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(54) AN AIRFLOW GENERATOR

(57) An airflow generator (1) comprising: an electrically powered ducted fan (2) provided with an inlet (3) and an outlet (4), a fluid conduit (5); and an air multiplier (6) for discharging air along a first axis (A), said air multiplier (6) comprising an inlet (8) and an outlet (9), said fluid conduit (5) fluidly connecting the outlet (4) of the ducted fan (2) to the inlet (8) of the air multiplier (6). The air multiplier (6) comprises an aerodynamic profile defined by a cross-sectional profile shape (P) swept along a profile path (PA), wherein the cross-sectional profile shape (P) comprises outer wall portions defining an inner space (S) and defining said outlet (9) which fluidly connects the inner space (S) to ambient air. The outer wall portions comprise a rounded leading portion (P1) for facing incoming ambient air moved by the air multiplier (6), an elongated first side portion (P2) extending from the leading portion (P1) towards a trailing portion (PT) of the profile shape (P), and an elongated second side portion (P3) extending from the leading portion (P1) towards the trailing portion (PT) of the profile shape (P), wherein the first side portion (P2) extends non-overlapping with respect to itself, wherein the second side portion (P3) extends non-overlapping with respect to itself, and wherein the first side portion comprises a curved end portion (P4) extending along said first axis (A) past a free end (E) of the second side portion (P3).

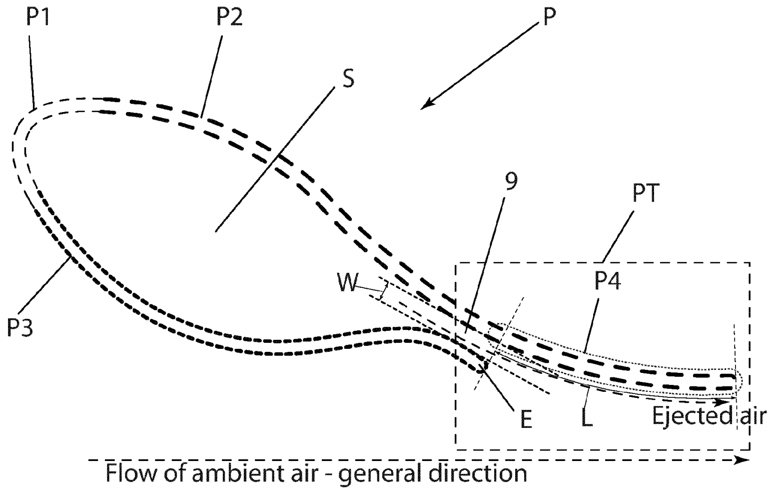

Fig. 3

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an airflow generator, and to an electric induction device assembly comprising such an airflow generator for cooling of a heat exchanger provided externally of an electric induction device of the electric induction device assembly, for cooling of the transformer.

BACKGROUND OF THE INVENTION

[0002] A power transformer is equipment used in an electric grid of a power system. Power transformers transform voltage and current in order to transport and distribute electric energy. Power transformers involve high currents; therefore, production of heat is inevitable. This heat propagates in oil inside a transformer tank. It is important to release this heat to the surroundings for the normal operation of transformers. An important part of oil-cooling is carried out by placing external devices by the transformer, such as radiators, cooler banks etc., through which the transformer oil is circulated and get cooled. State-of-the art air-cooling for a transformer is performed using conventional fans, i.e., bladed fans, or using natural convection. The state-of-the-art cooling systems using bladed fans typically produce high noise, have complex structure, are heavy, and are difficult to maintain. For high-power transformers, natural convection is not enough to cool the transformer, and therefore, forced cooling is needed.

[0003] External transformer cooling generally uses a one or more radiators external to the transformer, said radiators allowing oil to circulate from the transformer and out to the radiators, where heat is dissipated from the oil to surrounding ambient air. The cooling process typically uses natural convection or forced convection to move ambient air past the radiator.

[0004] This disclosure concerns cooling systems using forced convection. Forced convection is typically achieved using one or more large fans blowing air through or onto the radiator(s). Cooling efficiency is dependent on airflow rate and consequently on the power consumption of the fans.

[0005] Accordingly, an object of the present disclosure is to provide a compact and power-efficient airflow generator for cooling of an electric induction device, such as a transformer or a shunt reactor.

