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(56) Documents Cited:
CN 201843806 U **CN 102562625 A**
JP 2016014368 A **US 20190390685 A1**
KR 20160049199

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(54) Title of the Invention: **Vortex generators for jet fans**
Abstract Title: **Vortex generator for jet fans**

(57) A fan assembly for ventilation comprises a fan for generating a ventilating flow, with an inflow being substantially parallel to an outflow. The fan assembly is arranged such that a ventilating flow will pass through a nozzle 1 before exiting the assembly. A bellmouth 3 is attached to the nozzle and a vortex generator(s) 2 is arranged within the nozzle, extending from an inner surface 5, into the nozzle through-bore. The vortex generators assist in delaying the separation of the boundary layer from the lower part of the bellmouth, while the boundary layer on the upper part of the bellmouth is unaffected, assisting in turning flow away from the bounding external surfaces, overcoming a Coanda effect. The vortex generator(s) may have a generally triangular structure and / or upper corners of each vortex generator are rounded. Preferably the vortex generators are located opposite to the bounding surface of the space to be ventilated and arranged along one or more lines, separated by a pitch. The fan assembly may comprise two nozzles, one installed on each side of the fan. Preferably an angle made between the nozzle trailing edge and a centreline of the fan is not perpendicular.

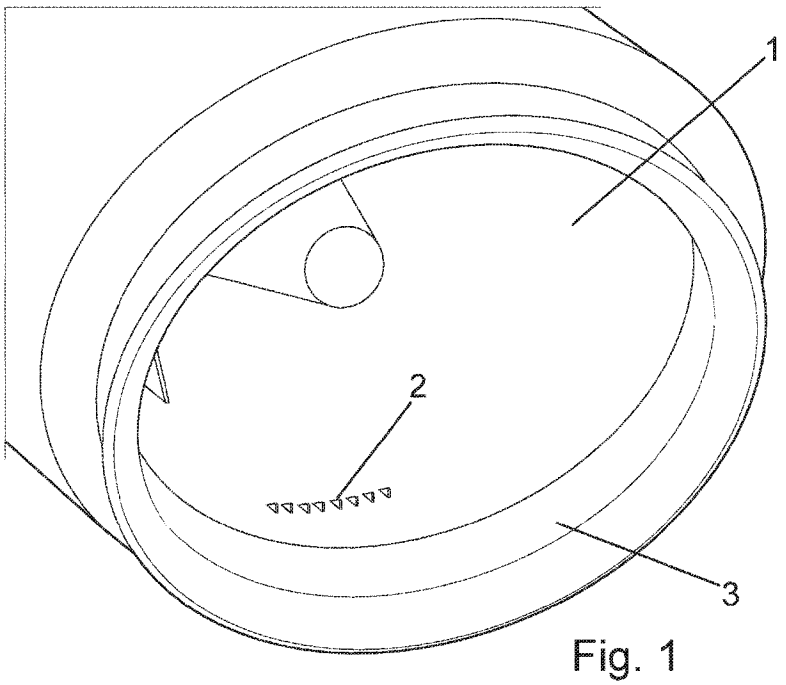

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

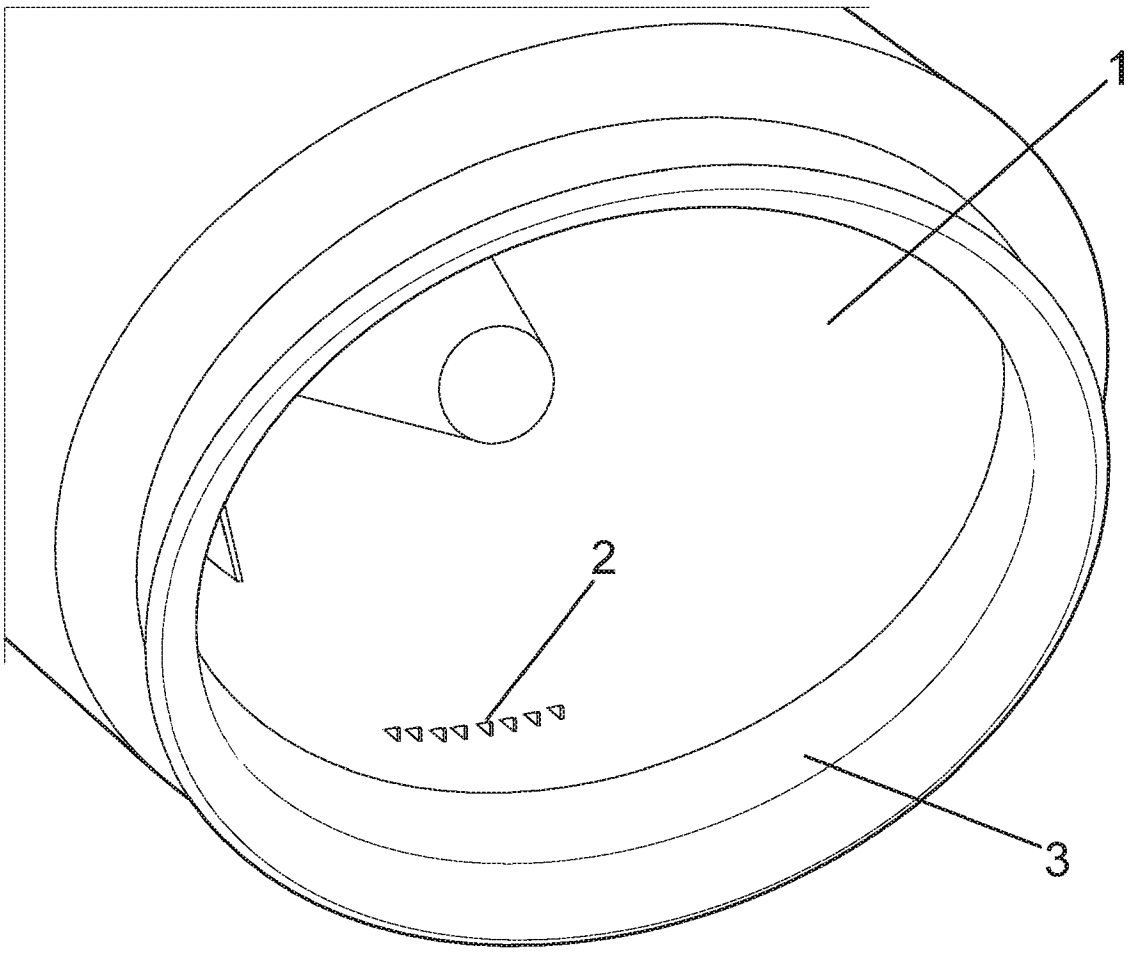

Fig. 1

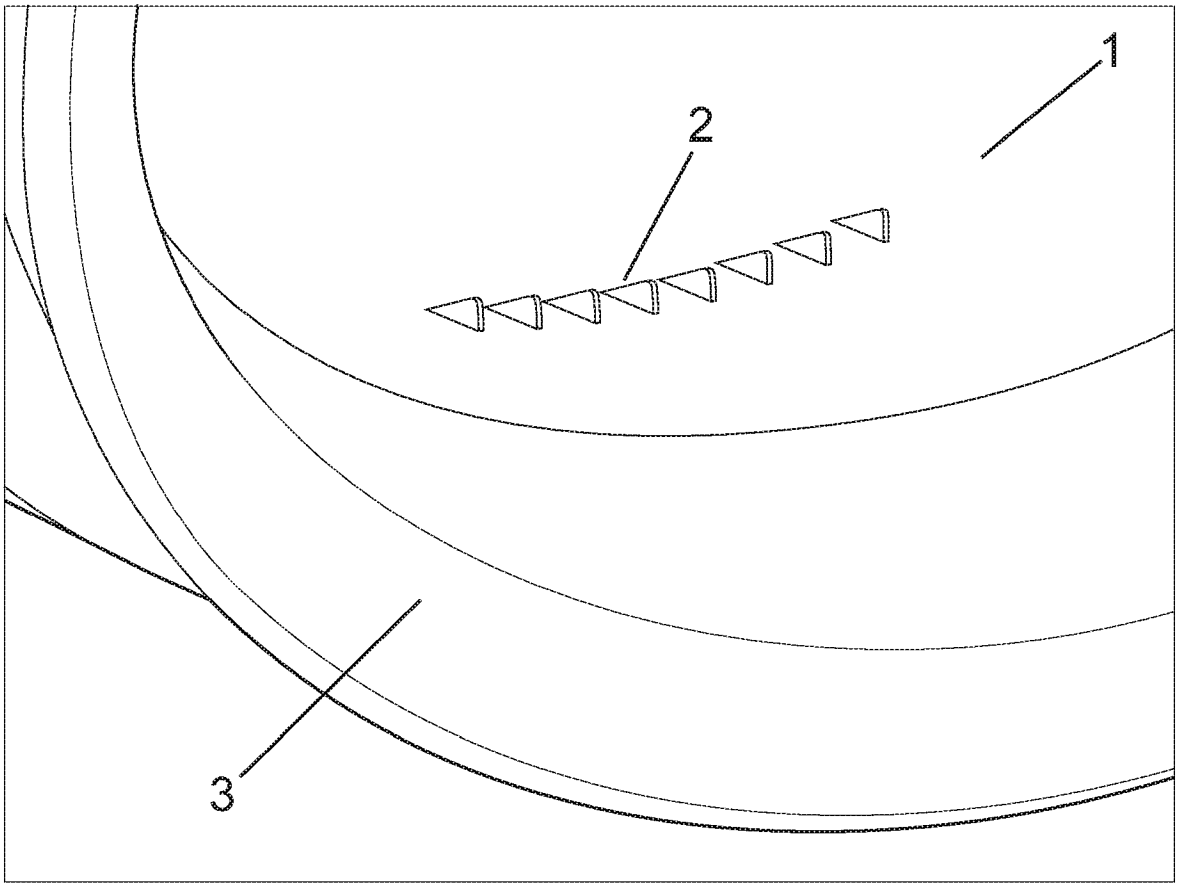

Fig. 2

VORTEX GENERATORS FOR JET FANS

BACKGROUND OF THE INVENTION

[0001] Underground car parks and tunnels are routinely ventilated using jet fans, both to maintain adequate air quality during normal operations, and also to control the spread of smoke in case of fire.

[0002] Bellmouths are generally installed at the inlet side of jet fans, to reduce the extent of flow separation and hence limit the entry loss. Most jet fans are designed for reversible operation, and for such jet fans, bellmouths are generally installed on both the inlet and discharge sides.

[0003] A previous patent application number WO 2018/203023Al filed by the present Applicant describes an optimised tunnel ventilation device, by tilting the nozzle trailing edge so that it forms an angle with respect to the fan centreline, with the surface of the nozzle throughbore being non-cylindrical in shape. The same patent application further describes bellmouths that can be attached to the nozzle trailing edges, in order to deflect the discharge airflow away from the surrounding tunnel surfaces. That invention reduces the Coanda effect of the jet issued from the jet fan, and hence improves the in-tunnel thrust.

[0004] Although the combination of tilted nozzle trailing edge and bellmouth in WO 2018/203023Al causes the flow along the upper edge ("pressure side") of the nozzle to turn away from the surrounding tunnel surfaces, the same is not true of the lower nozzle edge ("suction side"), which experiences little if any flow turning. Because of this asymmetry, the nozzle trailing edge must be set at a relatively high angle (typically 20° to 25° to the normal from the fan centreline), in order to compensate for the lack of flow turning along the lower nozzle edge.

[0005] The relatively high tilt angle of the nozzle trailing edge in WO 2018/203023Al causes a design issue on the inlet side of the jet fan, with a

significant depth of bellmouth required to avoid flow separation along the lower nozzle edge. If the depth of the bellmouth is greater than the thickness of silencer material and sheet metal, part of the bellmouth hangs underneath the jet fan, which would increase the required installation height.

[0006] Vortex generators have been successfully used in external aerodynamics applications, for example to inhibit flow separation on the suction side of aircraft wings. They have also been employed in internal flow applications, for example US2017114794A1 discloses a diffuser pipe with vortex generators as part of a gas turbine engine. However, they have not to date been used in jet fan applications to ventilate spaces such as tunnels or car parks.

