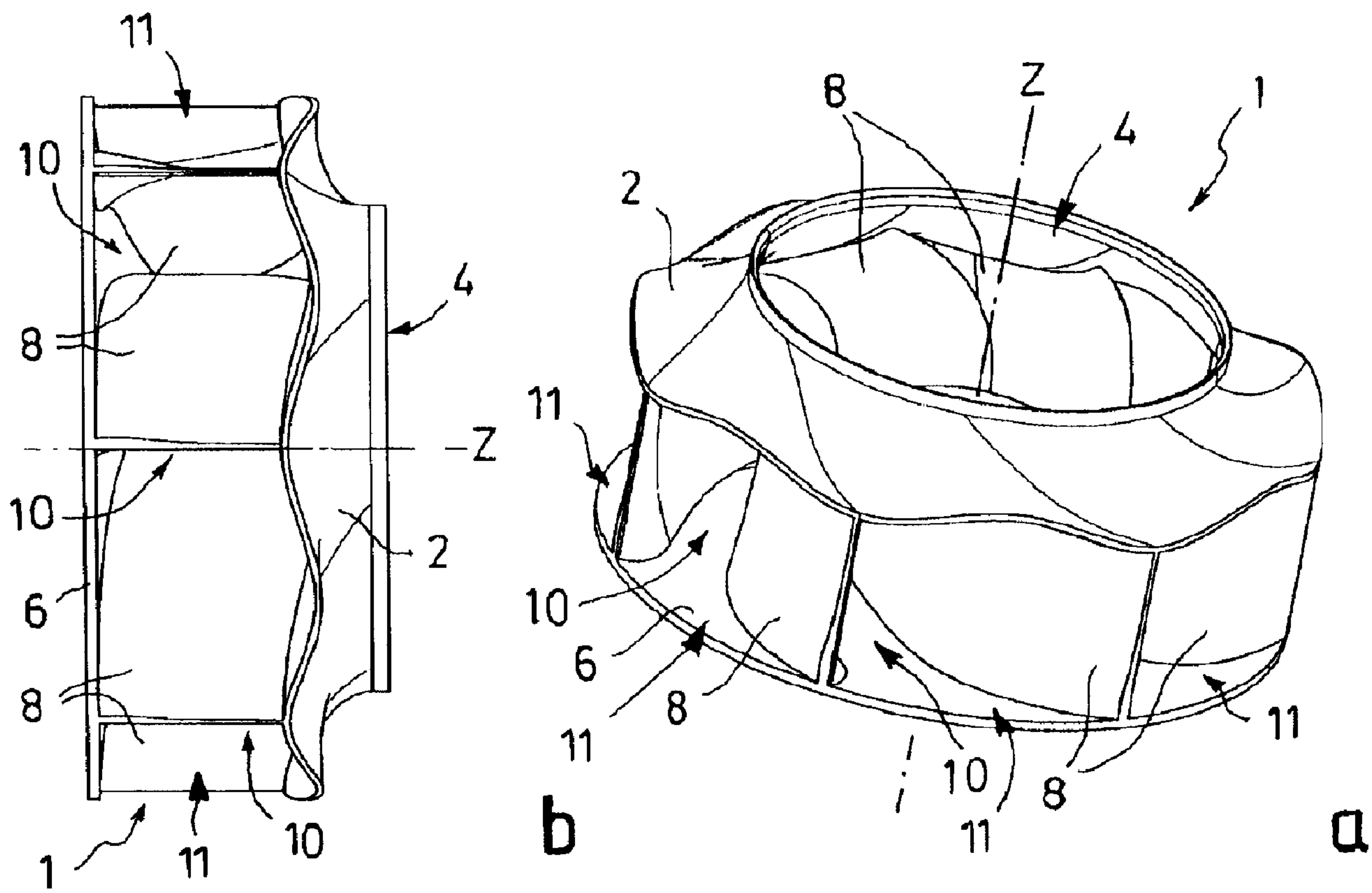
(51) Cl.Int./Int.Cl. *F04D 29/28* (2006.01), *F04D 29/22* (2006.01)

(71) Demandeur/Applicant: EBM-PAPST MULFINGEN GMBH & CO. KG, DE

(72) Inventeurs/Inventors:
BOHL, KATRIN, DE;
SCHNEIDER, MARC, DE;
SCHOENE, JUEGEN, DE

(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : TOURNIQUET DE VENTILATEUR RADIAL OU DIAGONAL
(54) Title: RADIAL OR DIAGONAL FAN WHEEL



(57) Abrégé/Abstract:
The invention relates to a fan wheel (1) designed as a radial or diagonal fan, comprising a top plate (2) with an inlet port (4), a base plate (6) and a plurality of fan blades (8) distributed around the inlet port (4) and around an axis of rotation (Z), as well as blade ducts (10) formed respectively between the adjacent fan blades (8) in a circumferential direction. The blade ducts (10) lead radially or diagonally outward from the area of the inlet port (4) and form blow-out ports (11) in the outer region. The blade ducts (10) are designed, with respect to their effective flow cross-section, as large enough that during operation, a turbulent flow with a Reynolds

(57) Abrégé(suite)/Abstract(continued):
number markedly greater than 2300 is achieved. The top plate (2) and/or the base plate (6) feature/features a non-rotationally symmetric geometry which, with respect to an axial or as the case may be axially parallel direction (Z), has a continuous, point-continuous shape.

ABSTRACT

The invention relates to a fan wheel (1) designed as a radial or diagonal fan, comprising a top plate (2) with an inlet port (4), a base plate (6) and a plurality of fan blades (8) distributed around the inlet port (4) and around an axis of rotation (Z), as well as blade ducts (10) formed respectively between the adjacent fan blades (8) in a circumferential direction. The blade ducts (10) lead radially or diagonally outward from the area of the inlet port (4) and form blow-out ports (11) in the outer region. The blade ducts (10) are designed, with respect to their effective flow cross-section, as large enough that during operation, a turbulent flow with a Reynolds number markedly greater than 2300 is achieved. The top plate (2) and/or the base plate (6) feature/features a non-rotationally symmetric geometry which, with respect to an axial or as the case may be axially parallel direction (Z), has a continuous, point-continuous shape.

Radial or Diagonal Fan Wheel

This invention relates to a fan wheel designed as a radial or diagonal fan, comprising a top plate with an inlet port, a base plate, and a plurality of fan blades distributed around the inlet port and around an axis of rotation, as well as blade ducts formed respectively between the adjacent fan blades in a circumferential direction, said fan blades leading radially or diagonally outward from the area of the inlet port and forming blow-out ports in the external region, the blade ducts being designed, with respect to their effective flow cross-section, as large enough that during operation, a turbulent flow with a Reynolds number markedly greater than 2300 is achieved, the top plate and/or the base plate displaying a non-rotationally symmetric geometry.

Fan wheels of his kind are termed turbo-machines (turbo-fans). They are characterized by the very high Reynolds number Re, which, with a value of at least 5000 (i.e. $Re \geq 5000$) is significantly greater by a factor of >2 than the sufficiently well known threshold value of approximately 2300 between laminar flow ($Re < 2300$) and turbulent flow ($Re > 2300$). In most cases, however, Re is actually ≥ 10000 (factor > 4) and can go up to several 10000 (for example 35000). Due to the turbulent flow in the blade ducts, high efficiency is achieved in the region above 0.6, and up to at least 0.8 (60-80%). In the flow ducts, it can be assumed that there is approximately a so-called tubular flow, where normally, as the characteristic quantities , a flow width -particularly an idealized substitute inner diameter d - the value of the flow velocity v_m averaged over the cross section, and the (kinetic) viscosity ν of the respective medium are used; the dimensionless Reynolds number is then:

$$\mathbf{Re} = \frac{\mathbf{v_m} \cdot \mathbf{d}}{\nu}$$

where it is assumed that air has a kinetic viscosity of v = 1.5 • 10-5 m2/s.

Efficiency is defined as the ratio of utilized output power to supplied input power, when, in the case of an electric motor drive, the electric input power or a mechanical shaft drive power used to rotate the fan can be applied as input power. In this case, the so-called "free-flowing efficiency" is defined as:

$$\eta_{ff} = \frac{\dot{V} \cdot \Delta p_{ff}}{P_w}$$

i.e. the ratio of the product of volume flow multiplied by pressure difference to input power .

It should be added that the relevant values are measured according to ISO 5801.

Furthermore, in connection with the invention, the term "non-rotationally symmetrical" means that any two different radial cross sections through the base plate and/or the top plate in two planes that contain the rotational axis and include a specific differential angle in the circumferential direction are not congruent when there are different circumferential angles, but rather deviate from one another. In this case, a deviation could in principle be present in the direction of the axis of rotation (axially) and/or in the radial direction (radially). In other words, this means that in the case of a non-rotational symmetry, a rotation of the body through specific angles around the axis of rotation does not map the object or its sectional plane on itself.

A fan wheel of the above-described type is described in various versions in the publication JP 2001-263 294. In this case, the top plate or the base plate, or each of the two, has a contour that is stepped obliquely in the circumferential direction. This step shape, which is oblique in the direction of rotation, is meant to reduce a tendency of the airflow to break away, and in this way to have a positive influence on noise and efficiency. The step shape results in each fan blade having different outlet widths (measured axially) on its suction side and its pressure side, which means, depending on the embodiment, that the outlet width on the suction side can be smaller or greater than the outlet width on the pressure side.

EP 1 933 039 A1 describes a radial fan with ribs, recesses or as the case may be, indentations on the outside of the top plate. This configuration is intended to reduce noise as a result of specific flow routing.

The additional publication, EP 1 032 766 B1, describes a fan wheel, in particular, as a turbocharger. In this fan wheel, blades are formed by embossings on at least one of the two plates (base plate and/or top plate). These embossings also produce a non-rotationally symmetrical geometry. However, this publication is not concerned with exerting an influence on flow; it is chiefly concerned with aspects of the manufacturing process and the factors that promote stability.

A non-rotationally symmetrical geometry is also produced according to the publication DE 32 47 453 C1, by means of cupping. Blade parts herein are molded from a base plate and an annular disk opposite to it after heating said blade parts, and are then fitted together to form a fan impeller by welding together the respective crest sections of the blade parts. However, as in the case of EP 1032 766 B1 cited above, this publication is not concerned with influencing flow. Its sole purpose is to simplify the production of a fan impeller from thermoplastic plastic and to increase the impeller's stability.

The publication US 2007/01 16561 A1, or as the case may be the corresponding US 7,455,504 B2 describes different embodiments of a quite special flow machine that is intended, in very small embodiments, for use in computers. Here, the flow ducts are designed with a very small flow cross-section in order to achieve a laminar flow. Consequently, this is not a "turbo-machine" in the sense of the invention; because in that prior art, the specific intention is that the Reynolds number be less than 2300. In concrete terms, the entire flow cross-section is divided into a plurality of small flow ducts. This is achieved, for example, by means of a honeycomb-like structure, which also appears to produce a non-rotationally symmetrical design. However, this is done only to avoid forming any flow ducts, in order to ensure laminar flows. Features of these known embodiments cannot be applied to a "turbo-machine" of the type described in the present invention, because they involve completely different operating principles.

For example, the peak efficiency of the known "laminar machine" is only around 0.2 (20%).

Numerous further publications describe rotationally symmetrical fan wheels. The following publications can be mentioned solely as examples: DE 29 40 773 C2, DE 199 18 085 A1, EP 1 574 716 B1, and DE 203 03 443 U1, as well as GB 438 036A1. Such fans, with rotationally symmetrically designed base plates and/or top plates display in part, both in the direction of the axis of rotation and in a circumferential direction, highly irregular velocity and pressure distributions, i.e. locally elevated velocity/pressure ranges. This can result in flow breakaway and even backflow, which in turn cause aerodynamic losses, efficiency losses, and increased noise emission. Regarding the cited document GB 438 036 A, it should also be mentioned that each fan blade and/or each top plate is meant to be comprised of two separate layers that are connected in a way similar to corrugated cardboard via wavy connecting webs. This results in a non-rotationally symmetrical profile between the two layers, however the surfaces of the top plates, which are responsible for the flow properties, are nevertheless rotationally symmetrical. There is no flow through the hollow space between the layers which is reinforced with "corrugated cardboard."

The present invention is based on the problem of providing a fan wheel of the type described in the introduction, by means of which, along with good mechanical stability, there will be improved influence on flow in order to optimize air output and efficiency and achieve better noise levels.

Inventively, this is done by means of the features of Claim 1, or by means of the features of Claim 2. Advantageous embodiments of the invention are described in the independent claims and in the description that follows below.

A first aspect of the invention, according to Claim 1, is that the respective non-rotationally symmetrical top plate or base plate, with respect to an axial or axially parallel direction, also has a continuous, point-continuous profile on the respective outer sides of the base plate and/or top plate along its entire circumference (across the blade regions as well). This means that there is a critical angle α G > 0° between two radial sections that run through the axis, beyond which angle further convergence of the two radial sections leads to the shape-deviations in an axial direction of the respective outer sides of the base plate and/or causes the top plate to become smaller. There is thus a continuous shape in an axial direction, by means of which marked improvement is achieved, in contrast to the stepped shape according to JP 2001-263 294, for example, and also according to EP 1 933 039 A1.

