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(54) **Title:** VORTEX FINDER FOR A CYCLONIC SEPARATOR

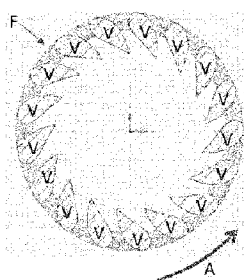


Fig. 1

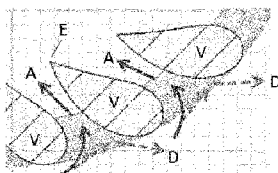


Fig. 2

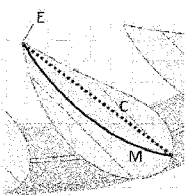


Fig. 3

(57) **Abstract:** A vortex finder (F) for a cyclonic separator, the vortex finder comprising a plurality of stationary vanes (V) having a round convex front end around which incoming air (A) is guided into the vortex finder (F), wherein, where air separates from the vane (V) inside of the vortex finder (F), a cross-section of the vanes (V) has only one sharp edge (E). Preferably, a mean line (M) of the cross-section of the vanes (V) does not cross a chord line (C) in an upstream half of the cross-section. Preferably, a side of the vanes (V) facing the incoming air (A) is provided with a protrusion (P) at a stagnation point (S). The protrusion (P) may be shaped so as to guide the incoming air (A) into the vortex finder (F), and may have a concave side following a shape of a neighboring vane, and a rounded top. Preferably, the protrusion (P) has a height in a range between 70% and 130%, and more preferably in a range between 85% and 115%, of a gap width between the vanes (V). Preferably, a gap width between adjacent vanes (V) increases from an outside to an inside of the vortex finder (F). A vacuum cleaner comprising a cyclonic separator preferably has such a vortex finder (F).



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VORTEX FINDER FOR A CYCLONIC SEPARATOR

FIELD OF THE INVENTION

The invention relates to a vortex finder for a cyclonic separator, and to a vacuum cleaner comprising such a vortex finder.

5 BACKGROUND OF THE INVENTION

A bag-less vacuum cleaner uses a cyclone in order to separate the dirt particles from the air. A cyclone consists of a cylindrical chamber in which the air flow rotates fast. Centrifugal force generated by the circular air flow throws the dust particles towards the wall of the cyclone chamber from where they fall into a collection chamber. The cleaned air flows
10 in an opposite direction through the center of the cyclone and is exhausted via the vortex finder to the outlet of the cyclone. The function of the vortex finder is to ensure a stable rotational flow to improve separation performance. The vortex finder usually has a plurality of vanes guiding the air towards the outlet.

US2012167336 discloses a vacuum cleaner with a separation module that
15 comprises an exhaust grill positioned fluidly between a separator chamber and an air outlet. The exhaust grill can comprise a body having a plurality of louvers and a plurality of inlets defined between adjacent louvers. At least one of the louvers comprises an airfoil configured to deflect dirt away from at least one of the plurality of inlets. The leading end of a louver can include an airfoil tip that is configured to deflect dirt particles away from the gap. In an
20 embodiment, the airfoil tip is formed by a curved guide surface formed on the upstream surface. The guide surface can be located at the outermost portion of the upstream surface. The guide surface can have a smaller radius of curvature toward the leading end as compared with the radius of curvature of the upstream surface toward the trailing end. The guide surface includes a transition point which defines the point at which the slope of a first tangent line on
25 the side of the transition point closer to the leading end is less than the slope of a second tangent line on the side of the transition point closer to the trailing end, which results in a concave crescent shape on the upstream surface of the airfoil tip.

WO2015150435 discloses a vortex finder for a cyclonic separator through which air flowing in a helical path about an axis of a cyclone chamber passes to an outlet. The
30 vortex finder comprises a plurality of stationary overlapping vanes extending in an axial

direction and spaced radially around the axis, the vanes being positioned relative to each other so a helical flow of air about the axis of the cyclone chamber passes over an outer surface of the vanes with a portion of the air flow being redirected around a leading edge of each vane and through a gap between adjacent vanes to the outlet. At any point along the axis, a portion
5 of an outer surface of each vane lies on a circle having its center coaxial with the axis, the outer surface of each vane having a portion leading towards the leading edge that extends inwardly away from the circle so that the leading edge of each vane about which air is redirected through the gap between vanes is located within a region bound by the circle to create a region of overpressure on the outer surface of the adjacent vane in the vicinity of the
10 gap.

