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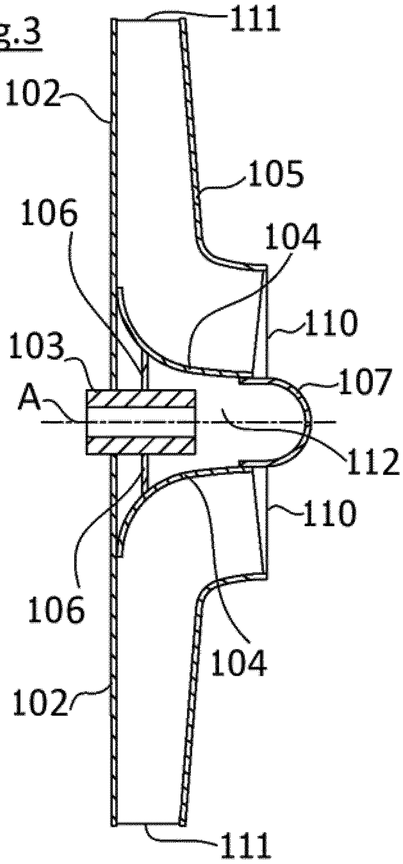
(54) CENTRIFUGAL FAN

(57) Centrifugal fan comprising a fan wheel apt to process a fluid between an inlet (10) and an outlet (11), said fan wheel comprising an array of blades (1) arranged around an axis (A), a disc-shaped base (2) normal to the axis (A) and to which said blades (1) are rigidly connected, a hub (3) coaxial to the axis (A) and rigidly connected to the base (2), an air conveyor (4) made in a piece separate from the hub (3), said air conveyor (4) being apt to gradually convey the fluid from a substantially axial motion at the inlet (10) to a substantially radial motion at the outlet (11).

Fig.3



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Description

[0001] The present invention relates to a centrifugal fan having high performance according to the preamble of the main claim.

[0002] A centrifugal fan is an operating machine transmitting energy to the fluid crossing the same, thus causing a pressure increase.

[0003] The pressure increase in a fan is generally quite low, differently from the one that can be obtained by means of a compressor.

[0004] In case of a centrifugal fan being inserted into a duct, possible pressure drops of the duct can be overcome.

[0005] Centrifugal fans are used in a number of industrial processes, such as for example in industries for cement and steel production, in the dairy industry, in the industry for beverage production, such as for example beer.

[0006] Due to their characteristics, fans are used in fields of the art different from compressors.

[0007] Fans are classified, depending on the pressure increase they cause, in low pressure fans with static pressure at the outlet lower than 720 Pa, intermediate pressure fans with static pressure at the outlet comprised between 720 and 3600 Pa, and high pressure fans with static pressure at the outlet comprised between 3600 and 20000 Pa.

[0008] Typically, an industrial fan has rotational speed of some thousands of revolutions per minute, whereas a compressor reaches rotational speeds of some tens of thousands of revolutions per minute.

[0009] Centrifugal fans allow obtaining manometric compression ratios higher than axial fans.

[0010] Due to different applications, industrial centrifugal fans have construction less strong than centrifugal compressors, are more lightweight and less expensive, as both manufacturing and operation costs.

[0011] As technique stands now, centrifugal fans comprise a fan wheel and an outer casing termed volute having the aim of directing the air flow. The fan wheel of a centrifugal fan is obtained from reciprocally welded sheet metals comprising a plurality of blades arranged around an axis, a disc-shaped base placed in the plane normal to the axis, to which the blades are welded, a hub coaxial to the axis, a closing element arranged on the edge of the blades. The disc, the outer part of the hub and the closing element define a duct with an inlet and an outlet, inside which the blades are arranged and form many blade channels.

[0012] The operating fluid moves closer to the fan wheel in a substantially axial direction, crosses the inlet, encounters the base, which prevents a further motion in the axial direction, and is thus forced to abruptly change the direction of motion from axial to radial passing through the blade channels defined by the blades driving the fluid motion.

[0013] A higher number of blades allow having a better driven fluid, but at the same time increases pressure drops due to sliding friction. Since the duct widens radially, the blades at the inlet are more concentrated (lower blade pitch).

[0014] The implementation of the fan with reciprocally welded sheet metals allows having lightweight fans at low manufacturing cost.