SUMMARY OF THE INVENTION

[0006] According to a first aspect of the present disclosure, these and other objects are achieved by an airflow generator as defined in claim 1, with alternative embodiments defined in dependent claims. The airflow generator is suitable for cooling an oil-to-air external heat exchanger of an electric induction device. The airflow generator comprises an electrically powered ducted fan provided with an inlet and an outlet, a fluid conduit; and an air multiplier for discharging air along a first axis, said air multiplier comprising an inlet and an outlet. The fluid conduit fluidly connects the outlet of the ducted fan to the inlet of the air multiplier. The air multiplier comprises an aerodynamic profile defined by a cross-sectional profile shape swept along a profile path. The cross-sectional profile shape comprises outer wall portions defining an inner space and defining said outlet which fluidly connects the inner space to ambient air.

[0007] The outer wall portions comprise a rounded leading portion for facing incoming ambient air moved by the air multiplier, an elongated first side portion extending from the leading portion towards a trailing portion of the profile shape, and an elongated second side portion extending from the leading portion towards the trailing portion of the profile shape. The first side portion extends non-overlapping with respect to itself. Also, the second side portion extends non-overlapping with respect to itself. The first side portion comprises a curved end portion extending along said first axis past a free end of the second side portion.

[0008] The fan provides an airflow into the air multiplier. The ducted nature of the fan enables it to efficiently pressurize the fluid conduit. By providing the airflow generator with an air multiplier, a much larger amount of air than the amount of air supplied by the fan, is discharged towards the oil-to-air heat exchanger. This reduces power-consumption as compared to use of conventional fans directly blowing air, for example blowing air towards an oil-to-air heat exchanger of a an electric induction device. Also, noise emitted from the fan and air multiplier combination is lower than a corresponding noise level emitted from a fan achieving the same airflow towards the heat exchanger.

[0009] In use, air is thus forced out of the outlet of the air multiplier. The ejected air follows the curved end portion of the air multiplier. Ejected air causes ambient air to be accelerated and moved past the air multiplier. The rounded leading portion is thus hit by incoming ambient air before the ambient air reaches the trailing portion of the air multiplier.

[0010] The non-overlapping extent of each respective side portion is associated with a technical effect being that the respective side portion does not direct an airflow back along itself within the inner space of the air multiplier and also does not introduce an inner edge facing into the inner space. The non-overlapping nature of the respective side portions could alternatively be defined by the presence of free ends of the cross-sectional profile shape, said free ends being configured to define external edges of the air multiplier.

[0011] Such configuration of the air multiplier leads to improved energy efficiency, likely associated with less turbulence inside the hollow air multiplier due to omission of inner edge facing into the inner space. Also, the non-overlapping nature seems to reduce the tendency of foreign particles collecting inside the air multiplier, thus increasing service life and reducing need of maintenance.

[0012] A gap width of the outlet of the air multiplier between the first side portion and the second side portion may be in the range of 0.1-10 mm.

[0013] The gap width may be non-constant along the length of the air multiplier. By providing a gap width changing along the length of the air multiplier, i.e., along the extent of the profile path, the local speed of airflow through the outlet can be adjusted to thereby control the overall airflow distribution of air accelerated by the airflow generator.

[0014] A longitudinal extent of the curved end portion past the free end of the second side portion may be at least five times the gap width.

[0015] The aerodynamic profile may form a closed loop. The closed loop design increases strength of the air multiplier. Further, the closed loop design mitigates turbulence since the air multiplier has no free ends.

[0016] An air ejection direction of the outlet may form an angle with an air ejection direction of the trailing portion of the air multiplier, said angle being in the range of 5-35 degrees, such as 10-30 degrees.

[0017] According to a second aspect of the present disclosure, these and other objects may be achieved by a electric induction device arrangement as defined in claim 7. The electric induction device arrangement comprises an airflow generator according to any one of the alternatives defined above, and an electric induction device provided with an oil-to-air external heat exchanger. The airflow generator is configured to discharge air towards the oil-to-air heat exchanger.

[0018] Electric induction devices provided with oil-to-air heat exchangers are known. By providing such electric induction devices with the claimed airflow generator, an energy efficient and compact cooling system for the electric induction device is achieved.

[0019] The electric induction device may be a static electric induction device, for example a transformer or a shunt reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 shows a perspective cross-sectional view of an air discharge device according to a first embodiment. The cross-sectional cut is vertical and the air multiplier extends in a circular closed loop which is thus not shown in full.