[0007] The Applicant believes that there remains scope to improve the effective thrust of longitudinal tunnel ventilation systems in tunnels and car parks.

SUMMARY OF THE INVENTION

[0008] According to one aspect of the invention, there is provided a fan assembly for installation in a space to provide ventilation in that space, the fan assembly comprising:

a fan for generating a ventilating flow,

the inflow into the fan being substantially parallel to the outflow from the fan;

the fan assembly is arranged or arrangeable such that a ventilating flow generated by the fan will pass through a nozzle before exiting the assembly to enter a space to be ventilated;

a bellmouth is attached to the nozzle;

wherein:

one or more vortex generators are arranged within the nozzle and extend from the inner surface of the nozzle into the nozzle throughbore.

[0009] Preferably two nozzles are provided, one installed on each side of the fan.

[0010] Preferably, a plurality of vortex generators are arranged at the nozzle internal surface, such that in use, they are located opposite to the bounding surface of the space to be ventilated.

[0011] The invention provides a solution to the technical issue of how to turn the flow from a jetfan away from the surrounding tunnel surfaces and hence achieve greater in-tunnel aerodynamic thrust, by reducing the Coanda effect.

[0012] The turning of the flow discharged into the space is achieved through the use of vortex generators installed within the nozzle. The vortex generators re-energise the boundary layer within the nozzle and inhibit the separation of the flow along part of the bellmouth that is opposite to the bounding surface of the space to be ventilated.

[0013] By selectively inhibiting the flow separation on one side of the bellmouth, the discharged flow can be turned away from the bounding surface and the Coanda effect can be overcome.

[0014] The selective inhibition of flow separation can be achieved by installing vortex generators on a sector of the internal surface of the nozzle. This sector subtends an angle typically in the range of 5° to 45°, measured around the fan centreline.

[0015] The flow on the discharge side of a fan is typically swirling. Preferably, the vortex generators are arranged along one or more lines and separated by an adequate pitch, in such a way that the wakes from the vortex generators will not negatively interfere with each another.

[0016] In order to reduce the pressure drop across the vortex generators installed on the inlet side of a fan, they should preferably be arranged with an acute attack angle (between 0° to ±60°) between their principal axis and the fan centreline. More

preferably still, the attack angle should be set to 0°, so as that the form drag associated with the vortex generators on the inlet side of the fan is minimised.

[0017] In order to generate more powerful vortices, it may be beneficial to arrange the vortex generators with alternate positive and negative attack angles, so that they form a herringbone pattern.

[0018] Nozzles on jet fans are typically arranged as acoustic silencers, with perforated sheet metal forming the internal surface of the nozzles. Vortex generators can preferably be formed by cutting the sheet metal with the required shapes and bending the shapes by approximately 90°, so that they project into the nozzle throughbore.

[0019] According to a second aspect of the invention, there is provided a fan assembly for installation in a space to provide ventilation in that space, the fan assembly comprising:

a fan for generating a ventilating flow,

the inflow into the fan being substantially parallel to the outflow from the fan;

the fan assembly is arranged or arrangeable such that a ventilating flow generated by the fan will pass through a nozzle before exiting the assembly to enter a space to be ventilated;

the angle made between the nozzle trailing edge and a centreline of the fan is not perpendicular;

a bellmouth is attached to the nozzle;

wherein:

one or more vortex generators are arranged within the nozzle and extend from the inner surface of the nozzle into the nozzle throughbore.

[0020] This aspect of the invention is applicable to jet fans designed broadly in accordance with the teachings of WO 2018/203023Al, since it assists in delaying flow separation and hence turning the flow along the lower part of the discharge

bellmouth, such that in use, the Coanda effect between the jet and the surrounding surfaces of the ventilated space is overcome.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] A number of preferred embodiments of the present invention will now be described by way of example only, and with reference to the accompanying drawings, in which like reference numerals are used for like components throughout the figures.

[0022] Figure 1 shows a view of a fan assembly with a nozzle and vortex generators as described in this invention installed on one side of a fan; and

[0023] Figure 2 shows a magnified view of the same fan assembly with a nozzle and vortex generators, showing details of the vortex generators.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0024] Referring to Figures 1 and 2, these show views of a fan assembly with a nozzle and vortex generators as described in this invention installed on one side of a fan.