SUMMARY OF THE INVENTION

It is, inter alia, an object of the invention to provide an improved vortex finder. The invention is defined by the independent claims. Advantageous embodiments are defined
15 in the dependent claims.

One aspect of the invention provides a vortex finder for a cyclonic separator, the vortex finder comprising a plurality of stationary vanes having a round convex front end around which incoming air is guided into the vortex finder, wherein, where air separates from the vane inside of the vortex finder, a cross-section of the vanes has only one sharp edge.
20 Preferably, a mean line of the cross-section of the vanes does not cross a chord line in an upstream half of the cross-section. Preferably, a side of the vanes facing the incoming air is provided with a protrusion at a stagnation point. The protrusion may be shaped so as to guide the incoming air into the vortex finder, and may have a concave side following a shape of a neighboring vane, and a rounded top. Preferably, the protrusion has a height in a range
25 between 70% and 130%, and more preferably in a range between 85% and 115%, of a gap width between the vanes. In another preferred embodiment, a gap width between adjacent vanes gradually increases from an outside to an inside of the vortex finder. A vacuum cleaner comprising a cyclonic separator preferably has such a vortex finder.

Prior art vanes of the vortex finder result in a relatively big turbulence in the air
30 flow separating from the vanes. Turbulence in general is an energy consuming flow behavior. Embodiments of the invention provide a new vortex finder vane geometry that significantly reduces the flow turbulence while it still maintains easy manufacturing properties. In embodiments of the invention, the vanes of the vortex finder have the shape of a droplet or an airfoil profile. It has only one sharp edge where the flow separates from the shape.

To a large extent, embodiments of the present invention are similar to those of WO2015150435, incorporated herein by reference. A major difference is formed by the shape of the vanes of the vortex finder, where embodiments of the present invention include vanes having a droplet-shaped cross-section of the vanes, i.e. with a round surface at the front, and at a trailing end of the droplet, it only has one sharp edge.

In US2012167336, the shape of the vanes is configured to deflect dirt away from at least one of the plurality of air inlets of the vortex finder. To that end, these prior art vanes have a concave crescent shape on the upstream surface of the vane tip. A clear disadvantage of that prior art shape is that not only the dirt, but also the air is deflected away from the air inlets of the vortex finder, while the air should eventually enter those inlets. So, a lot of suction energy is required to make the air turn so as to enter the air inlets of the vortex finder, and such a suction energy loss is particularly problematic in view of the increasingly strict energy consumption requirements imposed on vacuum cleaners. In embodiments of the present invention, the droplet-like shape of the vanes that results from the round convex front end, ensures that air is not first directed into the wrong direction away from the vortex finder, but that air can directly and smoothly enter into the gaps between the vanes of the vortex finder.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 - 3 show a cross-section of a first embodiment of a vortex finder in accordance with the present invention;

Fig. 4 shows the airflow in some more detail; and

Figs. 5A-7B illustrate further embodiments of a vortex finder in accordance with the present invention, provided with a protrusion.

DESCRIPTION OF EMBODIMENTS

Fig. 1 shows a cross-section of a first embodiment of a vortex finder F in accordance with the present invention. The vortex finder F has a plurality of vanes V. An incoming airflow A circulates around the vortex finder F.