Fig. 2 shows a cross-sectional profile shape of the air multiplier also shown in fig. 1.

Fig. 3 shows the extent of various outer wall portions of the air multiplier also shown in figs. 1 and 2.

Fig. 4 shows an example of a curve being non-overlapping with respect to itself.

Fig. 5 shows an example of a curve being overlapping with respect to itself.

Fig. 6 shows an alternative embodiment of a cross-sectional profile shape with a slightly different angle α.

Fig. 7 shows an electric induction device arrangement comprising an airflow generator and an electric induction device provided with an oil-to-air external heat exchanger to be cooled by the airflow generator.

[0021] All figures are schematical illustrations and are not drawn to scale.

DETAILED DESCRIPTION

[0022] Embodiments of the present disclosure will hereinafter be explained with reference to the appended drawings.

[0023] Fig. 1 shows an airflow generator 1 comprising an electrically powered ducted fan 2 provided with an inlet 3 and an outlet 4. The airflow generator 1 further comprises a fluid conduit 5 and an air multiplier 6 for discharging air along a first axis A. The air multiplier 6 comprises an inlet 8 and an outlet 9. The fluid conduit 5 fluidly connects the outlet 4 of the ducted fan 2 to the inlets 8 of the air multiplier 6.

[0024] The term air multiplier is used in the prior art and thus should be known to the skilled person. Air multipliers are nozzles typically used in bladeless fans. Herein, the term air multiplier may to refer to any type of air discharge device/nozzle designed to discharge air through an outlet, typically in the form of one or more elongate slits, such that air around the discharge device is brought along by the air discharged from the outlet at a rate of at least 5-15 times the amount of air discharged by the outlet. Another term which could be used instead of air multiplier is Coandă effect air flow multiplier. Such air discharge devices can vary greatly in design but are often shaped like an extruded hollow profile.

[0025] The present invention relates to a specific design of the air multiplier 6 based on a specific design of the cross-sectional profile shape of the air multiplier 6.

[0026] As shown in fig. 1, the air multiplier 6 comprises an aerodynamic profile defined by a cross-sectional profile shape P swept along a profile path PA. As indicated by the cross-sectional view fig. 1, the air multiplier, which is symmetric about the section plane, forms a closed circular loop. As elaborated below, other shapes could alternatively be used instead using either closed or open 'loops' or other shapes. As shown in fig. 3, the cross-sectional profile shape P comprises outer wall portions defining an inner space S and defining said outlet 9 which fluidly connects the inner space S to ambient air. The outer wall portions comprise a rounded leading portion P1 for facing incoming ambient air moved by the air multiplier 6. The outer wall portions further comprise an elongated first side portion P2 extending from the leading portion P1 towards a trailing portion PT of the profile shape P, and an elongated second side portion P3 extending from the leading portion P1 towards the trailing portion PT of the profile shape P. The first side portion P2 extends non-overlapping with respect to itself, and the second side portion P3 extends non-overlapping with respect to itself. Also, the first side portion P2 comprises a curved end portion P4 extending along said first axis A past a free end E of the second side portion P3.

[0027] In use, the air multiplier 6 ejects air from its outlet. The ejected air follows the curved end portion P4. The curvature is adapted to trigger the Coandă effect in use. Ejected air causes ambient air to be accelerated and moved past the air multiplier 6. The rounded leading portion P1 is thus hit by incoming ambient air before the ambient air reaches the trailing portion PT of the air multiplier 6.

[0028] The non-overlapping extent of each respective side portion P2, P3 is associated with a technical effect being that the respective side portion does not direct an airflow in the inner space S back along the respective side portion (itself). Another effect is that, since no inner edge faces into the inner space S, turbulence inside the inner space S is avoided (turbulence which would otherwise form by said edge). In other words, the non-overlapping nature of the respective side portions P2, P3 could alternatively be defined by free ends of the cross-sectional profile shape defining external edges of the air multiplier 6.

[0029] An example of a non-overlapping extent and an example of an overlapping extent are shown in fig. 4 and 5, respectively.

[0030] For a non-overlapping extent, a first directional component dx of the direction of curvature of the curve, changes direction/is reversed somewhere along the extent of the curve. This is illustrated in the example of fig. 5, where the x-axis component dx changes from positive to negative, i.e., from right to left in the figure. This is not the case for the non-overlapping extent of the curve of fig. 4, where this component dx of the direction of curvature is directed to the right all along the extent of the curve shown.

