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(54) **ENERGY-EFFICIENT TUNNEL VENTILATION DEVICE**

ENERGIEEFFIZIENTE TUNNELLÜFTUNGSVORRICHTUNG

DISPOSITIF DE VENTILATION À FAIBLE CONSOMMATION D'ÉNERGIE POUR TUNNEL

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Description

BACKGROUND OF THE INVENTION

[0001] Longitudinal ventilation via jetfans is generally acknowledged as being a cost-effective solution for tunnels, where the length and risk profile of the tunnel allows such an installation. However, jetfans are not particularly energy efficient, with typical installations wasting over half the supplied electrical power.

[0002] A major reason for the inefficiency of jetfans is the Coanda effect. This causes the stream of high-velocity air issuing from a jetfan to adhere to adjacent solid surfaces including the tunnel walls and soffit. A significant proportion of the aerodynamic thrust, typically 20% to 30%, is thereby wasted through the friction between the jet and the surrounding tunnel surfaces.

[0003] A previous patent GB2465261 granted to the present Applicant describes convergent nozzles that can be installed on one or both sides of jetfans, in order to accelerate the tunnel air and turn it away from the tunnel surfaces. In practice, this invention has been implemented by fitting conical nozzles onto jetfans.

[0004] The fitting of convergent nozzles onto jetfans does however come with an energy performance penalty where such nozzles are fitted to the inlet side of a reversible jetfan. The reason for this is that the power absorbed due to the inlet-side pressure drop cannot be recovered. This is contrary to the exit side where the kinetic energy of the discharged air serves to accelerate the tunnel air.

[0005] In order to reduce the inlet pressure losses to jetfans, circular bellmouths are typically fitted to the inlet side, in order to ensure a smooth flow. For reversible flow jetfans, such bellmouths are typically fitted to both sides of the jetfan. Due to manufacturing reasons, bellmouths are generally spun from sheet metal into a circular shape. The circularity of the bellmouths introduces a significant constraint on the shape of a jetfan nozzle. In particular, it has not previously been possible to combine the advantages relating to a reduction of the Coanda effect through the fitting of convergent nozzles with low inlet flow losses into a jetfan.

[0006] JP-A-H1-237400 discloses a jetfan with an undercut on the lower side of the cylindrical casing, to encourage the discharged air to turn away from the tunnel soffit. However, since the nozzle trailing edge is shaped as an ellipse, it is not feasible to attach bellmouths on the nozzle trailing edges, which in turn implies significant pressure losses. In addition, the nozzle is straight and hence there is no effective turning of the discharged air.

[0007] JP01130099A discloses an arrangement with multiple fans connected in parallel, delivering flow to a common plenum which in turn supplies air to a nozzle fitted with turning vanes. This complex arrangement is not suitable for most tunnels, which are ventilated using individual jetfans.

[0008] Applicant's earlier application no. US 2011/2755302 discloses a tunnel ventilation device with

a convergent nozzle arrangement.

[0009] The Applicant believes that there remains scope to improve the energy efficiency of longitudinal tunnel ventilation systems.

SUMMARY OF THE INVENTION

[0010] According to one aspect of the invention, there is provided a fan assembly for installation in a tunnel to provide ventilation in the tunnel according to claim 1.

[0011] The flow through a jetfans is driven by an axial fan, which gives an impulse to the tunnel airflow. 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, without choking the flow through the jetfan through increased pressure losses.

[0012] The first aspect of the invention is achieved by tilting the trailing edge of the nozzle, so that one side of the nozzle (the 'pressure side') is longer than the opposite side (the 'suction side'). The pressure side of the nozzle is termed thus because when the nozzle is placed on the discharge side of the jetfan, the pressure side 'pushes' the airflow away from the tunnel surrounding surfaces when the jetfan is in use. The pressure side would thus experience a static pressure that is greater than that on the opposite suction side.

[0013] In case a convergent nozzle is used as described in patent GB2465261, tilting the trailing edge of the nozzle has the effect of increasing the aerodynamic throat of the nozzle, and hence reducing the pressure drop through the nozzle throughbore. The power consumption of the jetfan is thus significantly reduced.

[0014] The range of angles between the trailing edge and the nozzle centre line has been selected on the basis of experimental evidence with the design, manufacture and testing of such jetfans. For a typical overall nozzle length to fan diameter ratio of unity and a circular trailing edge of the same diameter as the fan, the lower value of 45 degrees for the angle between the trailing edge and the nozzle centre line corresponds to a throughbore to fan area ratio of approximately 1.4, which would significantly choke most jetfan impellers. The higher value of 85 degrees for the angle between the trailing edge and the nozzle centre line corresponds to the minimum change from a conventional jetfan nozzle arrangement that our experience indicates would be commercially beneficial to produce.