Fig. 2 shows a section of the vanes of Fig. 1 in more detail. In the idealized representation of Fig. 2, air A enters between the vanes into the vortex finder F as a result of suction exercised by a fan (not shown). As a result of inertia, dirt particles D either do not

enter the vortex finder A but follow a straight line towards an outer hull of the cyclone, or are bounced off by a subsequent vane V. In this way, dirt D is separated from the air A. At a trailing edge of the vanes V, where air A separates from the vanes V, the vanes have only one sharp edge E. With an airfoil-shaped cross-section of the vanes, a sharp edge means that in a downstream half of the cross-section, upper and lower surfaces of the airfoil intersect at an angle of less than 90° . While in practice, manufacturing restrictions may result in a slight rounding, it still holds that in a downstream half of the cross-section of the vanes, straight lines approximating the upper and lower surfaces of the airfoil in that downstream half, intersect at an angle of less than 90° .

Fig. 3 shows a mean line M and a chord line C drawn in one of the vanes V. In line with the definitions used in the Wikipedia item on airfoils, the geometry of the airfoil is described with a variety of terms:

- The leading edge is the point at the front of the airfoil that has maximum curvature (minimum radius).
- The trailing edge is defined similarly as the point of maximum curvature at the rear of the airfoil.
- The chord line C is the straight line connecting leading and trailing edges. The chord length, or simply chord, is the length of the chord line.
- The mean camber line or mean line M is the locus of points midway between the upper and lower surfaces of the airfoil. Its shape depends on the thickness distribution along the chord.

In the embodiments shown, the mean line M has a C-shape that does not cross the chord line C. It at least holds that the mean line M does not cross the chord line C in the upstream half of the vane V. In contrast, in the prior art of US2012167336, the mean line has a S-shape and crosses the chord line at least once in the upstream half of the vane. As a result of the prior art concave crescent shape on the upstream surface of the airfoil tip, air is not smoothly entering the vortex finder, resulting in a high pressure loss.

As a result of the shape of the vanes in accordance with the present invention, air A is smoothly entering the vortex finder F, thereby minimizing pressure loss, so that the suction energy is most efficiently used. This positive effect also results from the feature that at their trailing ends, the vanes only have one sharp edge, so that turbulences resulting from blunt trailing ends are avoided. Such turbulences also contribute to an undesired pressure loss.

Advantageously, the vortex finder is shaped in the form of a cylinder, which results in that the desired shape of the vanes can be easily manufactured by means of molding.

Fig. 4 illustrates the air flow in some more detail. While in the idealized representation of Fig. 2 it was suggested that most of the air flow enters into the vortex finder F as a result of suction by the motor-fan aggregate of the vacuum cleaner (not shown), in reality, some of the air flow bumps into the vane V, and another part goes around the vane V. Where the air bumps into the vane V, dirt will be accumulated. The place where the air bumps into the vane V, is called the stagnation point S, which is usually defined (see e.g. Wikipedia) as a point in a flow field where the local velocity of the fluid is zero. Stagnation points exist at the surface of objects in the flow field, where the fluid is brought to rest by the object.

In accordance with preferred embodiments of the invention, a side of the vanes V facing the incoming air A is provided with a protrusion P at the stagnation point S, to thereby prevent dirt from accumulating on the vanes V at the stagnation points S. By doing so, the pollution can be significantly reduced, without influencing the separation performance or pressure loss.

It is noted that while the protrusions P are described here in the context of vanes V having only one sharp edge E where air separates from the vane V inside of the vortex finder F, the problem of dirt accumulation at stagnation points where air bumps into the vanes of the vortex finder, and the solution of providing the sides of vanes with protrusions, is not limited to such vanes, and that applicant reserves the right to separately protect (see our application EP20150969.2, reference 2019PF00905) providing different vanes (e.g. those described in US2012167336 or WO2015150435) with protrusions to prevent dirt accumulation from happening.

It is important that the protrusions P are positioned as close as possible to the stagnation points S. Fig. 12b of WO 2015150435 shows outer trailing end edges 45 resulting from cutting a part out of vanes 41. However, that solution will not help to prevent dirt from accumulating inside the hollow parts at the trailing end faces 42 in which the stagnation points are located. So, in this prior art solution, at the stagnation points, there are no protrusions that prevent dirt from accumulation at the stagnation points, but hollow shapes that collect dirt.