[0031] When studying a curve to determine whether or not it is non-overlapping with respect to itself, the so-called x-axis is typically chosen to extend parallel to the air ejection direction through the outlet of the air multiplier 6.

[0032] The direction of the other axis dy may vary along the extent of the curve studied without affecting whether the curve is overlapping or non-overlapping with respect to itself.

[0033] In other embodiments, the air discharge device may comprise more than one air multiplier. Also, the shape of the profile path PA may in other embodiments by shaped in any other suitable way, such as straight, elliptic, spiral-shaped, N-gonal, etc.

[0034] The air multiplier can be made of any suitable material, formed with any suitable production method. Typically, the aerodynamic profile of the air multiplier 6 is made from extruded aluminum or extruded plastic. Optionally, the air multiplier 6 may be produced by molding, for example by injection molding of plastic. The air multiplier 6 may comprise one or more parts joined together to form the air multiplier 6. For example, open ends of an extruded, or otherwise produced, hollow profile may need to be closed by caps, or fluidly connected to the fluid conduit such that air is supplied through open ends of the profile.

[0035] As shown in fig. 3, a gap width W of the outlet 9 of the air multiplier 6 between the first side portion P2 and the second side portion P3 may be in the range of 0.1-10 mm. In this embodiment, the gap width is substantially constant but in other embodiments, the gap width may alternatively be non-constant along the length of the profile path of the air multiplier 6.

[0036] A longitudinal extent L of the curved end portion P4 past the free end E of the second side portion P3 is preferably at least five times the gap width W.

[0037] An air ejection direction of the outlet 9 forms an angle α with an air ejection direction of the trailing portion of the air multiplier 6, said angle α being in the range of 5-35 degrees, such as 10-30 degrees.

[0038] For all embodiments, any other configuration of the fluid conduit 5 able to route air from the ducted fan to the air multiplier 6 could alternatively be used instead, such as internal channels of a housing.

[0039] The airflow generator 1 of the present disclosure is especially useful for providing an airflow directed towards a heat exchanger mounted externally on an electric induction device. Accordingly, the present invention also relates to an electric induction device arrangement 10. As illustrated in fig. 7, the electric induction device arrangement 10 comprises an airflow generator 1 as described above and an electric induction device. The electric induction device is provided with an oil-to-air external heat exchanger 7. The airflow generator 1 is configured to discharge air towards the oil-to-air heat exchanger 7.

[0040] The oil-to-air external heat exchanger 7 is external in the sense that it is mounted externally on the electric induction device, thereby able to radiate and conduct heat to surrounding air. Typically, oil from inside the electric induction device is pumped through the oil-to-air heat exchanger 7, wherein the oil transports heat generated within the electric induction device out to the heat exchanger 7, such that the airflow from the airflow generator 1 cools the heat exchanger 7.

Table of reference numerals

1	airflow generator
2	ducted fan
3	inlet of ducted fan
4	outlet of ducted fan
5	fluid conduit
6	air multiplier

(continued)

7	heat exchanger
8	inlet of air multiplier
9	outlet of air multiplier
10	electric induction device arrangement
P	cross-sectional profile shape
PA	profile path
S	inner space
P1	leading portion
P2	first side portion
P3	second side portion
P4	curved end portion
A	first axis
E	free end of second side portion
W	gap width of outlet

Claims

1. An airflow generator (1) comprising:

an electrically powered ducted fan (2) provided with an inlet (3) and an outlet (4), a fluid conduit (5); and
an air multiplier (6) for discharging air along a first axis (A), said air multiplier (6) comprising an inlet (8) and an outlet (9),
said fluid conduit (5) fluidly connecting the outlet (4) of the ducted fan (2) to the inlet (8) of the air multiplier (6),
said air multiplier (6) comprising an aerodynamic profile defined by a cross-sectional profile shape (P) swept along a profile path (PA), wherein the cross-sectional profile shape (P) comprises outer wall portions defining an inner space (S) and defining said outlet (9) which fluidly connects the inner space (S) to ambient air,
wherein the outer wall portions comprise a rounded leading portion (P1) for facing incoming ambient air moved by the air multiplier (6), an elongated first side portion (P2) extending from the leading portion (P1) towards a trailing portion (PT) of the profile shape (P), and an elongated second side portion (P3) extending from the leading portion (P1) towards the trailing portion (PT) of the profile shape (P),
wherein the first side portion (P2) extends non-overlapping with respect to itself,
wherein the second side portion (P3) extends non-overlapping with respect to itself, and wherein the first side portion comprises a curved end portion (P4) extending along said first axis (A) past a free end (E) of the second side portion (P3).