In addition to – but possibly also as an alternative to – this first aspect of the invention, a second aspect according to Claim 2 provides that, the non-rotationally symmetrical top plate or base plate, respectively, is designed between two radial sections containing the axis of rotation and being located on either side of each fan blade without a discontinuity across the fan blade. This too is advantageous in solving the basic problem.

In a further embodiment of the invention, the geometrical deviations of two different sections containing the axis of rotation of the respective, non-rotationally symmetrical plate (top plate or base plate) can be arbitrary in a radial direction (in contrast to the inventive shape, which is in any case point-invariable continuous in an axial direction). This means that, radially, a point-invariable continuous or an abrupt shape is optionally possible.

Whereas the velocity and pressure distribution in the direction of the axis of rotation can be influenced by means of the geometric configuration of the fan blades and the configuration of the flow ducts formed between the blades by means of a known, rotationally symmetrically designed base plate and/or top plate, the irregularity in the circumferential direction remains largely unaffected by this. In contrast, by means of the inventive, non-rotationally symmetrical configuration, an advantageous effect can also be exerted in a controlled manner on the circumferentially occurring irregularity of the velocity and pressure distribution. This results in the following advantages, among other things:

- Influence on the outflow from the fan wheel such that there is equalization of the flow, above all in a circumferential direction, and as a result, a reduction in the maximum local flow velocity, which has a positive effect on the aerodynamic and acoustic properties of the fan wheel; in particular, this leads to greater efficiency and reduces noise emission.

- Direct influence on the flow in the fan wheel, in that way reducing interaction with the blade-duct walls, reducing noise, and improving air output and efficiency.

- Greater latitude to influence flow (above all in a circumferential direction) and flow routing; resulting in stabilization of flow in the blade duct and thus reducing the tendency toward flow breakaway.

- Improvement in mechanical stability and thus the latitude to save material.

The invention will now be explained in greater detail on the basis of several exemplary embodiments illustrated in the drawing. The following is shown:

Fig. 1 a first embodiment of the inventive fan wheel, specifically, in Fig. 1 a, a perspective view and, in FIG. 1 b, an axial section in a diametrical sectional plane,

Fig. 2-9 in each case, an additional, different design of the fan wheel is illustrated, partial Figure a) being a perspective view and a partial Figure b) a side view, and

Fig. 10 an additional perspective view of an inventive fan wheel, for example in a version on a larger scale, as in Fig. 4 a, in order to further explain the invention.

In all of the exemplary embodiments, an inventive fan wheel 1, driven in rotation around an axis of rotation Z, consists of a top plate 2, preferably with an essentially centric inlet port 4 for the inflow of air, a base plate 6 that lies opposite to it in an axial direction Z, and a plurality of fan blades 8. These fan blades 8 are arranged between the base plate 6 and the top plate 2, or are formed completely or in regions by a specific shaping of the base plate 6 and/or of the top plate 2 (cf. Fig. 8), and the plates 2, 6 then being connected directly to one another in these regions. The fan blades 8 are arranged in a specific circumferential distribution around the axis of rotation Z and the inlet port 4. Formed in the circumferential direction in each case between two adjacent fan blades 8 are blade ducts 10 which lead radially or diagonally outward from the region of the inlet port 4 and form blow-out ports on the outer region of the fan wheel 1.

As explained above, it is provided, in a manner typical of "turbo-fans," that the blade-ducts 10, with respect to their effective flow cross-section, are designed as large enough that during operation, a turbulent flow with a Reynolds number Re >> 2300 with high efficiency is attained between 0.6 and 1.0. In addition, the inlet port 4 has an effective suction-port flow-width DS, whose ratio to an effective flow-width DK of each blade-duct is in each case less than 10, and can in particular be even less than 3. The cited flow-widths are normally related to a circular shape, the basis for this being an idealized diameter, even if the actual flow cross-sections deviate from the circular shape.

Regarding the inventive fan wheel 1, it is essential that the top plate 2, or the base plate 6, or alternatively each of the two plates 2, 6 has a non-rotationally symmetrical geometry, in order to influence flow. It is also essential that the top plate 2 and the base plate 6 not be parallel to each other.

Reference is made at this point to Fig. 10, which shows two additional radial planes E 1 and E 2, i.e. two planes running in a manner corresponding to a radius r and intersecting in the axis of rotation Z, the two planes forming a specific differential angle α. There is non-rotational symmetry in the inventive sense when the cross-sectional areas of the respective plate 2 and/or 6 , which lie in the planes E 1 and E 2, differ from each other, having different circumferential angles.

However, in addition, the profile of the respective non-rotationally symmetrical plate 2 and/or 6 running in an axial direction on the respective outer sides of the base plate 6 and/or the top plate 2 is point-invariable continuous across the entire circumferential region (also across the blades), which means that with a decreasing differential angle α, there is a critical angle αG > 0°, beyond which further convergence of the two radial sections E1 and E2 (Fig. 10) leads to a decrease in the dimensional deviations in the axial direction Z of the respective outer sides of base plate 6 and/or top plate 2. Alternatively or additionally, it is provided that two cross sections, which lie in two planes that contain the axis of rotation Z, and which consequently intersect in the axis of rotation Z, do not represent any abrupt change in the direction of rotation over the blade 8 on either side of each fan blade 8.

In contrast to point-continuous shape in an axial direction Z, the invention allows for arbitrary deviation in a radial direction in the geometry of two different sections containing the axis of rotation Z (radius r in Fig. 10). This enables both point-continuous and abrupt shapes.

Individual exemplary embodiments are briefly described in more detail below.

In the version according to Fig. 1, the top plate 2 is provided with a wheel inlet 12 in the region of the inlet port 4, the top plate 2 being designed in the region of this wheel inlet 12 as non-rotationally symmetrical in the direction of the axis of rotation Z. In the example illustrated, the wheel inlet 12 extends axially, in a web-like manner, away from the top plate 2 and displays, in a circumferential direction, a wavy contour with axial elevations interspersed with depressions. The fan wheel 1 is designed here as a radial fan. Additionally or alternatively, however, the top plate 2 can also be designed in the region of the inlet port 2, or as the case may be in the region of the wheel inlet 12, as non-rotationally symmetrical in a radial direction as well.

The version according to Fig. 2 is also a radial fan, however in this case only the top plate 2 is designed as non-rotationally symmetrical in the direction of the axis of rotation Z. To that end, in this example, the top plate 2 has a wave-like design in the circumferential direction, there being in each case a convex, outward-curving section between two fan blades 8. These sections merge continuously in the region of each fan blade 8.

Fig. 3 illustrates a version that is designed as a radial fan, in which only the base plate 6 is designed as non-rotationally symmetrical in an axial direction Z. In concrete terms, this could be a configuration identical to that provided for with the top plate 2 in Fig. 2.

The version according to Fig. 4 actually combines both versions according to Fig. 2-3. This means that this radial fan is designed as non-rotationally symmetrical in both the region of the top plate 2 and the region of the base plate 6.

Fig. 5 illustrates a version of the fan wheel 1 as a diagonal fan, the top plate 2 being designed as non-rotationally symmetrical in a radial direction r, and in this case, the changes not being continuous but abrupt. This is achieved by means of an outer circumferential edge 14 of the top plate 2 that is not continuous, but has a stepped shape across corners in the radius.

Fig. 6 illustrates a version as a radial fan in which the top plate 2 is designed as non-rotationally symmetrical in a radial direction r, and specifically as point-continuous. This means that here, the top plate 2 has a continuous circumferential profile, without corners or other steps.

The same also applies to the very similar version according to Fig. 7, in which, however, there is a corner or a bend in each case at points P.

Fig. 8 shows a version as a radial fan, the two plates, both the top plate 2 and the base plate 6, being designed as non-rotationally symmetrical in the direction of the axis of rotation Z by means of a contour which is wave-like in a circumferential direction. In addition, there is provision here for the top plate 2 and the base plate 6 to be directly connected in the outer circumferential region of the fan wheel 1, thereby forming together at least one partial region of the fan blades 8. For the purpose of illustration, a partial region of the top plate 2 is cut away in the region of one of the blade-ducts 10 in the supplementary Fig. 8c. In principle, the fan blades 8 as a whole could be formed by directly connecting the correspondingly shaped base and/or top plates 6, 2 across the entire contour of the blades 8. In the version shown, however, the plates 2, 6 are connected only in the outer circumferential region, conventional blade portions being formed as separate parts in the inner inflow region of the blade-ducts 10.

In all of the embodiments described above, the non-rotationally symmetrical configuration produces geometric structures that are designed to recur periodically in a circumferential direction. However, the scope of the invention also includes the possibility of choosing the geometric structures in such a way that they are irregular in form and/or arrangement.

An exemplary embodiment of this is illustrated in Fig. 9. Here too, there is a radial fan with a non-rotationally symmetrical top plate 2. The top plate has a radius r that changes abruptly at a circumferential point 16, and the outer circumferential edge 14 of the top plate 2 runs, starting at the circumferential point 16, with a continuously changing radius around the circumference, ending after 360° at the radius step at the circumferential point 16. In this example, therefore, the circumferential edge 14 has a spiral-like course.

Other versions that result in an irregular circumferential geometry of the top plate and/or base plate 2, 6 are of course possible.

In all embodiments, the fan blades 8 may have any desired profile. They might be curved forwards or backwards, for example, in relation to the direction of rotation.

Furthermore, any combination of the individual features described above is possible.

The invention is not limited to the embodiments presented and described here; it also extends to all embodiments that operate in the inventive sense. It is expressly emphasized that the exemplary embodiments are not limited to a combination of all of the features described; each individual sub-feature may in itself have inventive significance separately from all other sub-features. Furthermore, the invention is not, for the time being, limited to the combination of features defined in each independent claim; it can also be defined by any other combination of specific features, or the totality of all of the individual features disclosed. This means that, in principle, virtually every individual feature of each independent claim could be omitted or replaced by at least one individual feature that is disclosed in another part of the application. In this respect, the claims are to be understood only as a first attempt at a formulation for an invention.

CLAIMS:

1. A fan wheel (1) in the form of a radial or diagonal fan, comprising a top plate (2) with an inlet port (4), a base plate (6), and a plurality of fan blades (8) arranged so as to be distributed around the circumference of the inlet port (4) and around an axis of rotation (Z), as well as blade-ducts (10) formed in each case in a circumferential direction between the adjacent fan blades (8), said blade-ducts leading from the region of the inlet port (4) radially or diagonally outward and forming blowout-ports (11) in the outer region, the blade-ducts (10), with respect to their effective flow cross-section being designed as large enough that during operation, a turbulent flow with a Reynolds number (Re) obviously larger than 2300 is achieved, and with the top plate (2) and/or the base plate (6) displaying a non-rotationally symmetrical geometry, wherein in each case, the non-rotationally symmetrical geometry, with respect to an axial or as the case may be axially parallel direction (Z), has a continuous, point-continuous shape.

2. A fan wheel according to Claim 1, characterized in that the respective non-rotationally symmetrical geometry does not have a discontinuity across either fan blade (8) between two radial sections containing the axis of rotation (Z) lying on either side of each fan blade (8).

3. A fan wheel according to Claim 1 or 2, characterized in that the inlet port (4) has an effective intake opening flow width (D_S) whose ratio to an effective flow width (D_K) of each blade-duct (20) is less than 10, and is in particular less than 3.

4. A fan wheel according to any one of Claims 1-3, characterized in that the respective non-rotationally symmetrical geometry, with respect to a radial direction (r), has a continuous, point-continuous shape or a non-continuous step-like profile.

5. A fan wheel according to any one of Claims 1-4, characterized in that the top plate (2) is designed in the region of the inlet port (4) as non-rotationally symmetrical in the direction of the axis of rotation (Z), and/or in a radial direction (r), whereby ,in particular, an axially protruding wheel inlet (12) that encloses the inlet port (4) has a wavy contour with alternating projections and depressions.

6. A fan wheel according to any one of Claims 1-5, wherein the top plate (2) is designed as non-rotationally symmetrical in the direction of the axis of rotation (Z); the top plate (2) preferably displaying a wavy configuration in a circumferential direction.

7. A fan wheel according to any one of Claims 1-6, characterized in that the base plate (6) is configured as non-rotationally symmetrical in the direction of the axis of rotation (Z), the base plate (6) preferably displaying a wavy configuration in a circumferential direction.

8. A fan wheel according to any one of Claims 1-7, characterized in that the top plate (2) is configured as non-rotationally symmetrical in a radial direction (r).

9. A fan wheel according to any one of Claims 1-8, characterized in that the base plate (6) is configured as non-rotationally symmetrical in a radial direction (r).

10. A fan wheel according to any one of Claims 1-9, characterized in that the fan blades (8), at least in regions, are formed by means of a direct connection between the correspondingly shaped top plate (2) and base plate (6).

11. A fan wheel according to any one of Claims 1-10, characterized in that the non-rotationally symmetrical geometry is designed, with regard to shape and/or arrangement, as recurring periodically or irregularly in a circumferential direction.