Figs. 5A and 5B show a first embodiment of vanes V provided with protrusions P to prevent dirt from accumulating. Here, both sides of the protrusions P are concave.

Figs. 6A and 6B show a second embodiment of vanes V provided with protrusions P to prevent dirt from accumulating. Here, the sides of the protrusions P facing into the vortex finder F are concave, and the sides of the protrusions P facing the outside of the vortex finder F are convex.

The concave shapes of Figs. 5A – 6B serve to ensure that the protrusions P are shaped so as to guide the incoming air A relatively smoothly into the vortex finder F.

The protrusions P preferably have a rounded top, which is more forgiving as regards manufacturing tolerances than a sharp top. However, a sharp top is possible.

5 In a practical embodiment, the vanes are separated by gaps having a gap width of about 1.75 mm; with a different gap width, the size of the other dimensions discussed below needs to be scaled accordingly.

In the embodiment of Figs. 5A and 5B, the design goal that the protrusions P are positioned as close as possible to the stagnation points S means that the protrusions P
10 preferably deviate by less than 1 mm from the stagnation points S. The diameter of any rounded tops of the protrusions P is preferably in a range between 0.25 mm and 0.35 mm, such as about 0.3 mm. Compared to the basic shape of the vanes as shown in Figs. 1-4, the height of the protrusions P is preferably in a range between 0.75 mm and 1.25 mm, such as about 1 mm. The footprint of the protrusions P is preferably in a range between 2.5 mm and 3.5 mm, such
15 as about 3 mm.

In the embodiment of Figs. 6A and 6B, the concave sides of the protrusions P are preferably shaped in such a way that a gap width between adjacent vanes V is substantially constant, i.e. these concave sides follow the shape of the neighboring vanes V. Compared to
20 the basic shape of the vanes as shown in Figs. 1-4, the height of the protrusions P is preferably in a range between 1.25 mm (70% of the gap width of 1.75 mm) and 2.25 mm (130% of 1.75 mm), and more preferably in a range between 1.5 mm (85% of 1.75 mm) and 2.0 mm (115% of 1.75 mm), such as about 1.75 mm, which most nicely results in the protrusions P being located at the stagnation points S. The concave sides of the protrusions P are preferably shaped
25 in such a way that there is a continuous curve from the basic shape of the vane towards the tops of the protrusions P. The diameter of any rounded tops of the protrusions P is preferably in a range between 0.15 mm and 0.25 mm, such as about 0.2 mm.

In the embodiments of Figs. 7A and 7B, the protrusions P are shaped such that the gap width between adjacent vanes V increases from the outside towards the inside of the vortex finder F. The gap width increase is preferably gradually and/or continuously. As a
30 result, the gap obtains a diffuser-like shape. Diffusers are known from e.g. I.E. Idel'chik – Handbook of hydraulic resistance (1960). The gap width increase (here between curved shapes of neighboring vanes V) is preferably comparable to a gap width increase between flat plates positioned at an angle of between 5° and 30°, and more preferably about 12°. In one example,

the gap has an initial width W_i of 0.9 mm, and, beyond the protrusion P, an end width W_e of 1.75 mm. The protrusion P has a rounded top, a height of 2.3 mm, and a footprint FP of 7 mm.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative
5 embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a
10 plurality of such elements. The claimed feature that the vanes V have a protrusion P at a stagnation point S does not mean that the protrusion P must be exactly at the stagnation point S, but merely that the protrusions P are positioned close to the stagnation points S. Measures recited in mutually different dependent claims may advantageously be used in combination.