2. An airflow generator (1) according to claim 1, wherein a gap width (W) of the outlet (9) of the air multiplier (6) between the first side portion (P2) and the second side portion (P3) is in the range of 0.1-10 mm.

3. An airflow generator (1) according to claim 2, wherein the gap width is non-constant along the length of the air multiplier (6).

4. An airflow generator (1) according to any one of claims 2-3, wherein a longitudinal extent (L) of the curved end portion (P4) past the free end (E) of the second side portion (P3) is at least five times the gap width (W).

5. An airflow generator (1) according to any one of claims 1-4, wherein the aerodynamic profile forms a closed loop.

6. An airflow generator (1) according to any one of claims 1-5, wherein an air ejection direction of the outlet (9) forms an angle (α) with an air ejection direction of the trailing portion of the air multiplier (6), said angle (α) being in the range of 5-35 degrees, such as 10-30 degrees.

7. An electric induction device arrangement (10) comprising an airflow generator (1) according to any one of claims 1-6, and an electric induction device provided with an oil-to-air external heat exchanger (7), said airflow generator (1) being configured to discharge air towards the oil-to-air heat exchanger (7).

8. An electric induction device arrangement according to claim 7, wherein the electric induction device is a static electric induction device.

10. An electric induction device arrangement according to claim 8, wherein the electric induction device is a transformer.