[0015] On the contrary, centrifugal compressors are usually made by casted pieces subsequently cold worked, so as to obtain the desired geometry. Compressors are designed to support higher pressures and larger centrifugal stresses.

[0016] Compressors have therefore a more fluid-dynamically accurate geometry, but are heavier and have higher manufacturing cost.

[0017] The process for implementing the fan wheels of sheet metal comprises the steps of welding the blades to a base and eventually welding the hub to the fan wheel. Thereby the fan wheel, adequately stiffened by the blades, can be welded to the hub without significantly deforming.

[0018] A problem with the currently manufactured centrifugal fans is the high electric power consumption, since they work for many hours per year.

[0019] Another problem with centrifugal fans operating for many hours per year relates to the wear the fan wheels are subjected to when the fluid at the inlet contains solid particles.

[0020] This causes maintenance costs for the fan wheel replacement, in addition to those due to the installation machine downtime.

[0021] Another problem is that the blade pitch at the inlet is often too small, since the blades are very close.

[0022] Another problem is that the currently manufactured fans are noisy.

[0023] Another problem with the fans is the limited application field due to the fact that they produce small increments between pressure at the inlet and pressure at the outlet.

[0024] Object of the present invention is therefore to implement a centrifugal fan that allows overcoming the mentioned drawbacks, in particular an object is to implement a fan that, by keeping implementation costs low, allows having high efficiency and low energy consumption.

[0025] Another object is to improve the blade pitch at the inlet.

[0026] A further object is to reduce the noisiness of the fans.

[0027] Still an object is to obtain higher pressures at the outlet, to widen the application field of the fans to fields in which the most expensive compressors are currently used. The invention will be better understood by the following specification provided for illustration purposes only, thus without limitation, of three preferred embodiments depicted in the attached drawings, in which:

fig. 1 shows a perspective view without closing element of a first embodiment of the fan wheel according to the invention;

fig. 2 shows a longitudinal section of the first embodiment of the fan wheel according to the invention;

fig. 3 shows a longitudinal section of the second embodiment of the fan wheel according to the invention;

fig. 4 shows a longitudinal section of a variation of said second embodiment;

fig. 5 shows the experimental results obtained for the static pressure as a function of the volumetric flow for both a conventional fan (lower curve denoted by V1) and a fan according to the invention (upper curve denoted by V2);

Fig. 6 depicts the efficiency increase that can be obtained for two different exemplary flow rates.

[0028] Referring to figure 1 and figure 2, the centrifugal fan is seen in the first embodiment as comprising a fan wheel apt to process an operating fluid between an inlet 10 and an outlet 11. The operating fluid is in general air subjected to pressure increase between the inlet 10 and the outlet 11. The fan wheel comprises an array of blades 1 arranged around an axis A between the inlet 10 and the outlet 11, a disc-shaped base 2, placed in the plane normal to the axis A, to which said blades 1 are welded, a hub 3 coaxial to the axis A, a closing element 5 arranged at the edge of the blades 1, an air conveyor 4 having axially symmetrical shape, rigidly connected to the base 2 and apt to gradually convey the fluid from a substantially axial motion at the inlet 10 to a substantially radial motion at the outlet 11.

[0029] The blades are inside the duct formed by the closing element 5, the base 2 and the air conveyor 4.

[0030] The hub 3 is a hollow cylindrical element apt to be arranged on a shaft and to transmit the drive shaft motion to the fan wheel, for example through a spline.

[0031] The air conveyor 4 is made in a piece separate from the hub 3 and is directly and rigidly connected to the base 2, the latter being directly and rigidly connected to the hub 3.

[0032] In fig. 1 the air conveyor 4 is also directly and rigidly connected to the hub 3.

[0033] In order to obtain good structural strength and low cost construction at the same time, the blades 1, the base 2, the air conveyor 4 and the closing element 5 are made of sheet metal and the mutual rigid connections are made by welding.

[0034] The air conveyor 4, made of sheet metal, is welded to the base 2, the blades 1 and the hub 3.

[0035] The blades 1 are welded to the base 2, the air conveyor 4 and the closing element 5. In the easiest embodiment (not depicted) the air conveyor 4 is obtained from a planar sheet metal bent to form a frusto-conical surface and arranged such that the unit vector normal to the surface forms an angle of about 45° to the axis A.