CLAIMS:

1. A vortex finder (F) for a cyclonic separator, the vortex finder comprising:
a plurality of stationary vanes (V) having a round convex front end around
which incoming air (A) is guided into the vortex finder (F), wherein, where air separates from
the vane (V) inside of the vortex finder (F), a cross-section of the vanes (V) has only one sharp
5 edge (E).
2. A vortex finder (F) as claimed in claim 1, wherein a mean line (M) of the cross-
section of the vanes (V) does not cross a chord line (C) in an upstream half of the cross-
section.
10
3. A vortex finder (F) as claimed in any of the preceding claims, wherein a side of
the vanes (V) facing the incoming air (A) is provided with a protrusion (P) at a stagnation
point (S).
- 15 4. A vortex finder (F) as claimed in claim 3, wherein the protrusion (P) is shaped
so as to guide the incoming air (A) into the vortex finder (F).
5. A vortex finder (F) as claimed in claim 3 or 4, wherein the protrusion (P) has a
concave side following a shape of a neighboring vane.
20
6. A vortex finder (F) as claimed in claim 3, 4 or 5, wherein the protrusion (P) has
a rounded top.
7. A vortex finder (F) as claimed in any of the preceding claims 3-6, wherein the
25 protrusion (P) has a height in a range between 70% and 130% of a gap width between the
vanes (V).
8. A vortex finder (F) as claimed in claim 7, wherein the protrusion (P) has a
height in a range between 85% and 115% of a gap width between the vanes (V).

9. A vortex finder (F) as claimed in any of the preceding claims 3-6, wherein a gap width between adjacent vanes (V) increases from an outside to an inside of the vortex finder (F).

5

10. A vacuum cleaner comprising a cyclonic separator having a vortex finder (F) as claimed in any of the preceding claims.