11. An electric device arrangement according to claim 8, wherein the electric induction device is a shunt reactor.

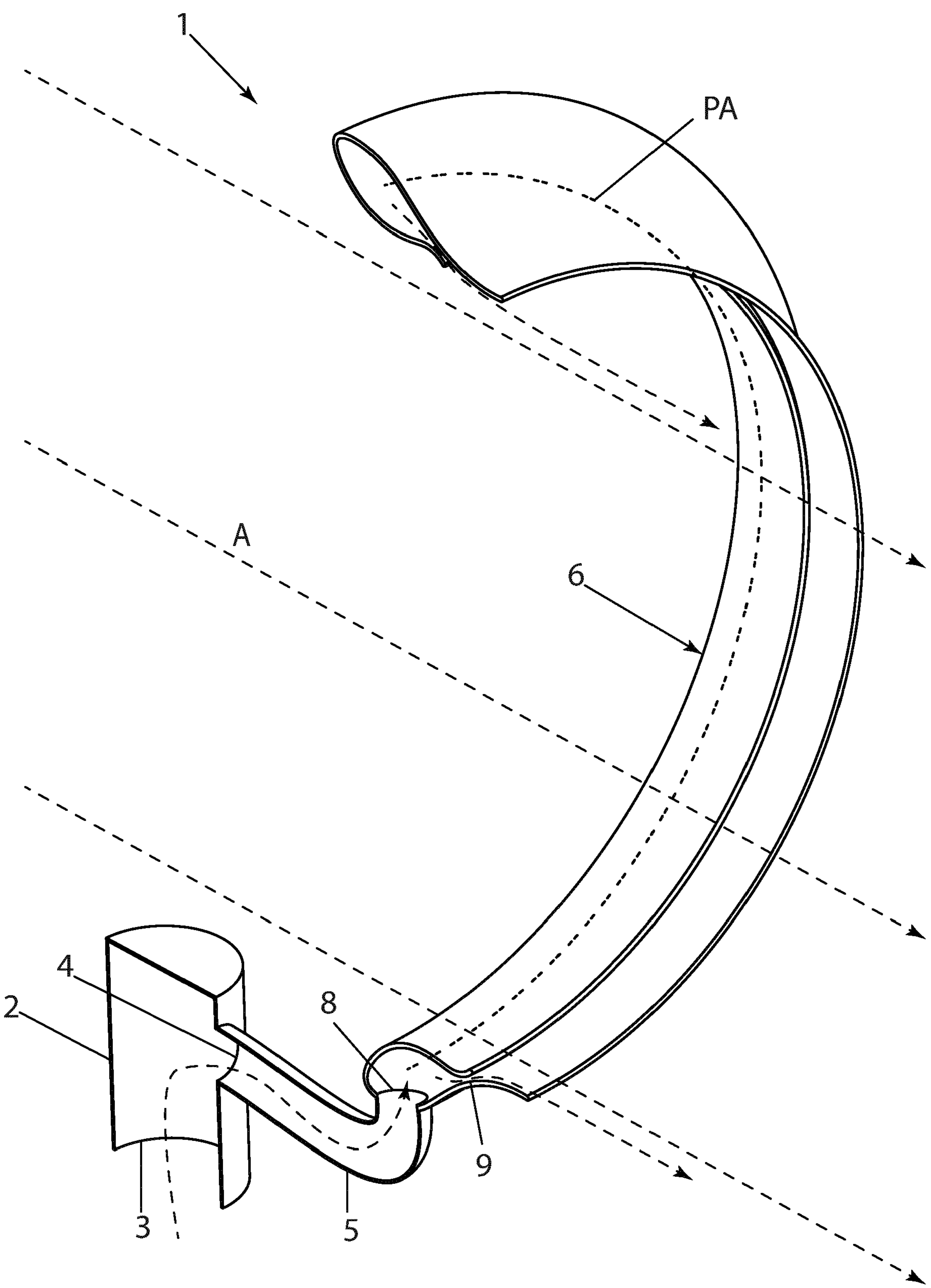

Fig. 1

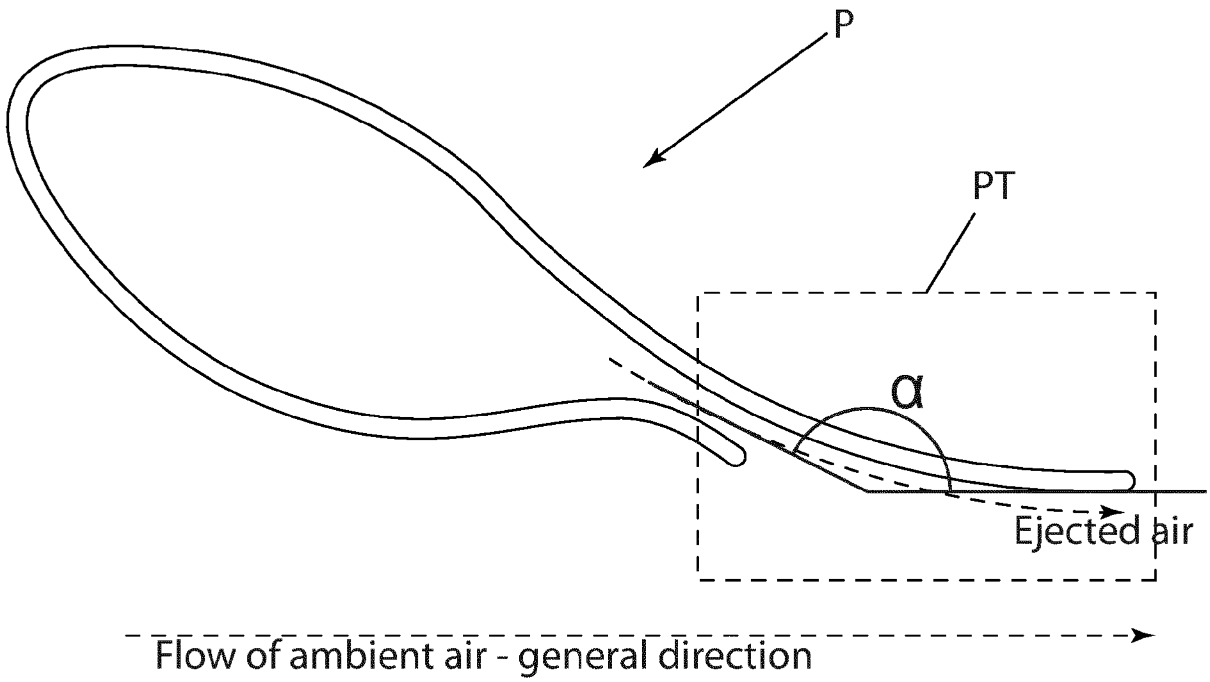
P
PT
α
Ejected air
Flow of ambient air - general direction