Fig.1

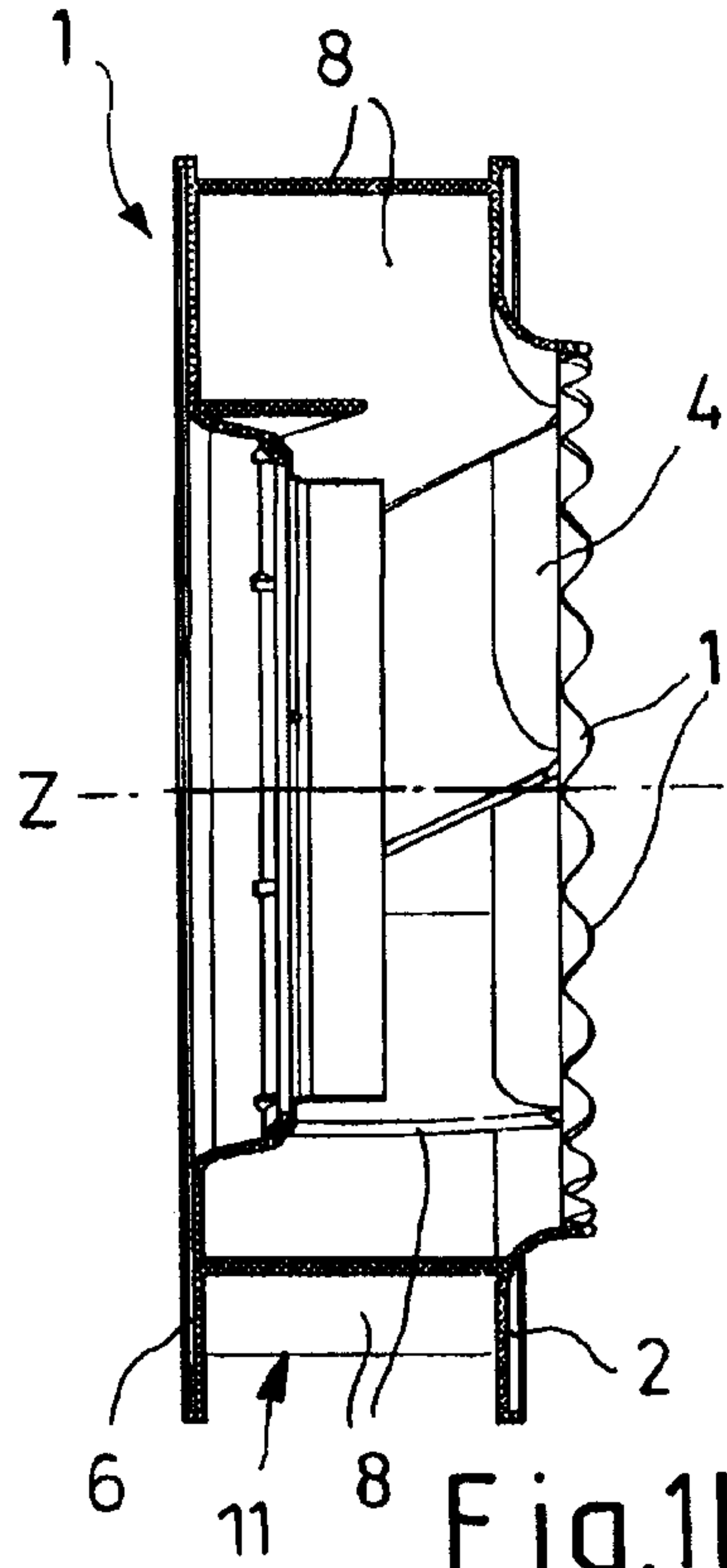


Fig.1b

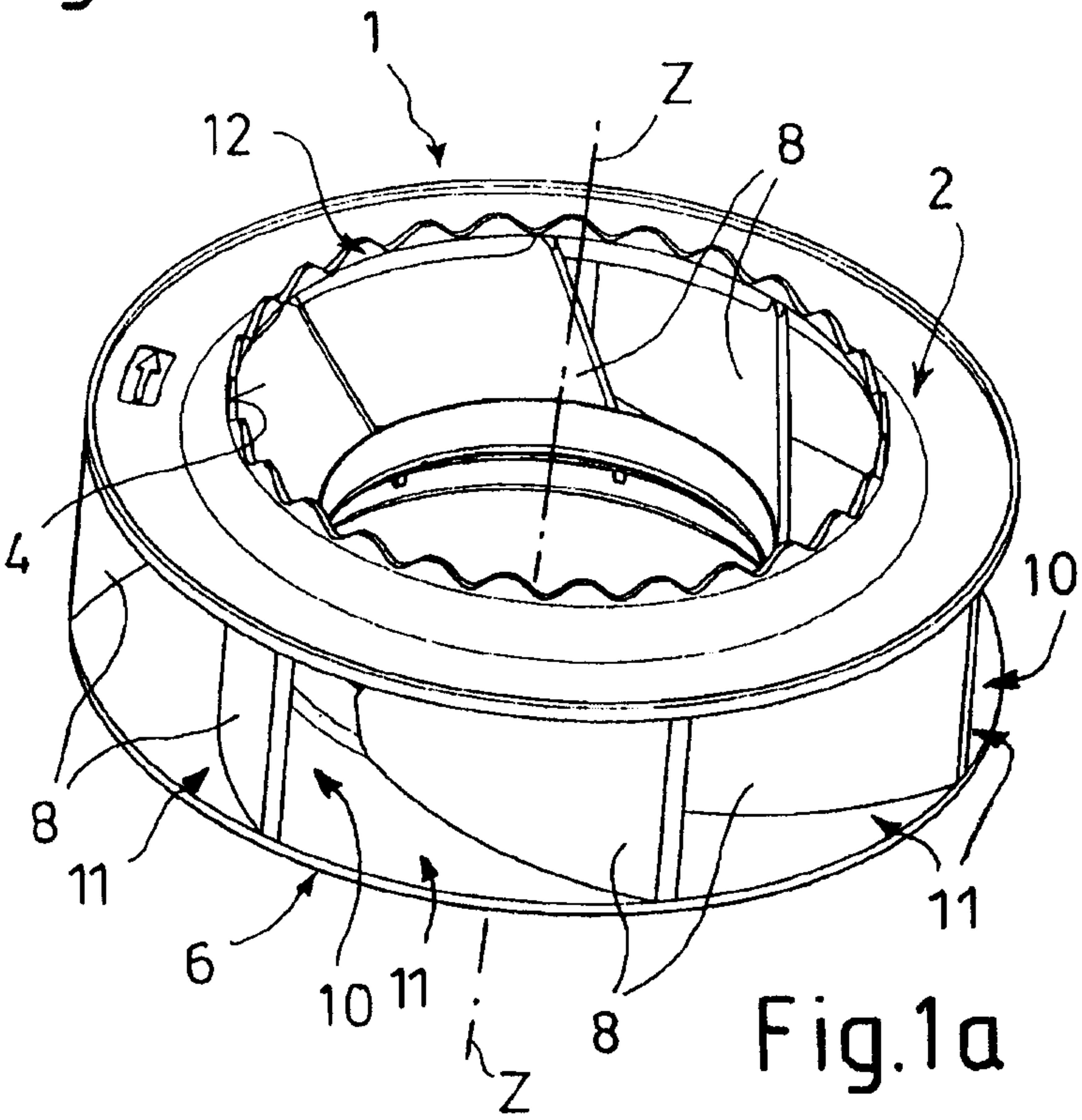


Fig.1a

Fig.2

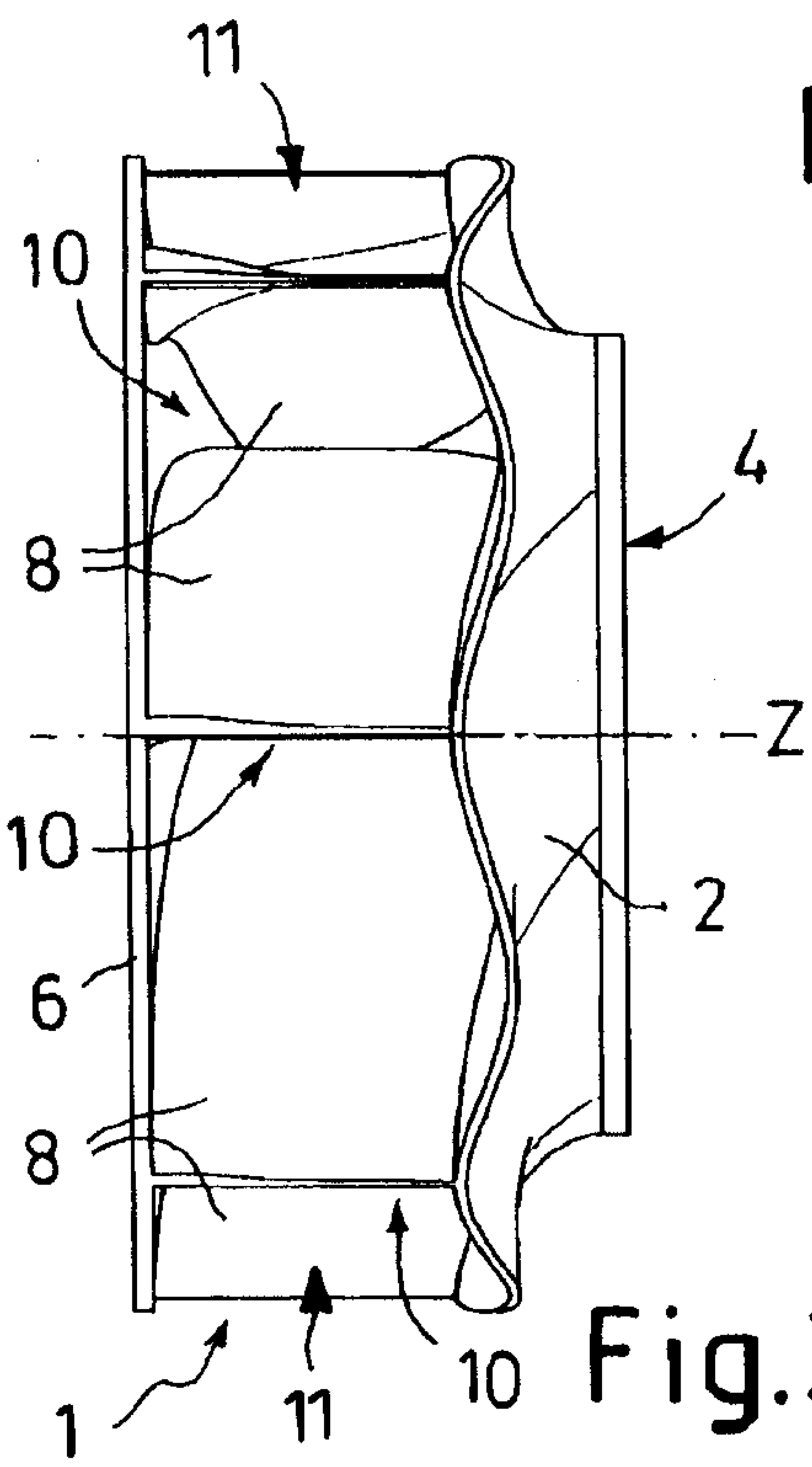


Fig.2b