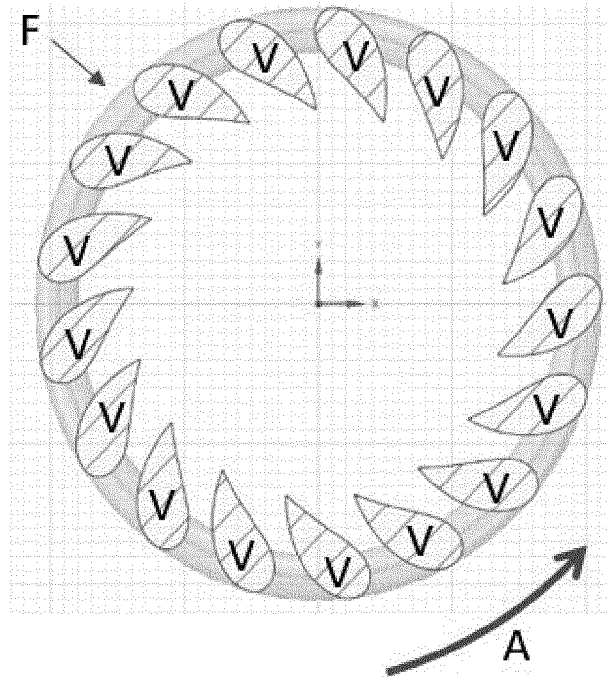


Fig. 1

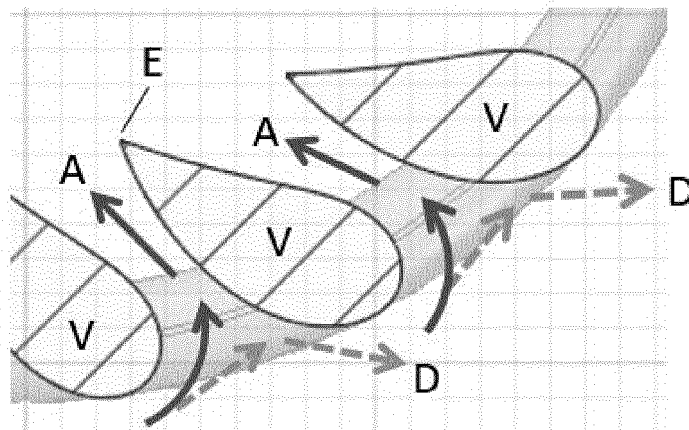


Fig. 2

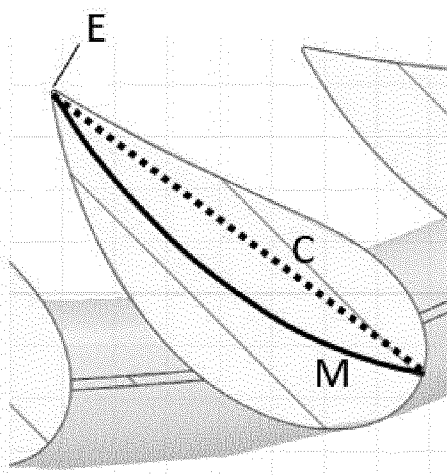


Fig. 3

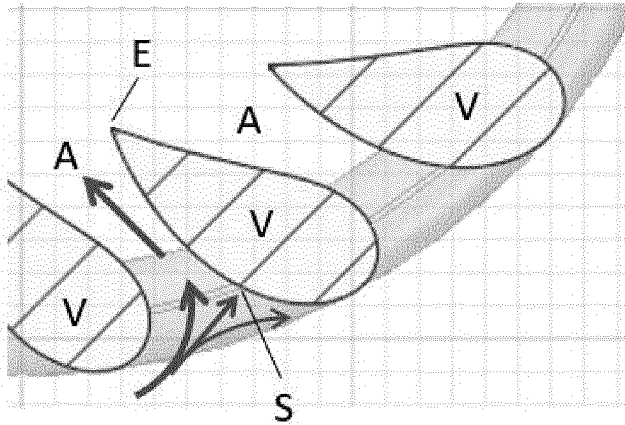


Fig. 4

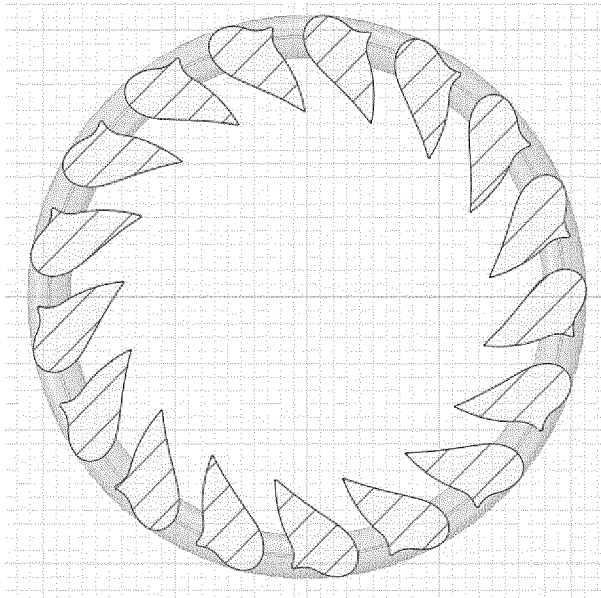


Fig. 5A

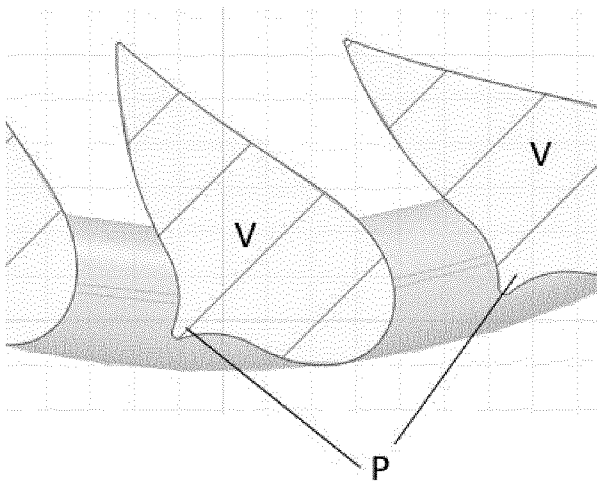


Fig. 5B

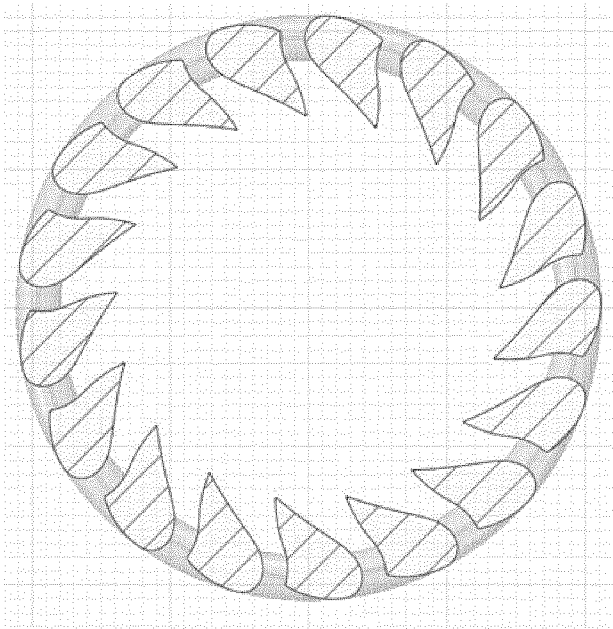


Fig. 6A

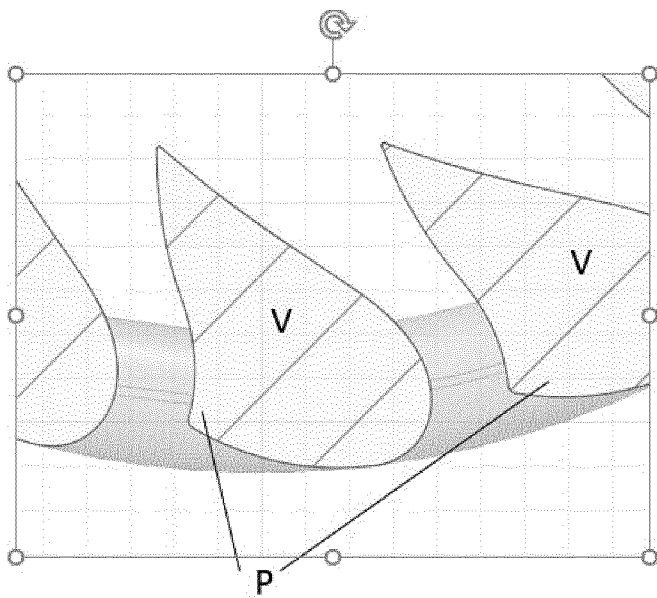


Fig. 6B

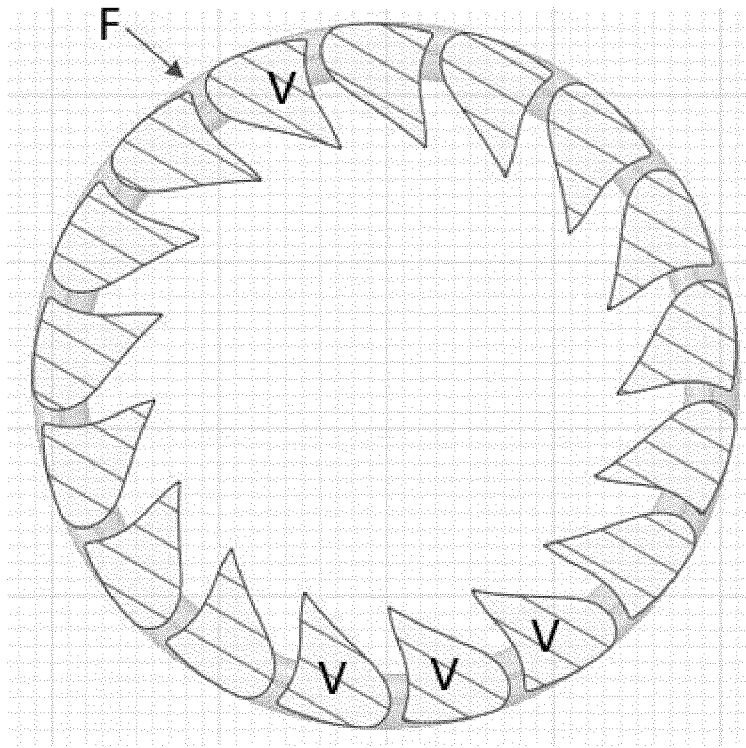


Fig. 7A

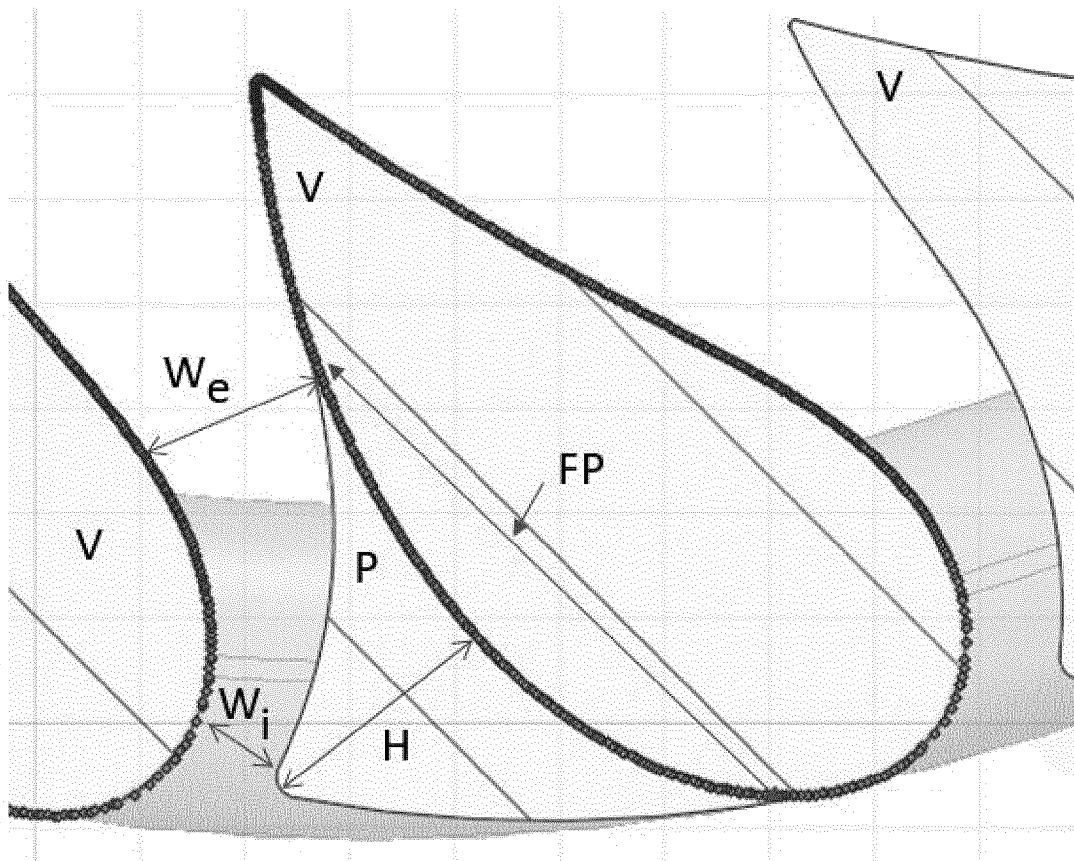


Fig. 7B

INTERNATIONAL SEARCH REPORT

International application No PCT/EP2020/054517
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A. CLASSIFICATION OF SUBJECT MATTER INV. A47L9/16 B04C5/13 ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols) A47L B04C				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	WO 2015/150435 A1 (KONINKL PHILIPS NV [NL]) 8 October 2015 (2015-10-08) abstract figures 6-9b -----	1-10		
A	EP 2 044 996 A1 (JAPAN COOPERATION CT PETROLEUM [JP]; NIPPON OIL CORP [JP]) 8 April 2009 (2009-04-08) abstract figures 1-6 -----	1-10		
A	US 2006/037294 A1 (OH JANG-KEUN [KR] ET AL) 23 February 2006 (2006-02-23) abstract figures 2-7 -----	1-10		
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.				
* Special categories of cited documents : <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family			
Date of the actual completion of the international search 7 May 2020	Date of mailing of the international search report 09/06/2020			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Redelsperger, C			

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2020/054517

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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