Fig. 2

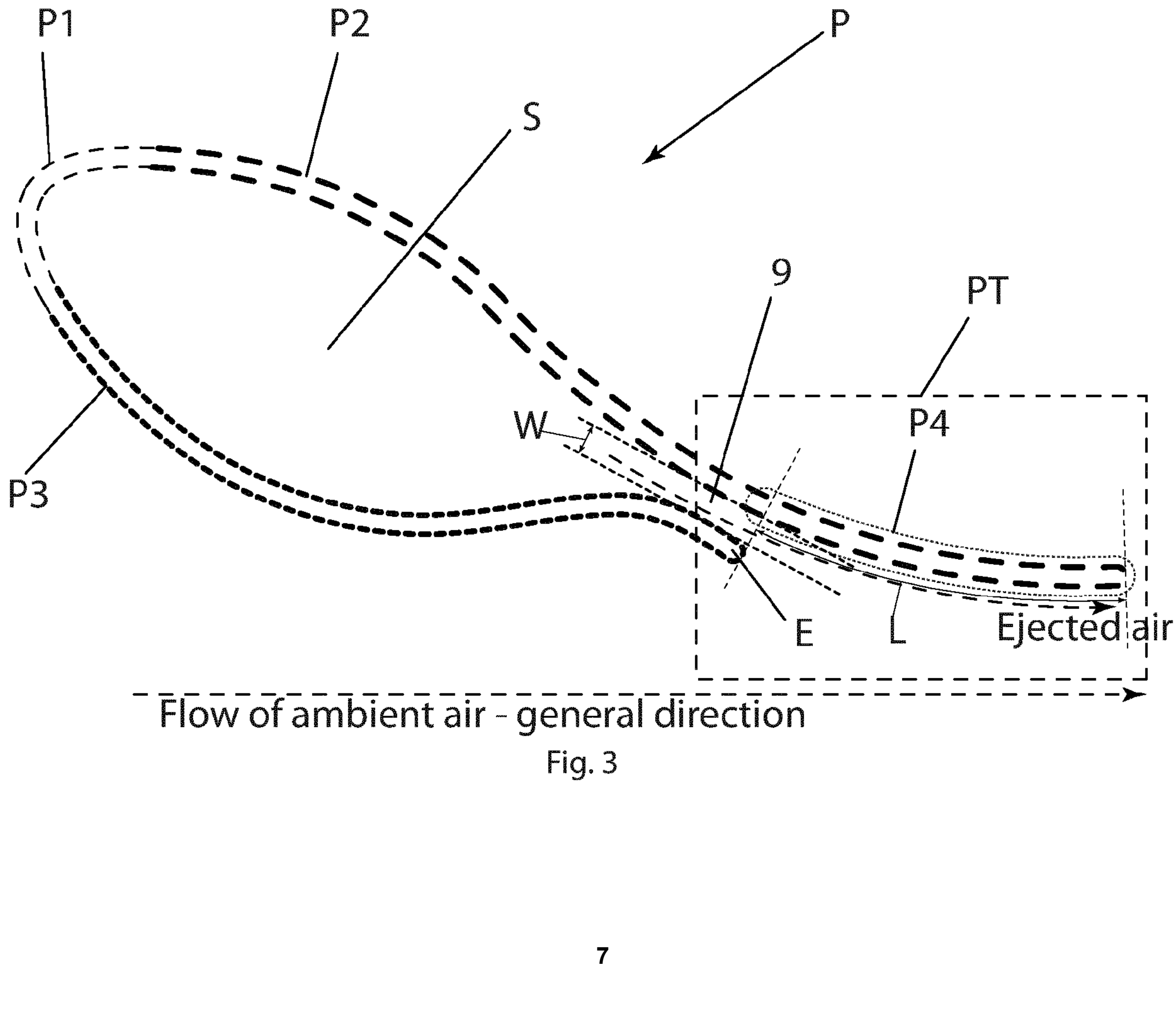
P1
P2
P
S
9
PT
W
P4
P3
E
L
Ejected air
Flow of ambient air - general direction