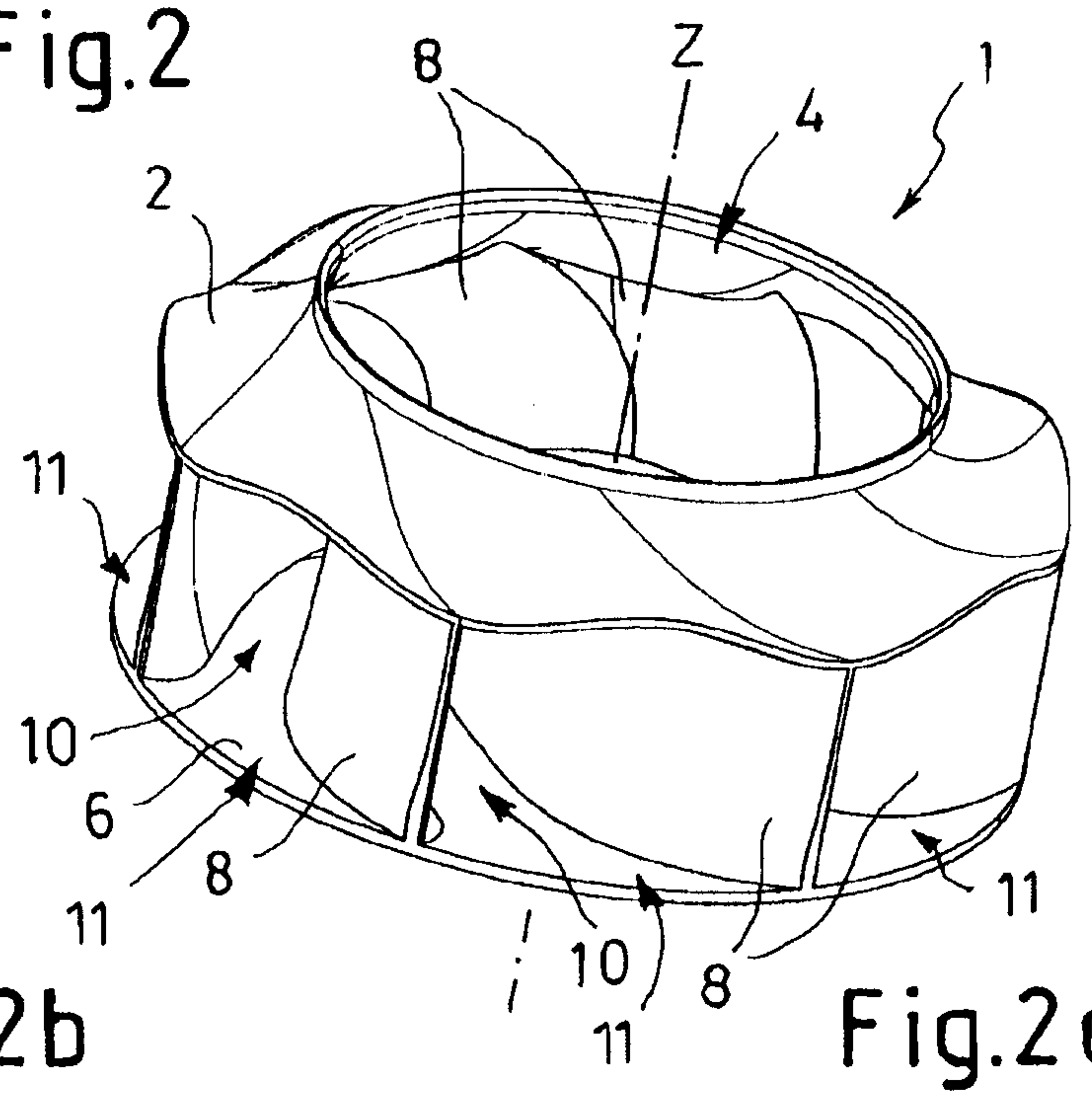


Fig.2a

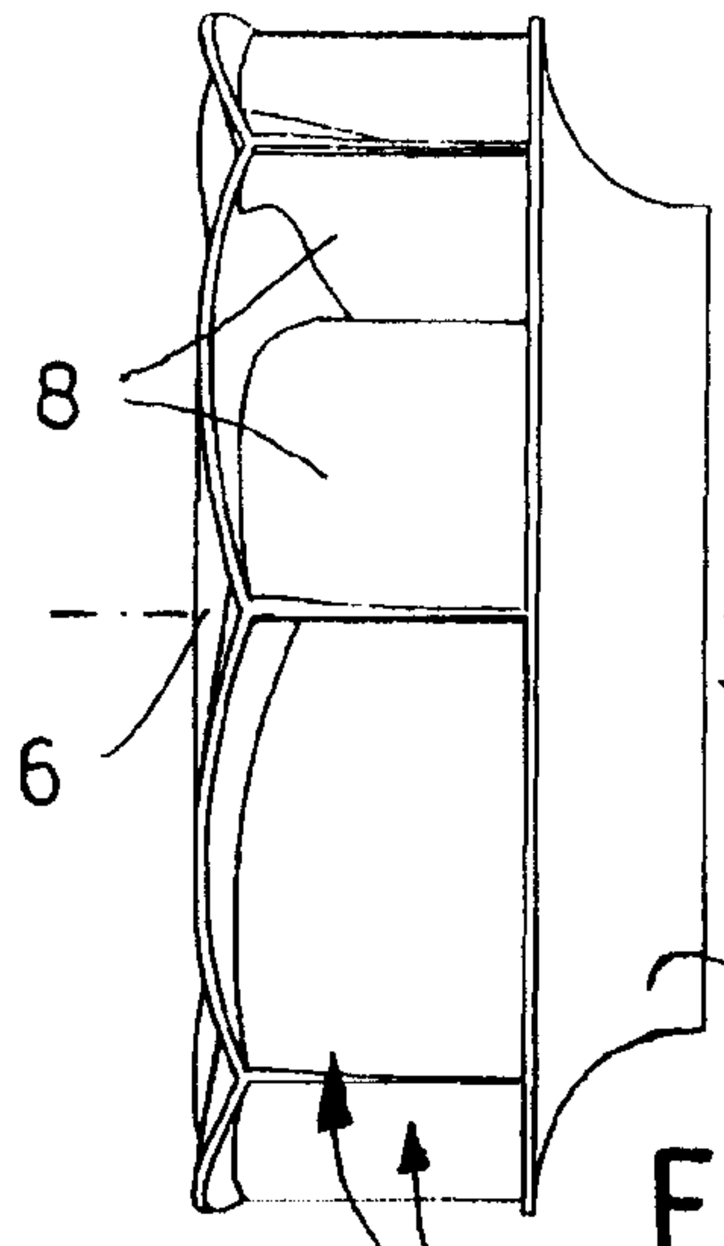


Fig.3

Fig.3b

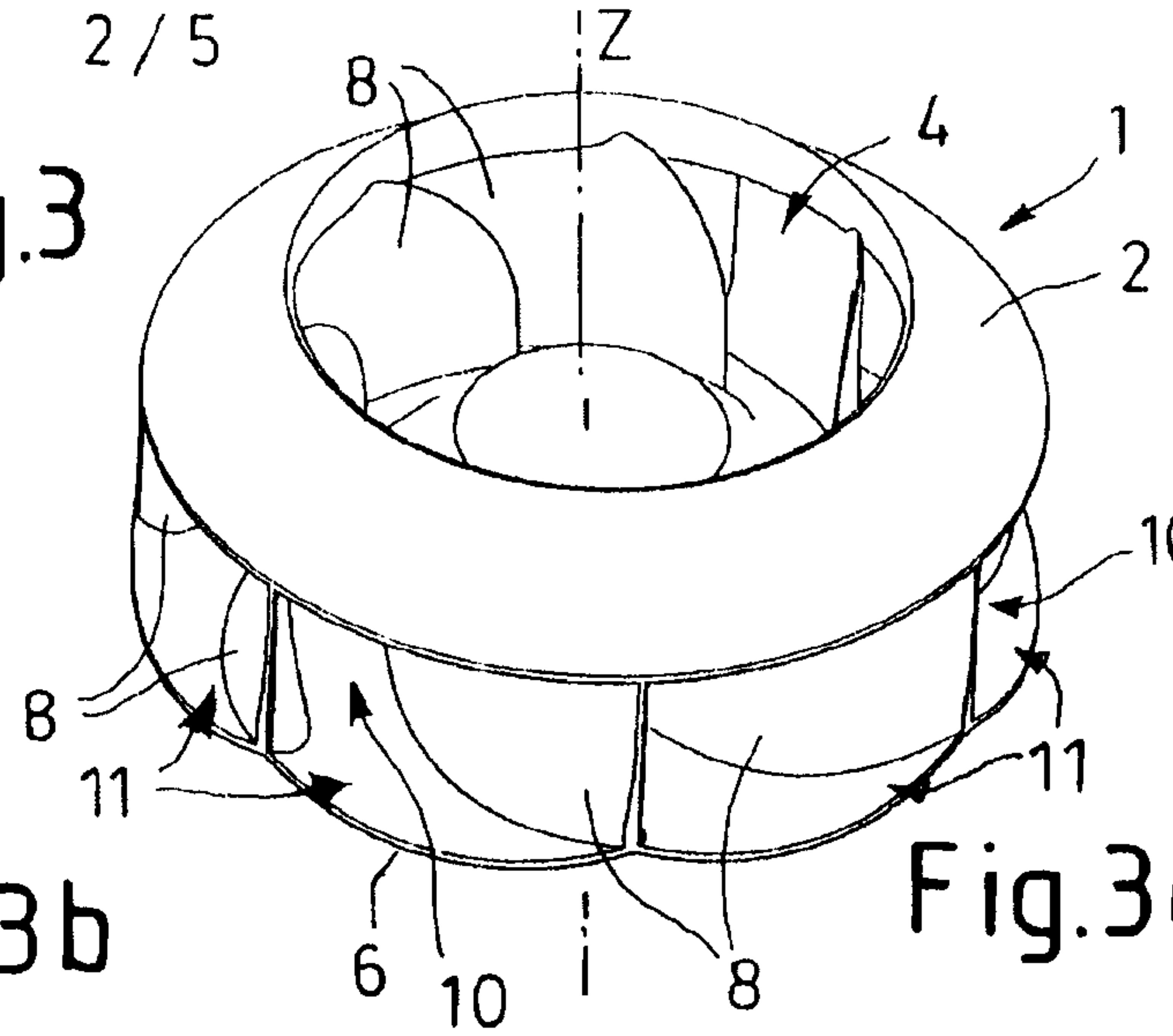


Fig.3a

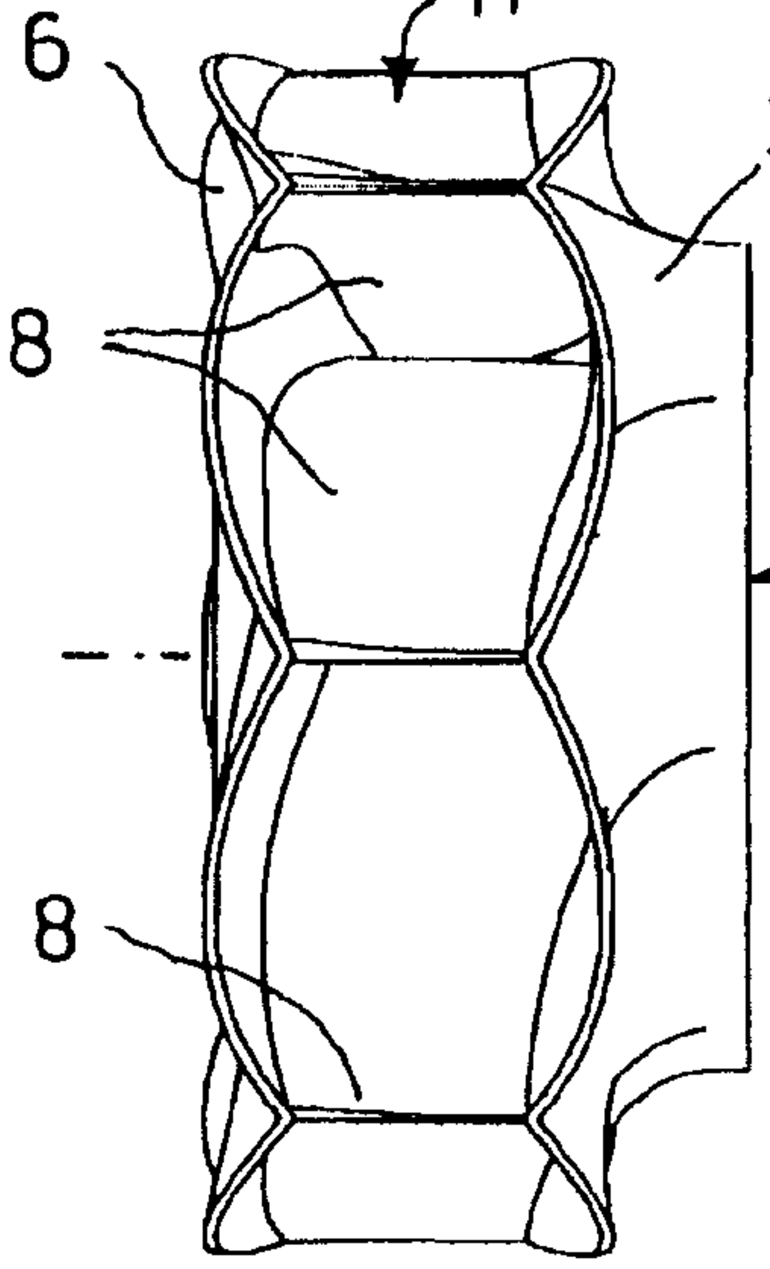