[0025] In this embodiment, a series of vortex generators (2) are arranged on the internal surface of a nozzle (1), upstream of a bellmouth (3).

[0026] Airflow passes through the nozzle (1) and is discharged into an external space through a bellmouth (3). The vortex generators (2) are arranged in a line upstream of the bellmouth, on the opposite side to the surrounding surfaces of the external space (e.g. opposite to the tunnel soffit).

[0027] Preferably, the vortex generators are designed broadly in the shape of triangles. An acute angle is preferably arranged between the leading edge of the

vortex generator and the internal nozzle surface. The preferred shape of the vortex generators may equivalently be described as delta winglets.

[0028] Preferably, the upper corners of the triangles forming the vortex generators are rounded.

[0029] The vortex generators assist in delaying the separation of the boundary layer from the lower part of the bellmouth, while the boundary layer on the upper part of the bellmouth is unaffected. Therefore they assist in turning the flow away from the bounding external surfaces, and in overcoming the Coanda effect.

CLAIMS

1. A fan assembly for installation in a space to provide ventilation in that space, the fan assembly comprising:

a fan for generating a ventilating flow, the inflow into the fan being substantially parallel to the outflow from the fan and wherein the fan assembly is arrangeable in use such that a ventilating flow generated by the fan will pass through a nozzle before exiting the assembly to enter a space to be ventilated;

a bellmouth attached to a nozzle; and

at least one vortex generator arranged within the nozzle and extending from the inner surface of the nozzle into the nozzle throughbore.

2. A fan assembly according to claim 1, wherein a plurality of vortex generators are provided on the nozzle internal surface, such that in use, they are located opposite to the bounding surface of the space to be ventilated.

3. A fan assembly according to claim 2, wherein the vortex generators are located in an area on the internal surface which subtends at an angle of between 5% and 45% from the fan centreline.

4. A fan assembly according to claim 2 or 3, wherein the vortex generators are arranged along one or more lines and are separated by a pitch.

5. A fan assembly according to any one of claims 2 to 4, wherein the vortex generators are located on the inlet side of the fan.

6. A fan assembly according to claim 1, wherein the vortex generators are arranged with an angle of 0° to ±60° between their principal axis and the fan centreline.

7. A fan assembly according to claim 1, wherein the vortex generators are arranged at an angle of 0° between their principal axis and the fan centreline.

8. A fan assembly according to any one of claims 1 to 7, wherein one or each vortex generator is shaped and dimensioned to project into the nozzle throughbore.

9. A fan assembly according to any preceding claim wherein one or each vortex generator has a generally triangular structure.

10. A fan assembly according to any preceding claim, wherein one or each vortex generator forms an acute angle between the leading edge of the vortex generator and the internal nozzle surface.

11. A fan assembly according to claim 9 or claim 10, wherein the upper corners of each triangular vortex generator are rounded.

12. A fan assembly according to any preceding claim, wherein the fan assembly comprises two nozzles, one installed on each side of the fan.

13. A fan assembly according to any preceding claim, wherein an angle made between the nozzle trailing edge and a centreline of the fan is not perpendicular.

Intellectual Property Office

Application No:	GB2009713.5	**Examiner:**	Mr Mat Smith
Claims searched:	1-13	**Date of search:**	24 November 2021

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-9, 10-13	CN 102562625 A (LIJUN) See figures and EPODOC abstract & WPI abstract Accession No. 2012-L67786. In particular vortex generators 32.
X	1-9, 11-13	US 2019/0390685 A1 (USAMI) see figures and description. In particular vertical swirl (vortex) generator.
X	1-8, 12, 13	JP 2016014368 A (OTAGURO) See figures and EPOC abstract & WPI abstract Accession No. 2016-09096M.
A	-	KR 20160049199 A (KIM) See figures and EPODOC abstract & EPODOC abstract Accession No. 2016-30546C.
A		CN 201843806 U (ZHESHENG & XIANQUN) See figures and EPODOC abstract & WPI abstract Accession No. 2011-H42129.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

F04D

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, Patent Fulltext

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
F04D	0029/54	01/01/2006
F04D	0029/66	01/01/2006