[0015] In practice, manufacturers stock a standard range of bellmouths. The present invention permits the selection of a standard bellmouth size which can be installed at a tilt to the nozzle centre-line. In particular, a bellmouth with the same nominal diameter as the fan on which the nozzle is to be installed can be used. This option to use standard jetfan parts is a key advantage of the present invention.

[0016] The nozzle can typically be used for acoustic silencing, as well as for turning the discharged flow away

from the tunnel surrounding surfaces. From previous laboratory measurements, it has been established that the performance of the silencer is dependent upon the solid angle subtended by the silencer surface onto the fan outlet. Through judicious choice of nozzle geometry, adequate acoustic silencing can be achieved, given the occlusion of the fan outlet by the nozzle 'pressure side'.

[0017] The arrangement of the circular fan outlet connected to a tilted bellmouth typically leads to a non-conical shape for the nozzle, and a complex developed shape for the nozzles skins is required for sheet metal cutting. The shape of the proposed nozzle is thus different from the shapes envisaged in GB2465261 and JP-A-H1-237400. In the case of the latter reference, since the nozzle trailing edge is shaped as an ellipse, it is not feasible to attach bellmouths on the nozzle trailing edges, which in turn implies significant pressure losses. In addition, the nozzle is straight and hence there is no effective turning of the discharged air. That prior art design therefore does not provide a practical or efficient solution for tunnel ventilation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] 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:

[0019] Like reference numerals are used for like components throughout the figures;

Fig. 1 shows an embodiment of a ventilation apparatus with nozzles as described in this invention installed on both sides of a fan;

Fig. 2 shows an end view of a ventilation apparatus with a nozzle as described in this invention;

Fig. 3 shows an embodiment of a ventilation apparatus with a nozzle as described in this invention installed on one side of a fan.

Fig. 4 shows a typical flat developed pattern for a nozzle skin which is to be cut from sheet metal.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0020] Referring to Figure 1, this shows a side view of an embodiment of the present invention within a bidirectional ventilation apparatus, which is designed to operate in a fully reversible manner.

[0021] In this embodiment, a fan assembly comprising a fan rotor (3) driven by a motor (4) is installed within a fan housing (15). Airflow (5) enters the fan rotor (3) through a bellmouth (1) and an inlet nozzle throughbore (10A), before being discharged thorough an outlet nozzle throughbore (10B).

[0022] As can be seen in Figure 1, the nozzle has a centreline (8), defined as the geometric mean between the pressure side (11) and suction side (12) lines. An angle (13) is defined between the fan centreline (7) and the nozzle centreline (8). The pressure side of the nozzle (11) is arranged to turn the flow direction, so that in use, the discharged air flows away from the surrounding tunnel surfaces.

[0023] A further angle (16) is defined between the nozzle centreline (8) and a trailing edge (6) of the nozzle. Preferably, the angle (16) is between 45 degrees and 85 degrees. Preferably still, the angle (16) is approximately 65 degrees.

[0024] The embodiment of Figure 1 shows a nozzle pressure side angle (17) of 7 degrees. A larger geometric throat (14) can be arranged at both the inlet and discharge sides of the nozzle, by tilting the nozzle trailing edge (6) by the angle (16) between the nozzle centreline (8) and the trailing edge (6). This leads to reduced pressure losses and improved energy efficiency.

[0025] It is possible to arrange the length of the suction side to be approximately equal to one fan diameter, and selecting the pressure side angle (17) to be 6 degrees. This preferred embodiment provides an enhanced level of acoustic attenuation compared to the embodiment described in Figure 1.

[0026] Figure 1 shows a preferred embodiment where the suction side of the nozzle throughbore (12) is arranged to be parallel to the fan centreline (7).

[0027] Referring now to Figure 2, which shows an end view of an embodiment of this invention, the nozzle shape is arranged to turn to flow in a prescribed direction, preferably away from the surrounding tunnel surfaces.

[0028] Figure 2 shows that the nozzle trailing edge is circular in shape, to allow attachment to a circular bellmouth. Such a circular bellmouth significantly reduces the inlet pressure drop.

[0029] We refer now to Figure 3, which shows a side view of a particular embodiment of this invention which would normally (but not exclusively) be operated in a unidirectional manner.

[0030] In this embodiment, the indicated airflow direction is from left to right, i.e. the airflow enters into a straight nozzle via a bellmouth (1) first, prior to being accelerated by the fan rotor (3) into a shaped nozzle with a throughbore (10). The discharged flow is turned by a pressure side (11) which is longer than the suction side (12), such that in use, the discharged air flows away from the surrounding tunnel surfaces. Since a straight inlet nozzle is selected in this embodiment, the inlet pressure drop to the fan is less than that for the embodiment depicted in Figure 1. The aerodynamic thrust can therefore be expected to be higher for the embodiment described in Figure 3 compared to that in Figure 1.