Fig.4

Fig.4b

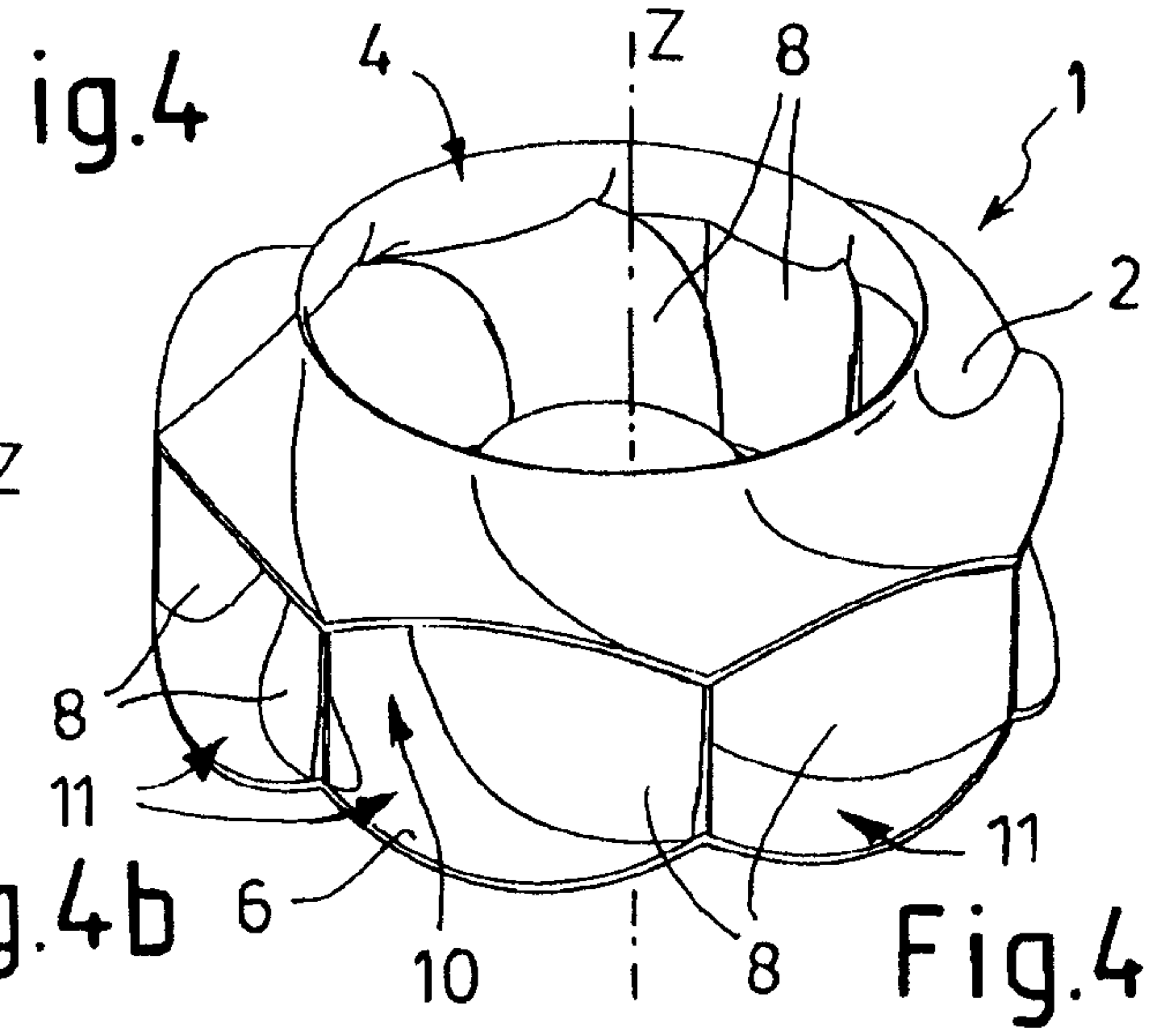


Fig.4a

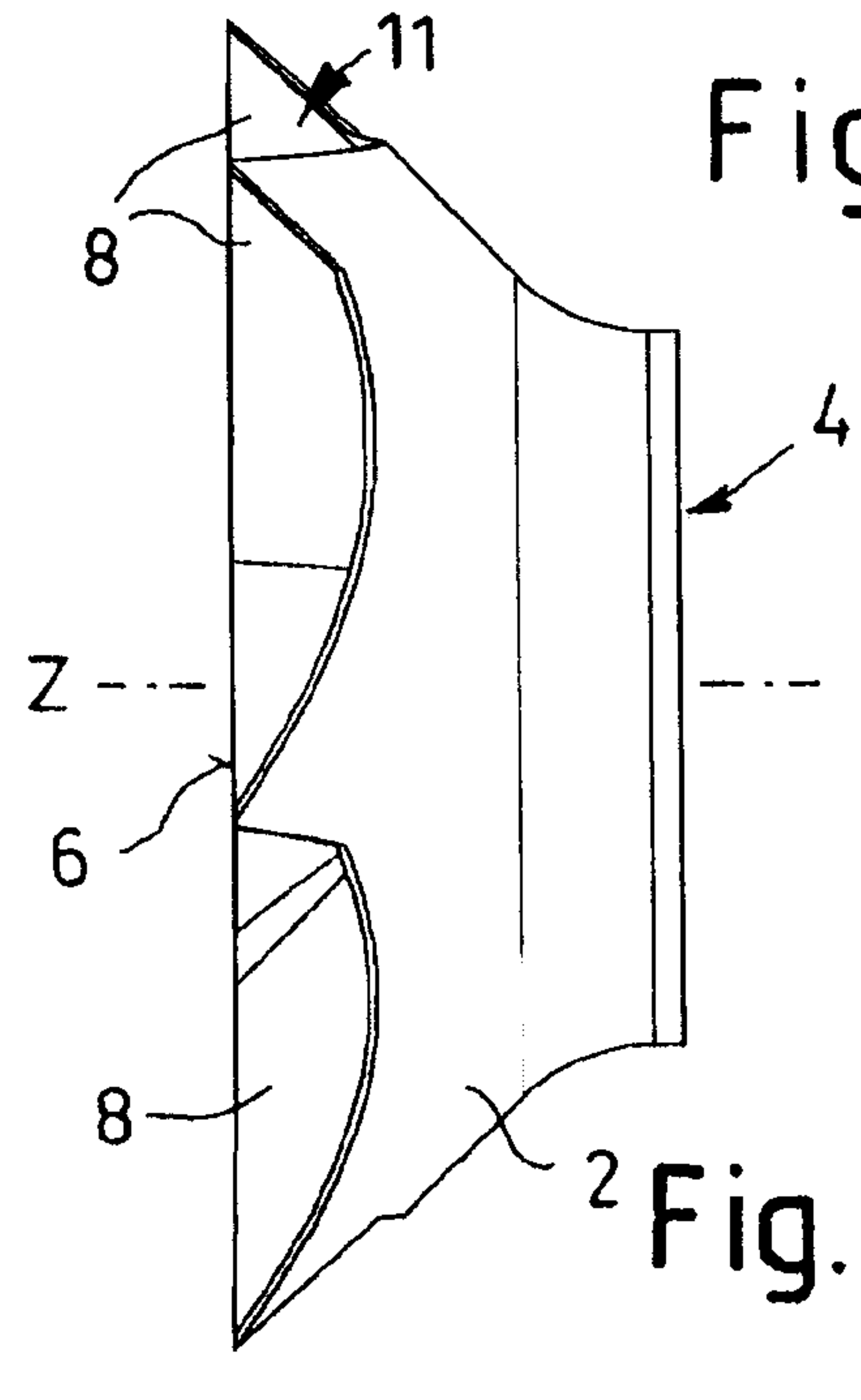


Fig.5

Fig.5b

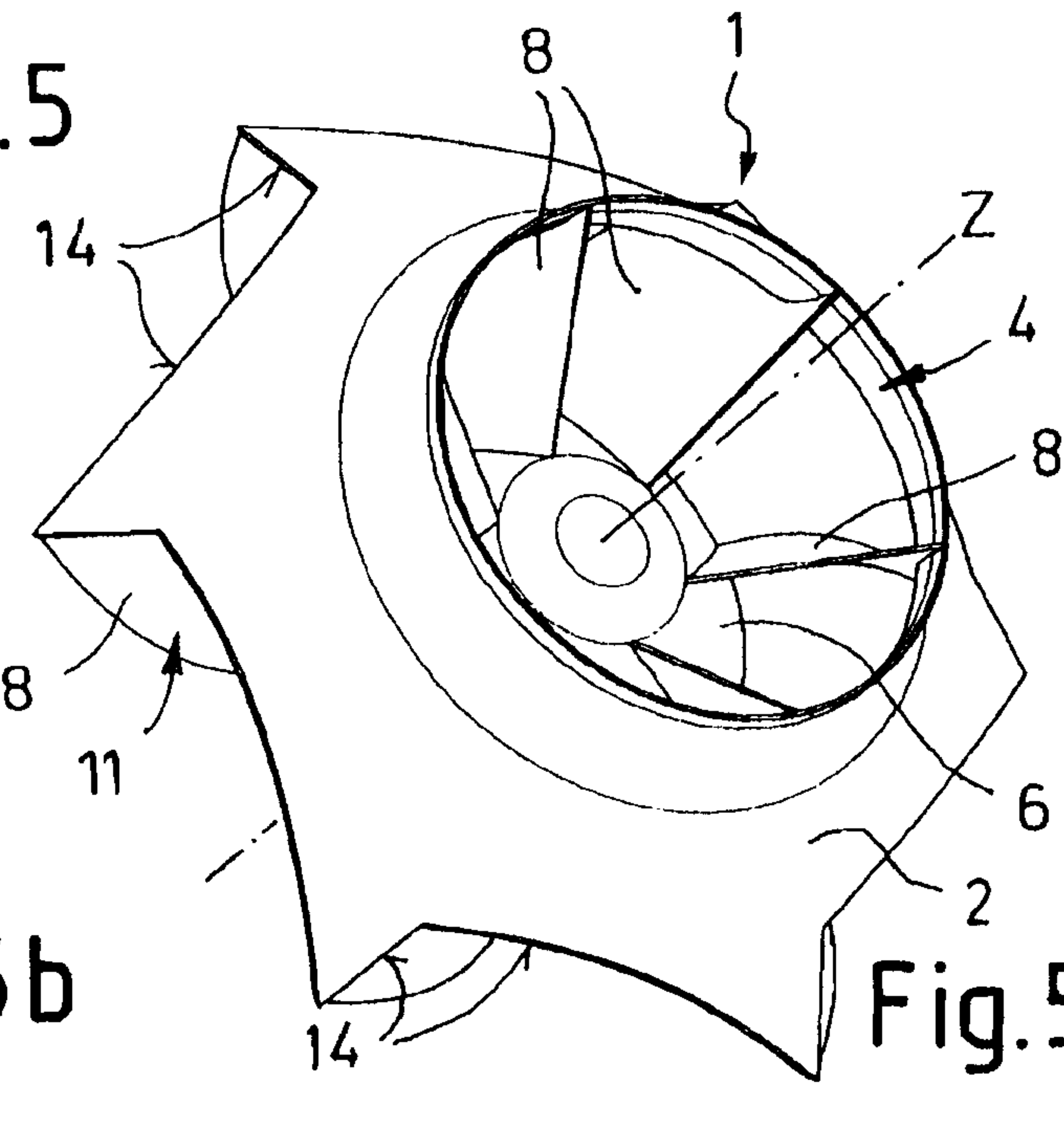


Fig.5a