[0036] However, in a preferred embodiment, the air conveyor 4 has a curved longitudinal section, as in fig. 1, and is obtained by bending a sheet metal for example through deep-drawing or calendering or cold molding processes.

[0037] Between the hub 3 and the air conveyor 4 connecting structural elements can be arranged, apt to counter centrifugal forces acting on the air conveyor 4.

[0038] A first cavity 8 is formed between the air conveyor 4, the base 2 and the hub 3.

[0039] A plug 7, constrained by welding or screws to the hub 3, closes a second cavity 9.

[0040] In a second embodiment depicted in figure 3, the air conveyor 104 is spaced apart from the hub 103 at the inlet 110 in order to have an inlet area no longer dependent on the hub section.

[0041] Referring to figure 3, the fan wheel of the centrifugal fan comprises a connecting structural element 106 between the hub 103 and the air conveyor 104, which is apt to counter the centrifugal stresses.

[0042] The presence of said connecting structural element 106 is important especially in case the fan wheel is large-sized.

[0043] The plug 107 connected to the air conveyor 104 closes a cavity 112 delimited by the portion of base 102 closest to the hub 103.

[0044] Said connecting structural element 106, arranged inside the cavity 112, is not contacting with the operating fluid processed by the fan, but is however contacting with the air being generally inside the cavity 112. For this reason, the connecting structural element 106 has shape with low aerodynamic resistance when the fan wheel rotates and can have for example the shape of a disc or one or more spokes which are elongated parallel to the plane of rotation perpendicular to the axis A and thin in the longitudinal one, so as to oppose low resistance to the rotation.

[0045] In fig. 4 the hub is seen as having a terminal machined in such a way to form a spacer 114.

[0046] Such a spacer 114 is comprised within the connecting structural elements. It results from the continuation of the hub 103 towards the air conveyor 104 and is formed from one piece with the conveniently turned hub 103.

[0047] In the second embodiment the inlet 110 has the shape of an annulus wherein the inner circumference is separated from the hub 103. In this way, the blades at the inlet are more spaced from the axis A, in order to increase the free passage and can be extended in the axial direction to obtain an inductor.

[0048] In figures 3 and 4 the plug 107 closes a third cavity 112, defined by the air conveyor 104 and the hub 103, and contains the connecting structural elements.

[0049] Advantageously the first, second and third cavities 8, 9 and 112 are apt to allow vacuum to be obtained in their inside, so that to reduce even more the losses by friction with the air in their inside, that would otherwise form vortexes originating dissipations.

[0050] In the different embodiments the blades advantageously go up along the axial direction at the inlet and the edge of the blades at the inlet is slightly bent, as shown in fig. 1, in order to facilitate the fluid input and to obtain what is termed an inductor. In order to limit manufacturing costs, the blades, the base, the air conveyor, the closing element and the connecting structural elements are made of sheet metal and welded one to another.

[0051] The process for implementing the different embodiments of sheet metals differs from the one followed for implementing known fans. The hub is in fact welded to the base before the blades and the air conveyor are welded to the base, since it would be difficult, if not impossible, implementing the welding between hub and air conveyor after the air conveyor has been welded to the base and blades.

[0052] In particular, in regard to the first embodiment (fig. 2), the assembling sequence is the following:

a) the base 2 is fastened to a centrally pierced bed so that to accommodate the hub;
b) the hub 3 is prepared for the assembly of the connecting structural elements, for example the hub is turned to obtain an abutment step in case the connecting structural element is a disc;
c) the hub 3 is arranged at the center of the base 2 and the reciprocal welds are carried out, by pressing the base 2 against the bed, to prevent it from deforming;
d) the connecting structural element are arranged on the hub and welded to the hub;
e) the air conveyor 4 is arranged on the base 2 and is welded to the base 2 and the hub 3;
f) the welds are worked on the lathe in order to obtain the connecting radii according to the design;
g) the blades 1 are arranged on the base 2 and are welded to the base 2;
h) the blades 1 are welded to the air conveyor 4;
i) the welds are machined in order to have an adequately smooth surface;
j) the closing element 5 is arranged on the edge of the blades 1 and is welded to the blades 1.