Fig. 3

Non-overlapping with respect to itself

Fig. 4

Overlapping with respect to itself

Fig. 5

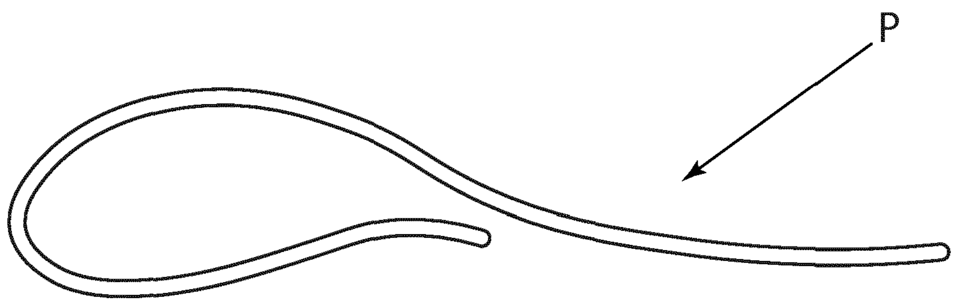

Fig. 6

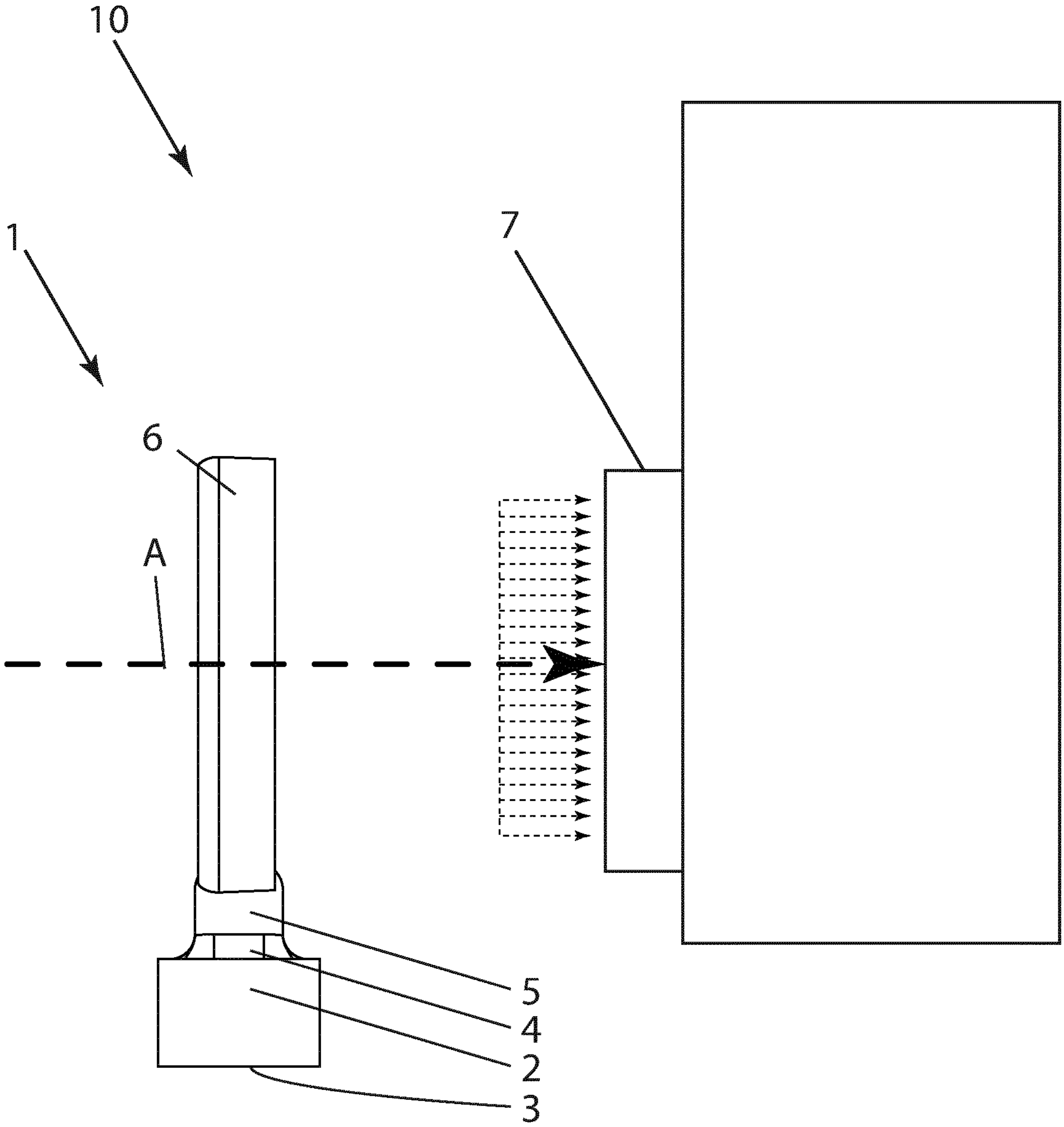

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 6776

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 March 2024	Gnüchtel, Frank

CATEGORY OF CITED DOCUMENTS

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