Fig.6

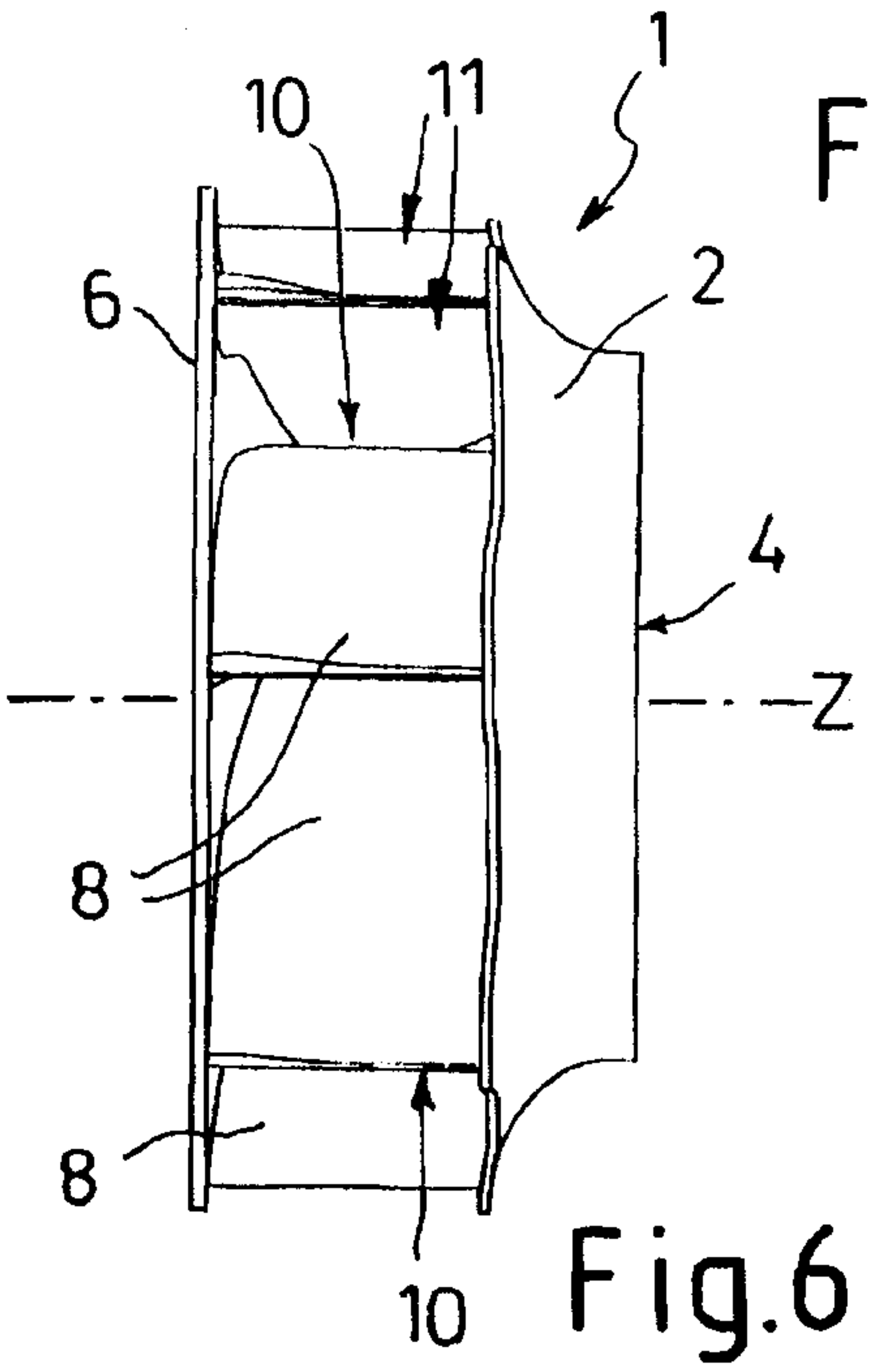


Fig.6b

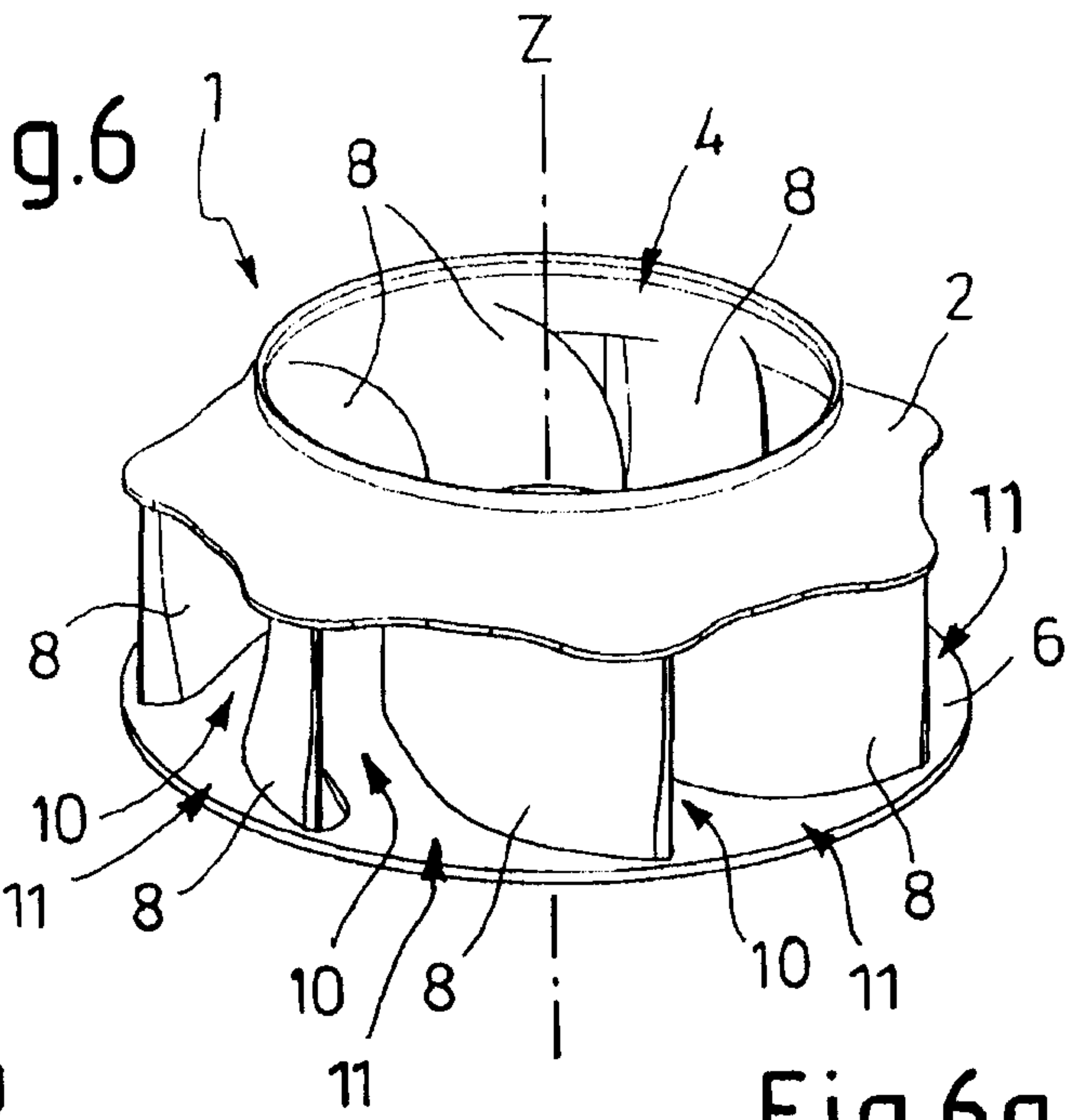


Fig.6a

Fig.7

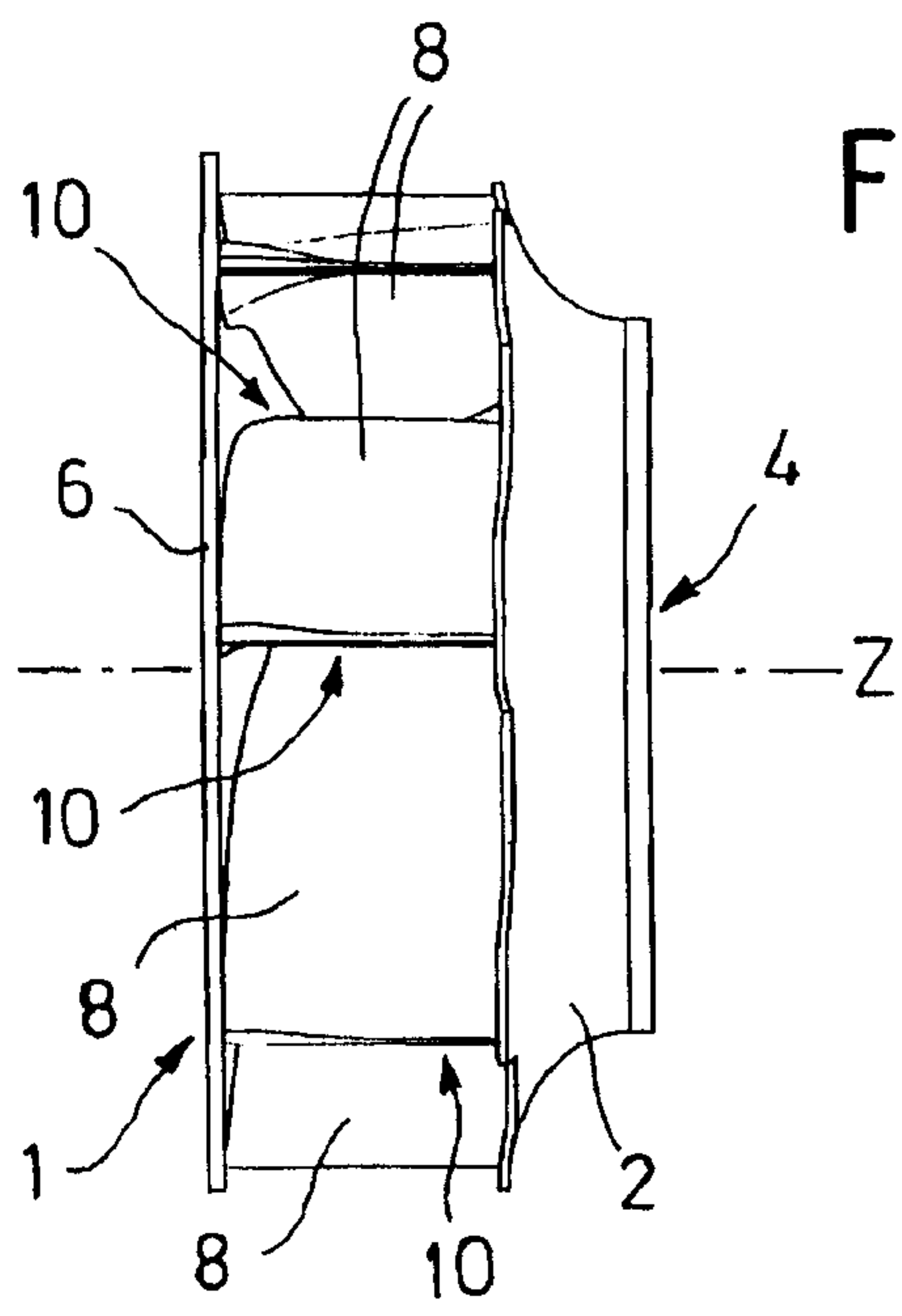


Fig.7b