[0053] For some embodiments, such as for example those of figures 3 and 4, steps d) and e) precede step c) and the hub is welded to the base after the connecting structural elements have been welded to the hub.

[0054] In any case, the welding of the hub to the base 2 occurs before the welding of all the blades to the base 2.

[0055] The presence of the blades welded to the base 2 would prevent the hub and the air conveyor from being welded to the base 2.

[0056] In order to carry out such a welding process, the issue of the welding of the hub to the base, carried out before the blades are welded to the base, determining an unacceptable bending of the base, had to be overcome. Such a bending of the base can be prevented if it is firmly fastened to a bed, so that to prevent it from deforming during the process of welding the hub.

[0057] Once the welding of the various parts of the fan wheel has been completed, the inner surface of the hub is turned to be perfectly circular, and the fan wheel is balanced with some weights in order to limit unbalances due to centrifugal forces.

[0058] It is of course possible that, in order to have a more lightweight fan wheel, some parts as the blades or the air conveyor 4 are made of plastic material, such as for example a glass fiber or carbon fiber composite material.

[0059] In fig. 5 experimental results are reported for the static pressure at the outlet, as a function of the volumetric flow for both a known fan (lower curve denoted by V1) and a fan according to the invention (upper curve denoted by V2).

[0060] Experimental data of figure 5 have been obtained by carrying out a test in accordance with ISO 5801 standard, category C, with suction sample tube and relate to a fan wheel rotating at a speed of 1500 revolutions/minute with air density of 1.204 kg/m^3: the pressure at the inlet is equal to the atmospheric pressure, whereas the volume flow, expressed in cubic meters per hour, is measured at the inlet.

[0061] Thanks to experimental tests, whose results are shown in fig. 5, it has been surprisingly found that the fan according to the invention has performance increase by far higher than expected, such to justify the increase on manufacturing costs according to the invention.

[0062] In fig. 5 it can be seen for example that at a rotation speed of the fan wheel of 1500 revolutions per minute, for a flow rate of 3200 m^3/h a known fan achieves a static pressure at the outlet of 1900 Pa, whereas the fan according to the invention achieves a static pressure at the outlet of 2400 Pa.

[0063] The curve of the static pressure at the outlet for the fan according to the invention is by far less dependent on the required flow rate, with respect to the same curve for a conventional fan.

[0064] In case a given designed static pressure is required at the outlet, the fan according to the invention allows obtaining it at lower speed of rotation of the rotor, and therefore with remarkable energy saving.

[0065] Fig. 6 depicts in ordinates the efficiency increase obtained experimentally for two exemplary flow rates, where such an efficiency increase is expressed by the following formula:

$$\Delta\eta\% = (\eta_{V2} - \eta_{V1})100$$

$$\eta_{V1} = \frac{Q_{V1}\ Pst_{V1}}{N_{V1}}$$

$$\eta_{V2} = \frac{Q_{V2}\ Pst_{V2}}{N_{V2}}$$

Q = volumetric flow at the inlet [m^3/s]
Pst = static pressure increase assessed with respect to the static pressure at the inlet in accordance with ISO 5801 standard of 15/12/2007 [Pa]
N = absorbed electric power [W]
the subscripts V1 and V2 referring respectively to the known fan and the fan according to the invention.

[0066] For a flow rate of 3200 m^3/h, the fan wheel implemented according to the invention has efficiency of about 4% higher than the efficiency of the fan wheel implemented according to known art, whereas for a flow rate of 5000 m^3/h the efficiency increases by about 16%, as further evidence of lower energetic consumption.

[0067] In its operation, a flow for example of air or vapor, enters the inlet 10 of the centrifugal fan according to the invention and moves in a substantially axial direction, inserts in the blade channels by running across the inductor and being accelerated and compressed. In its motion it encounters the air conveyor that diverts the flow in a substantially radial direction and gradually leads it with its concave surface. In the motion diversion, the flow is driven by the blades and the air conveyor, such that the change of direction occurs gradually and by limiting the turbulence generated by abrupt changes of direction and subjecting the fluid to compression as similar as possible to reversible adiabatic or isentropic one. The fan provides mechanic power to the fluid that then exits from the outlet.