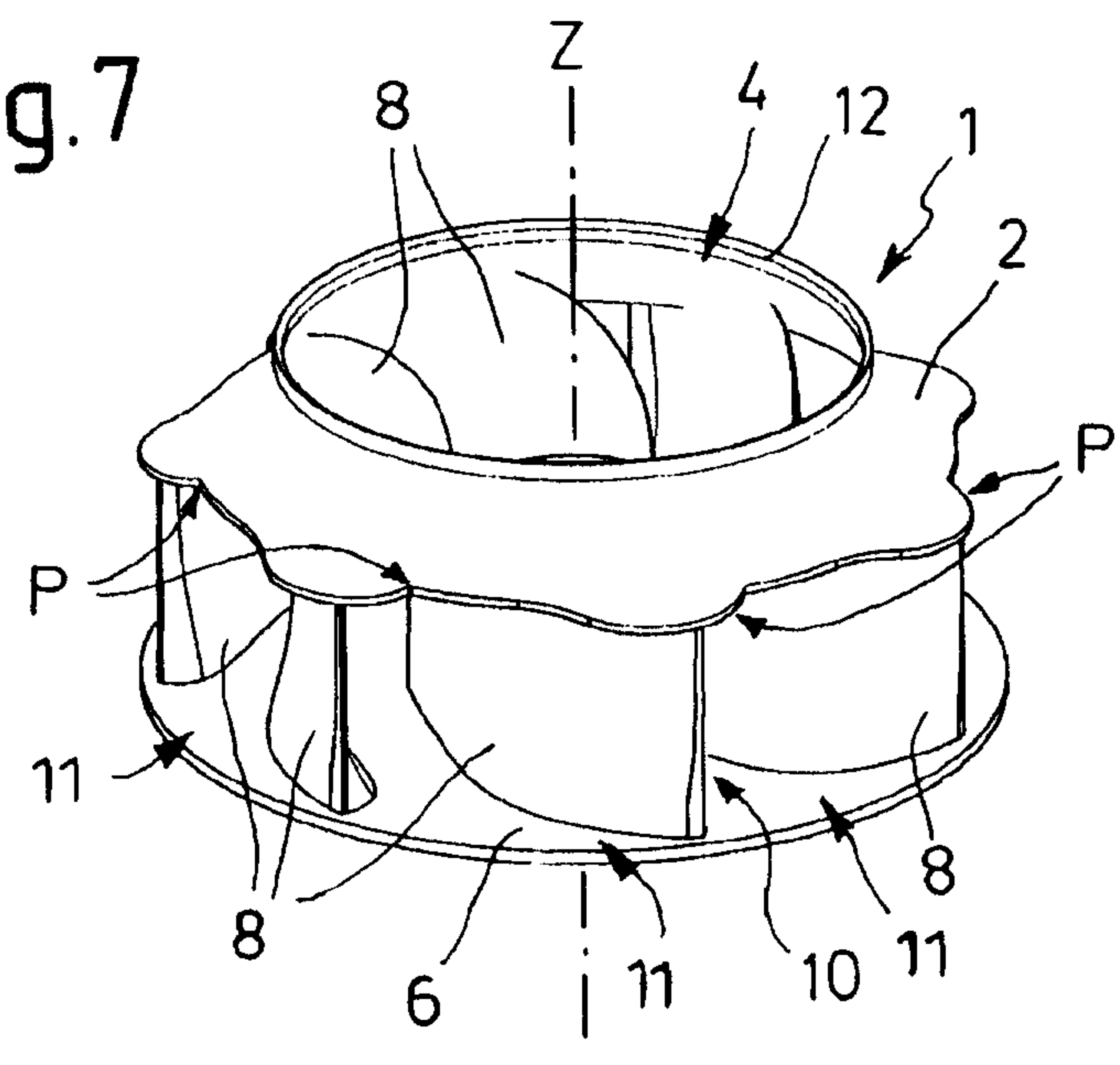


Fig.7a

Fig.8

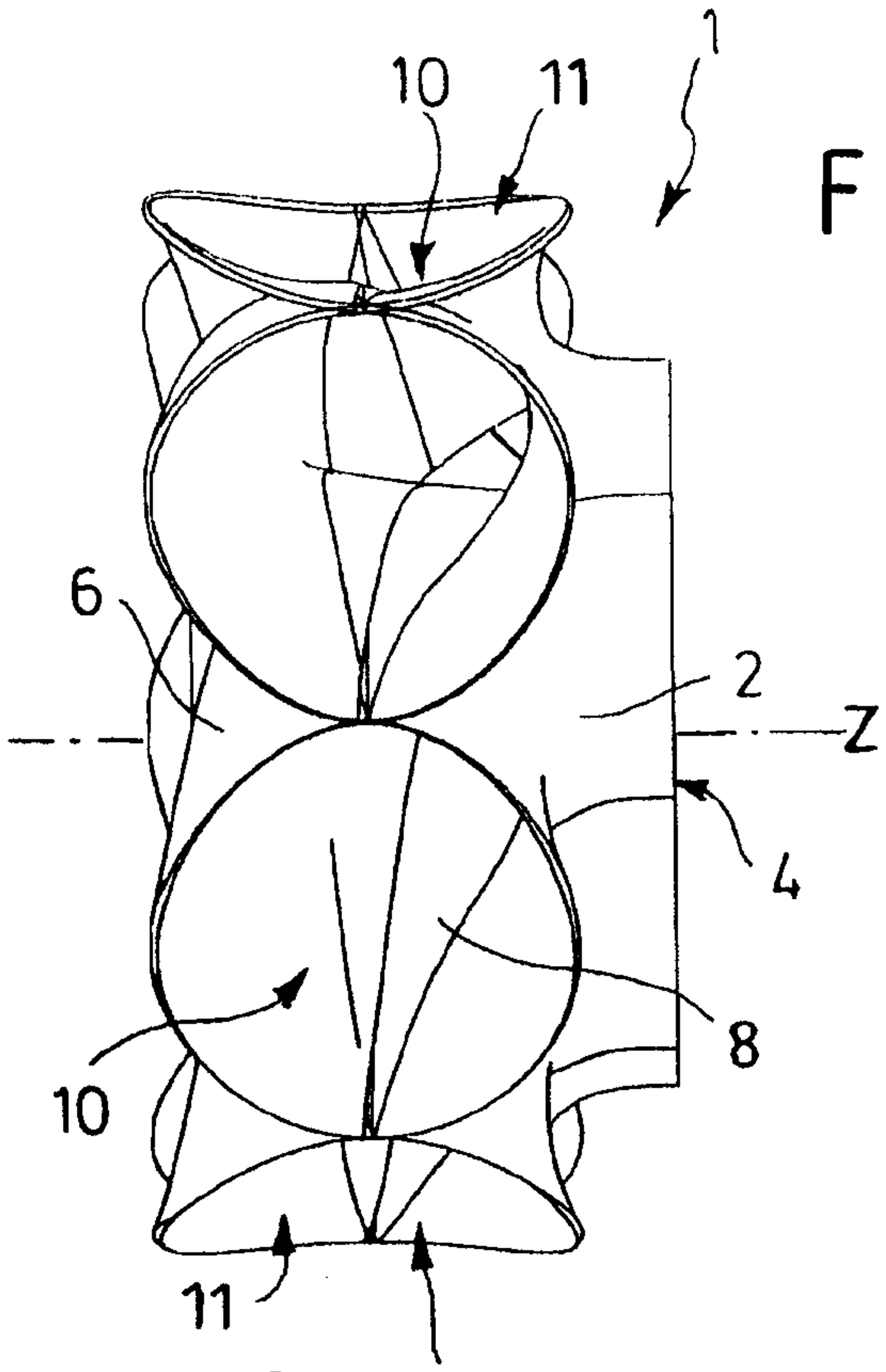


Fig.8b

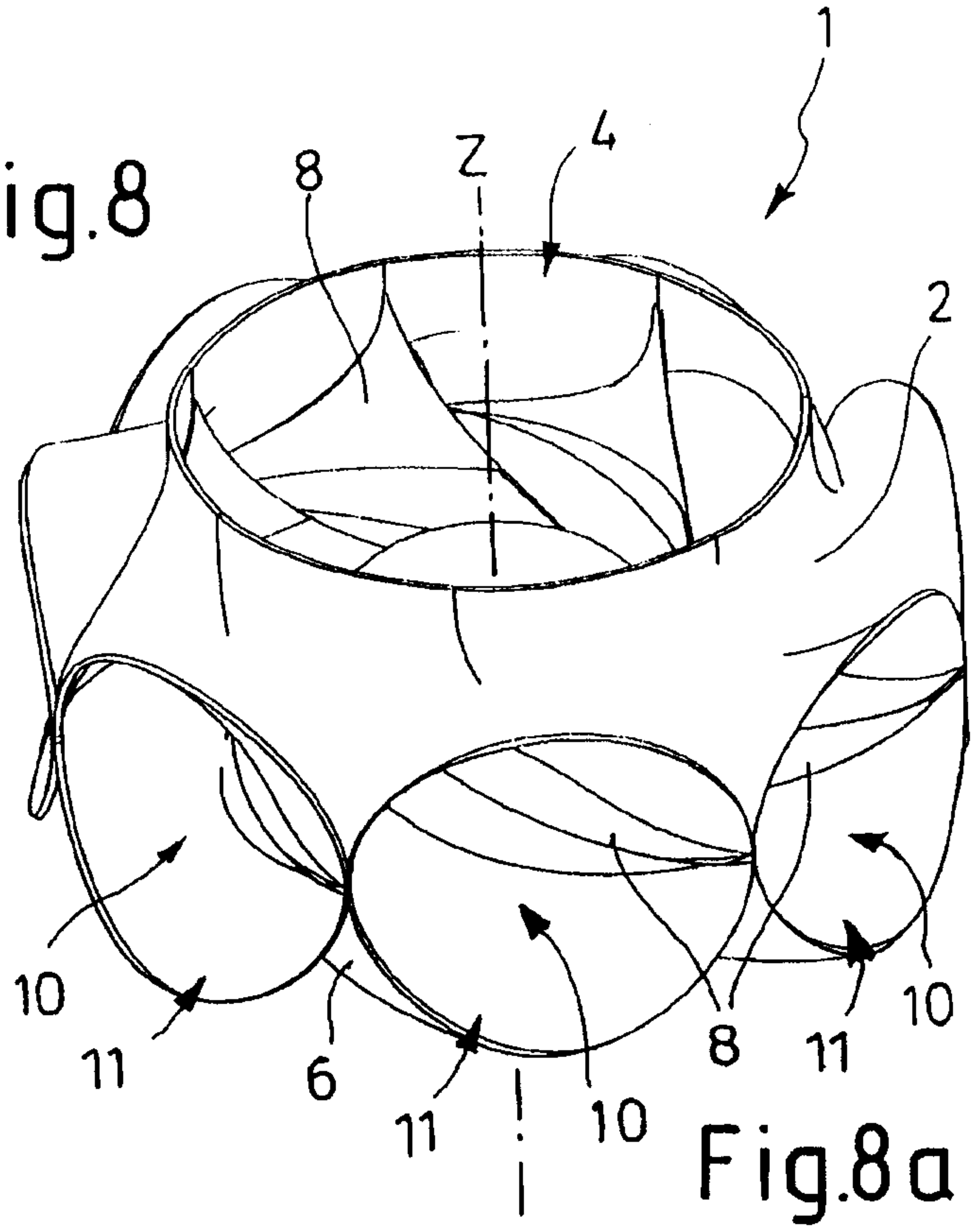
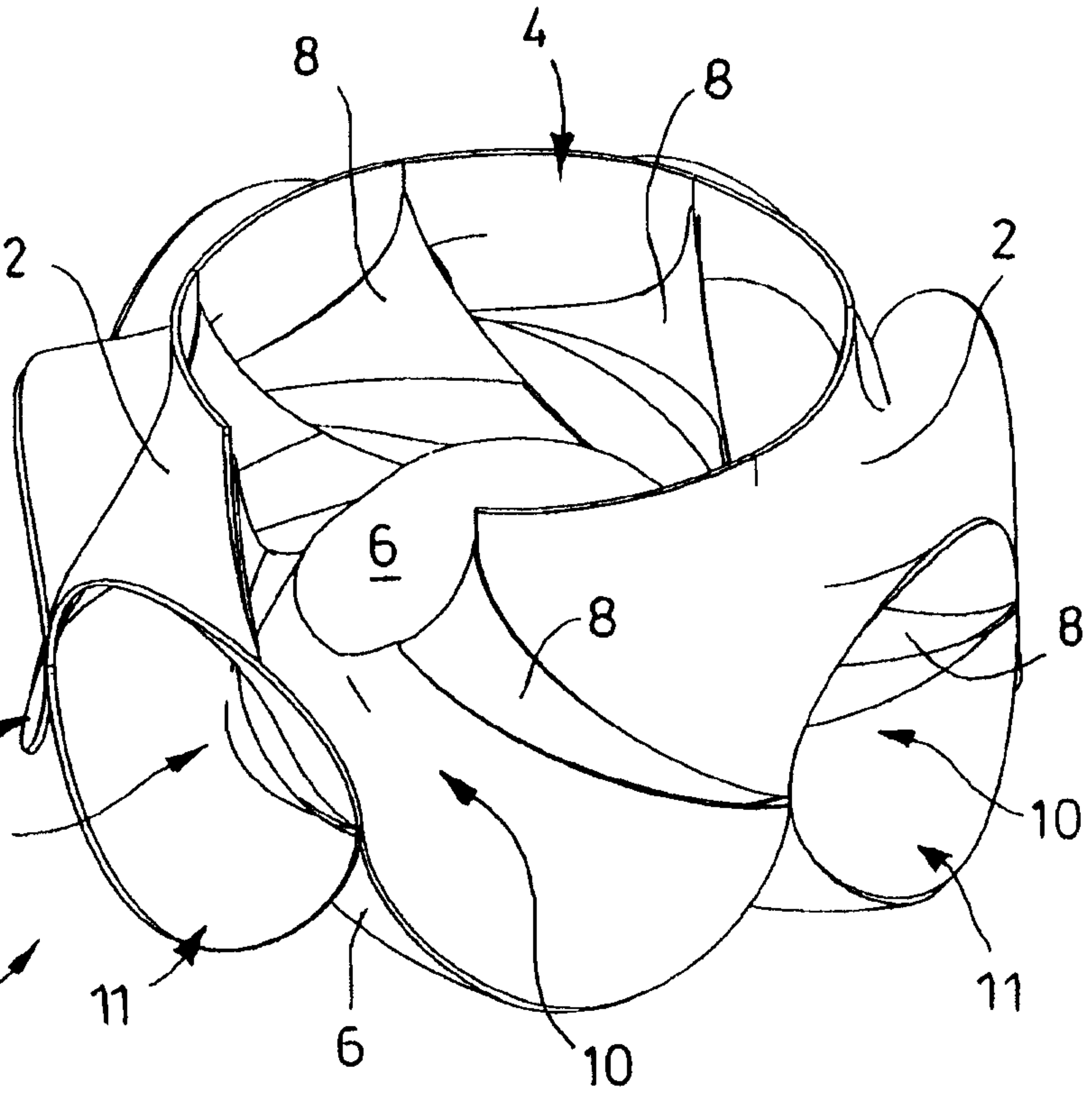


Fig.8a

Fig.8c



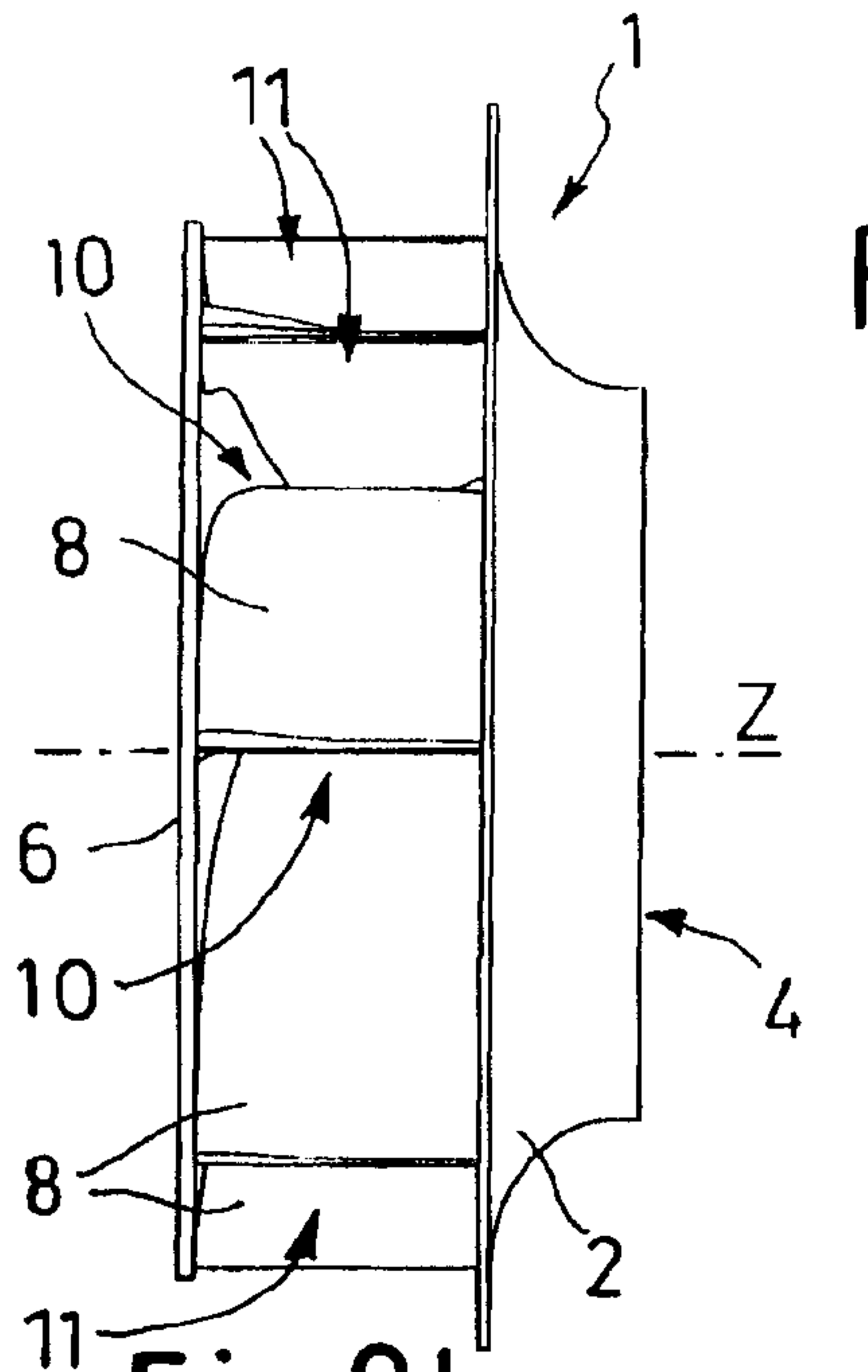


Fig.9b

Fig.9

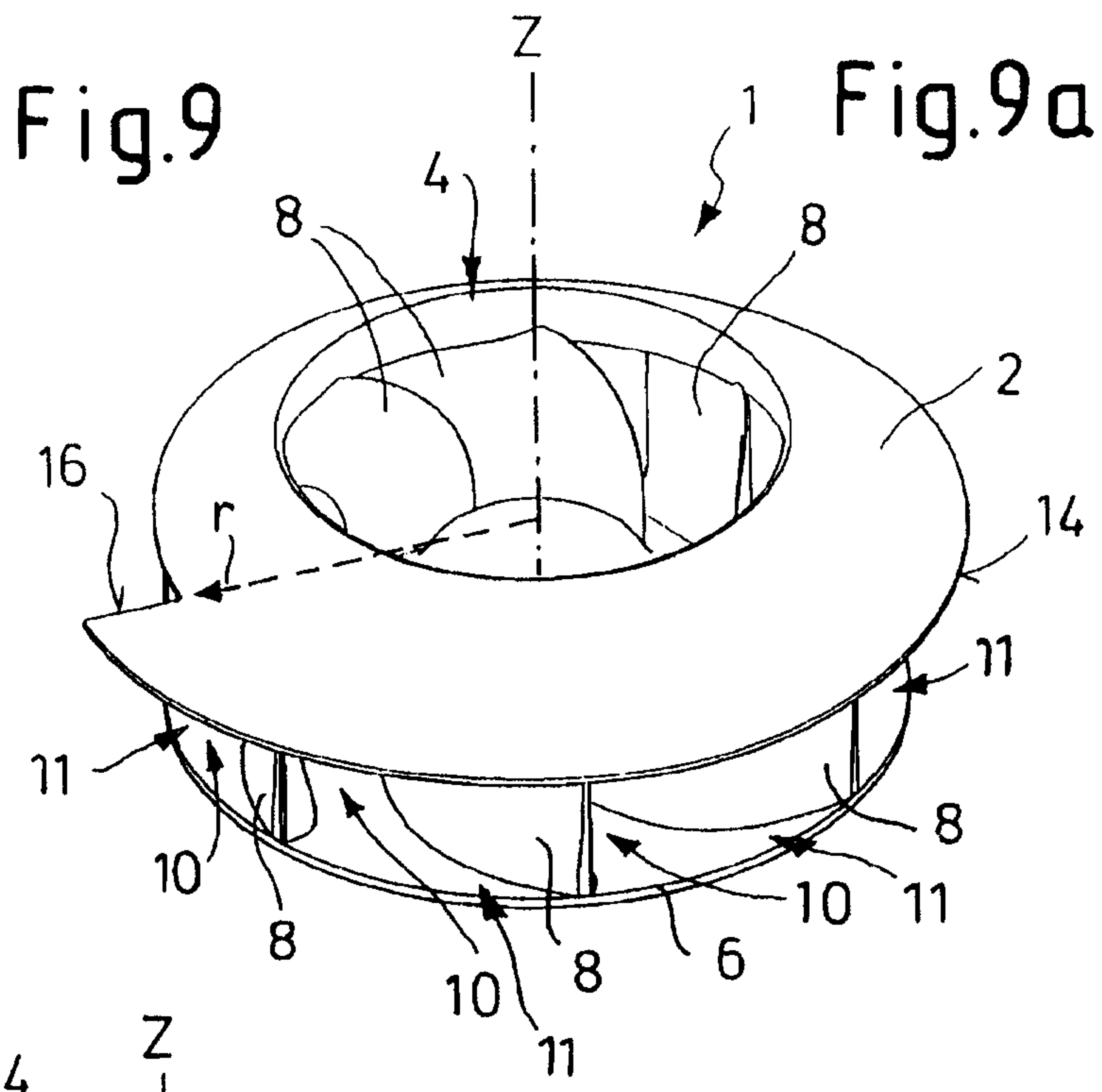


Fig.9a

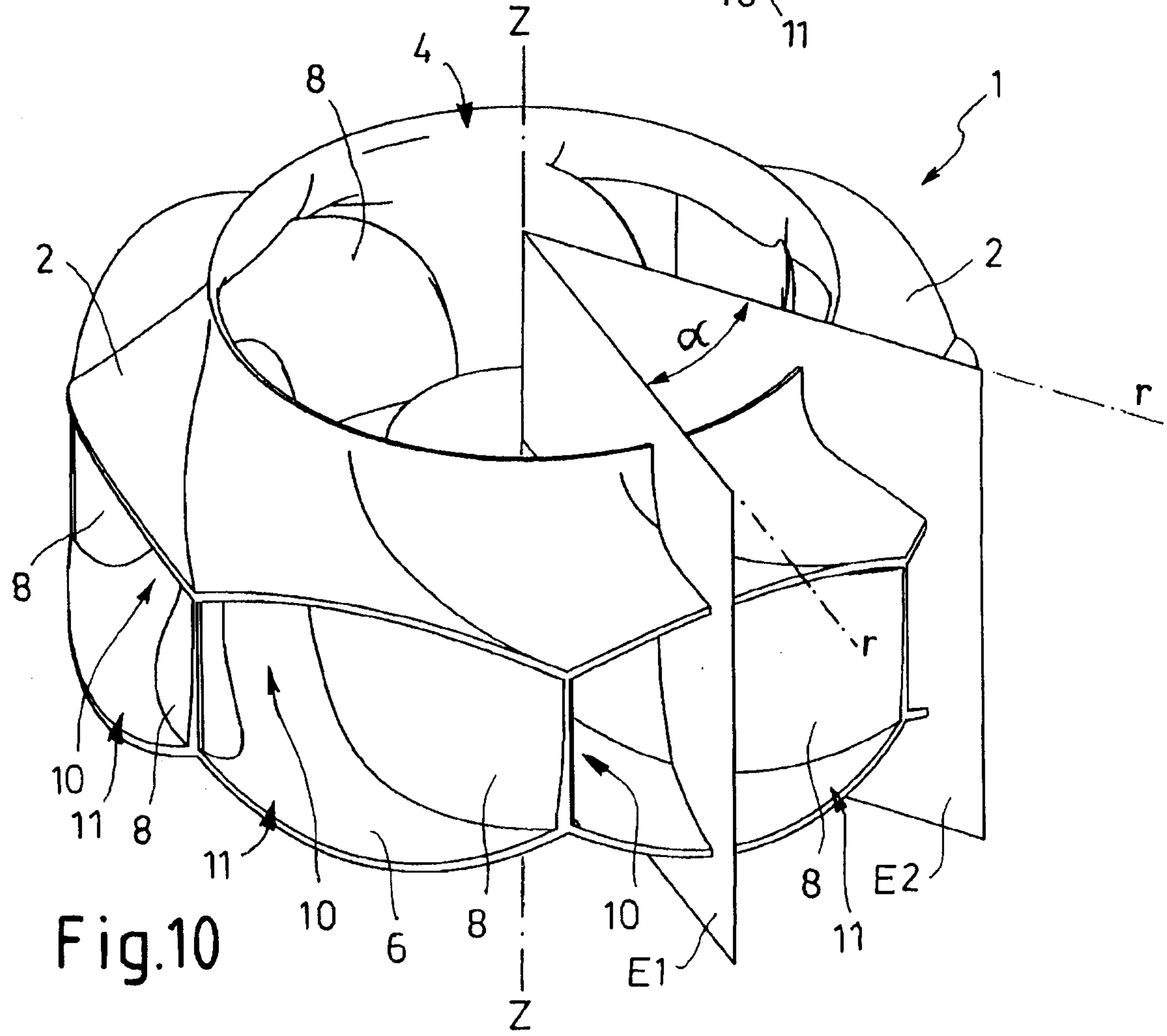
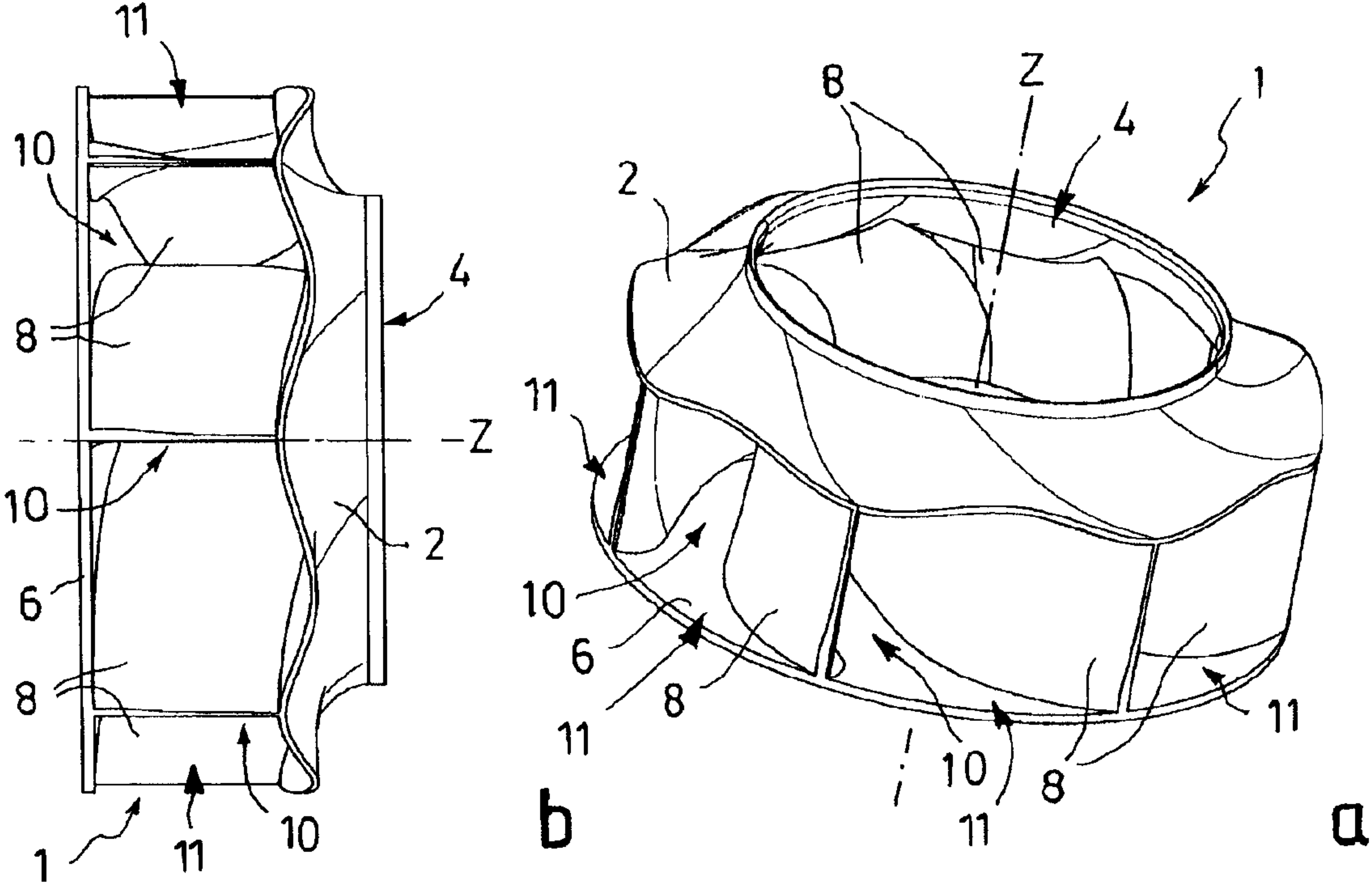


Fig.10



11
10
8
10
6
8
1
11
10
4
Z
2
b
8
Z
1
2
4
11
10
6
11
8
10
11
8
11
a