[0068] The air conveyor 4, 104 is supported by the connecting structural elements having a small longitudinal section and thus offering low resistance to the rotation caused by the air friction.

[0069] In the second embodiment, the inlet is spaced from the axis A and the outer surface of the hub.

[0070] In the simplest embodiment, the radiused air conveyor comprises a sheet metal forming a truncated cone.

[0071] In order to better lead the fluid in the change of motion direction from axial to radial, it is however preferable that the air conveyor is made of bent sheet metal, for example deep-drawn, and has a curved longitudinal section, as in figures 2, 3 and 4. The closing element is welded to the edge of the blades and rotates with them.

[0072] In order to limit the pressure drops at the inlet, the blades do not extend beyond the closing element, whereby they are inside the duct formed by the closing element on the outside and the base, the radiused air conveyor and possibly the hub on the inside.

[0073] The fan according to the invention achieves two effects: it reduces the turbulence of the processed fluid and reduces the friction with the air of the surrounding environment.

[0074] This allows reducing the fan noisiness, amongst other things.

[0075] In a further embodiment not depicted, the fan wheel is symmetrical with respect to the plane normal to the axis A passing though the base.

[0076] In this way, the fan can process twice the flow rate while being compact.

[0077] The air conveyor, since it is radiused, reduces the motion turbulence of the fluid processed by the fan, pressure drops are reduced and the pressure at the outlet can be higher, the rotation speed of the fan wheel being the same.

[0078] The aerodynamically-shaped connecting structural elements contribute to reduce pressure drops by friction with the surrounding air.

[0079] The plug and vacuum in the cavities further reduce losses by air friction and this allows reducing the electric power the fan requires.

[0080] Since the fan remains operating for many hours, remarkable economic saving follows.

[0081] The smaller turbulences due to the air conveyor allow obtaining, the other parameters remaining the same, higher manometric compression ratios (equal to the ratio between the static pressure at the outlet and the static pressure at the inlet), whereby the fan can be used also in fields in which low end compressors are currently used. The smaller turbulences also allow having lower wear of the fan wheel in case the processed fluid contains solid and thus abrasive particles.

[0082] This translates in longer lifetime of the fan wheel with remarkable cost saving. Given the higher inexpensive construction of the fans, this represents a significant economical benefit.

[0083] An advantageous feature of the invention is that the connecting structural elements arranged at the inlet allow the duct through which the fluid flows to be spaced from the axis and widening the inlet area in order to have better distribution of the blades, with lower losses at the inlet.

Claims

1. Centrifugal fan comprising a fan wheel apt to process a fluid between an inlet (110) and an outlet (111), said fan wheel comprising an array of blades (1) arranged around an axis (A), a disc-shaped base (102) normal to the axis (A) and to which said blades (1) are rigidly connected, a hub (103) coaxial to the axis (A) and rigidly connected to the base (102), an air conveyor (104) made in a piece separate from the hub (103), said air conveyor (104) being apt to gradually convey the fluid from a substantially axial motion at the inlet (110) to a substantially radial motion at the outlet (111), said base (102) being made of sheet metal and said air conveyor (104) being rigidly connected to the base (102), **characterized by** comprising at least one connecting structural element (106) between the hub (103) and the air conveyor (104), the inlet (110) having the shape of an annulus wherein the inner circumference is separated from the hub (103).

2. Centrifugal fan according to the preceding claim, **characterized in that** said air conveyor (104) is made of sheet metal.

3. Centrifugal fan according to claim 2, **characterized in that** said air conveyor (104) is welded to the blades (1).

4. Centrifugal fan according to one or more of the preceding claims, **characterized in that** said air conveyor (104) is obtained by bending a sheet metal.

5. Centrifugal fan according to one or more of the preceding claims, **characterized in that** said air conveyor (104) has a curved longitudinal section.

6. Centrifugal fan according to claim 1, **characterized in that** said connecting structural element (106) has a shape apt to obtain a low fluid dynamic resistance when the fan wheel rotates.

7. Centrifugal fan according to the preceding claim, **characterized in that** said connecting structural element (106) is disc-shaped.

8. Centrifugal fan according to the preceding claim, **characterized in that** said connecting structural element (114) is made in one piece with the hub.

9. Centrifugal fan according to one or more of the preceding claims, **characterized by** comprising one or more cavities (112) apt to allow vacuum to be obtained in their inside.

10. Process for making a centrifugal fan made of sheet metal according to claims 1 and 2, **characterized in that** the hub is welded to the base (102) before welding all the blades to the base (102).

Fig.1

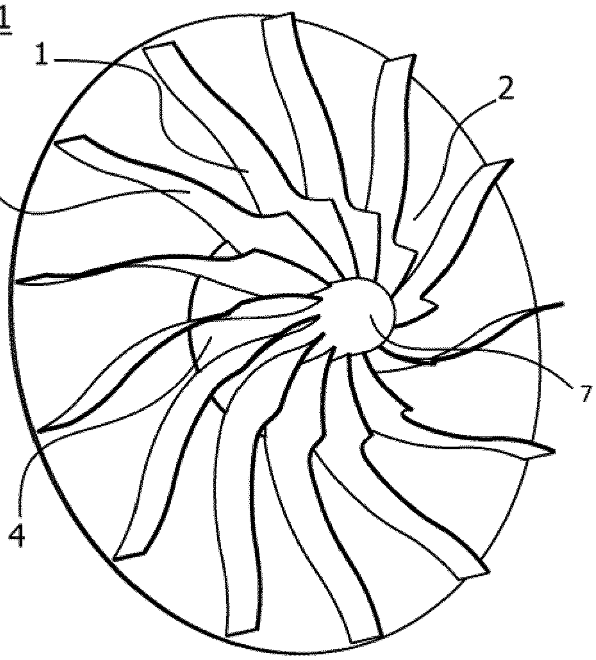


Fig.2

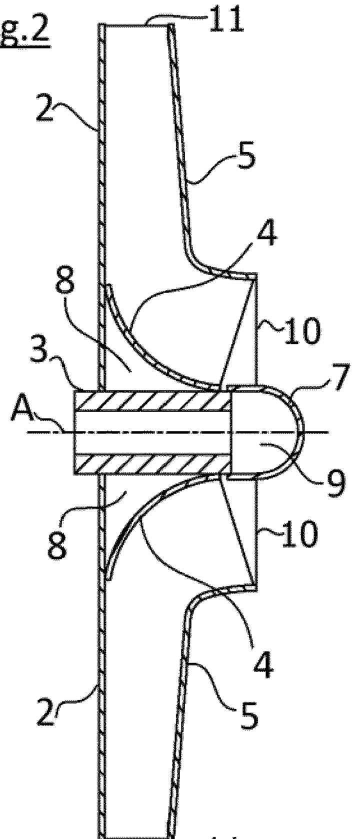


Fig.3

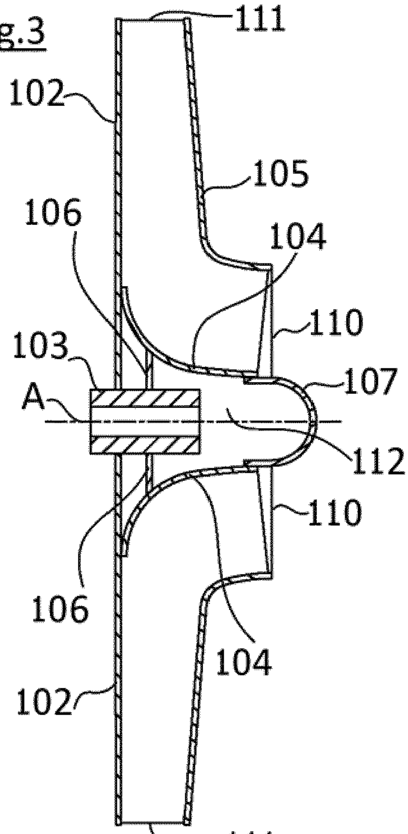


Fig.4

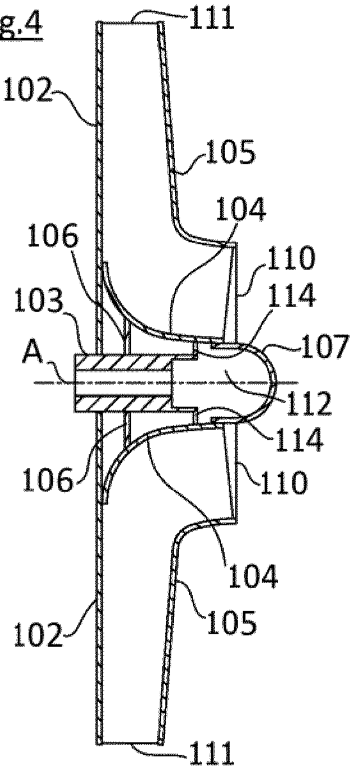


Fig.5

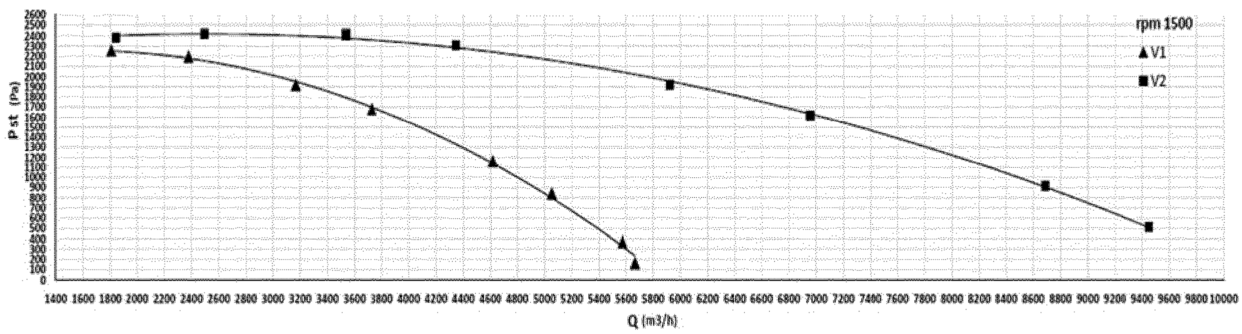
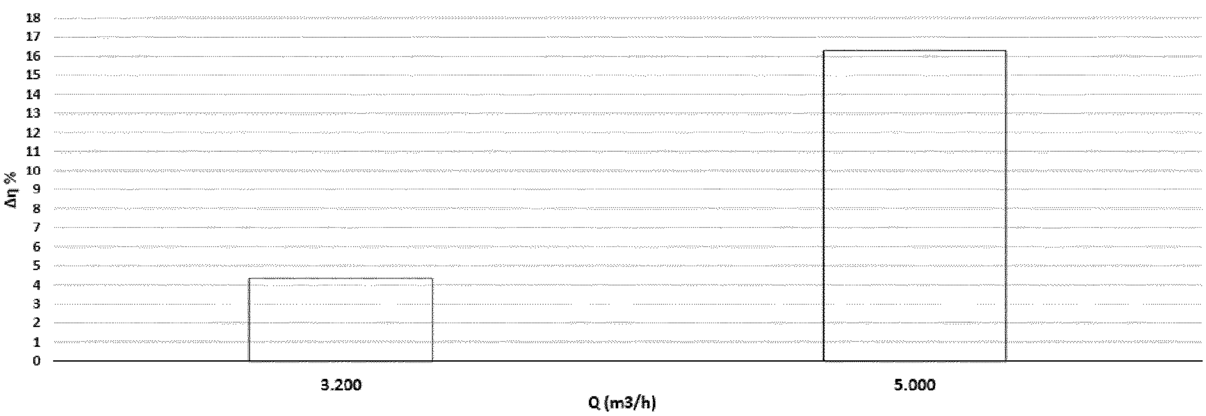


Fig.6



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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 9249

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 221 398 A (MAYNE RUTH D) 7 December 1965 (1965-12-07) * abstract * * column 1, line 56 - column 4, line 21 * * figures *	1-10	INV. F04D29/28 F04D29/62
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A	DE 103 10 981 A1 (PILLER INDUSTRIEVENTILATOREN G [DE]) 23 September 2004 (2004-09-23) * abstract * * paragraph [0029] - paragraph [0048] * * figures *	1-10	TECHNICAL FIELDS SEARCHED (IPC) F04D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	4 May 2017	Kolby, Lars

CATEGORY OF CITED DOCUMENTS

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