[0031] In Figure 3, the flow direction can if necessary be reversed by running the fan rotor in the opposite direction. Due to the increased Coanda effect and additional inlet pressure drop, a reduction of the in-tunnel

aerodynamic thrust can be expected in the reverse flow direction (i.e. from right to left) in the embodiment described in Fig. 3.

[0032] It would be possible to modify an existing fan assembly in order to fit nozzles as described in this invention to one or more sides of a fan, and hence reap the benefits of improved performance.

[0033] There are no restrictions on the degree of divergence or convergence of the throughbore area with this invention. In particular, the throughbore areas at the inlet and discharge can be arranged to be equal to, or greater than, the fan area. Depending on the fan flow characteristics, this flexibility can increase the efficiency of the fan assembly. The present invention relieves the 'choking' of the inlet flow which can be present in GB2465261, and thus delivers a significant improvement in fan performance.

[0034] Fig. 4 shows the flat developed pattern for a nozzle skin which is to be cut from sheet metal, for the jetfan depicted in Figs. 1 and 2. The present invention requires a single direction of curvature for the nozzle skins, and the nozzle skins can therefore be developed from a flat sheet without the need for stretching. The topology of the nozzle skins in this invention is therefore particularly suitable for sheet-metal manufacture.

[0035] The manufacturability and cost-efficiency of the nozzles in this invention have been proven through production trials. It has been found that the nozzle skin can be rolled from a single flat sheet of metal for small fan diameters (around 500mm), while separate sections of nozzle skin, each rolled from a flat sheet, are required for larger fan diameters of up to 2m. Both the inner and outer nozzle skins can be rolled into the requisite shapes, with acoustic material inserted between them for sound attenuation during fan operation.

[0036] It will be appreciated that the foregoing are merely an examples of embodiments and just some examples of their use. The skilled reader will readily understand that modifications can be made thereto without departing from the true scope of the invention which is defined by the appended claims.

Claims

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

a fan rotor (3) for generating a ventilating flow; and
the inflow into the fan rotor being substantially parallel to the outflow from the fan rotor; and
a nozzle coupled to the fan, the nozzle having a trailing edge (6) at the distal end from the fan; and
the assembly being arranged or arrangeable such that a ventilating flow generated by the fan

will pass through the nozzle before exiting the assembly to enter a tunnel to be ventilated; and the nozzle shape being arranged to turn the flow away from the surrounding tunnel surfaces, wherein at least one edge of the nozzle throughbore (12) is at an angle to the fan centreline (7); wherein

the angle made between the nozzle trailing edge and the fan centreline is not perpendicular, and wherein

the angle (16) made between the nozzle trailing edge and the centreline of the nozzle (8) is within the range of 45 degrees to 85 degrees;

characterised in that the nozzle trailing edge forms the shape of a circle.

2. A fan assembly according to claim 1, wherein at least one edge of the nozzle throughbore is parallel to the fan centreline.
3. A fan assembly according to any preceding claims wherein a bellmouth (1) is attached to the nozzle edge.
4. A fan assembly having two nozzles, both constructed according to any preceding claim, and wherein one nozzle is installed on each side of a fan.

Patentansprüche

1. Lüfteranordnung zur Installation in einem Tunnel, um Belüftung in dem Tunnel bereitzustellen, wobei die Lüfteranordnung Folgendes umfasst:

einen Lüfterrotor (3) zum Erzeugen eines Belüftungsstroms; und

wobei der Zufluss in den Lüfterrotor im Wesentlichen parallel zu dem Abfluss von dem Lüfterrotor ist; und

eine Düse, die an den Lüfter gekoppelt ist, wobei die Düse eine Hinterkante (6) an dem distalen Ende von dem Lüfter aufweist; und

wobei die Anordnung so angeordnet ist oder angeordnet werden kann, dass ein Belüftungsstrom, der durch den Lüfter erzeugt wird, durch die Düse verläuft, bevor er aus der Anordnung austritt, um in einen zu belüftenden Tunnel einzutreten; und

wobei die Düsenform angeordnet ist, um den Strom von den umgebenden Tunneloberflächen wegzulenken, wobei

zumindest eine Kante der Düsendurchgangsbohrung (12) in einem Winkel zu der Lüftermittellinie (7) ist; wobei

der Winkel zwischen der Düsenhinterkante und der Lüftermittellinie nicht senkrecht ist, und wobei

- der Winkel (16) zwischen der Düsenhinterkante und der Mittellinie der Düse (8) innerhalb des Bereiches von 45 Grad bis 85 Grad liegt;
dadurch gekennzeichnet, dass die Düsenhinterkante die Form eines Kreises bildet.
2. Lüfteranordnung nach Anspruch 1, wobei zumindest eine Kante der Düsendurchgangsbohrung parallel zu der Lüftermittellinie ist. 10
 3. Lüfteranordnung nach einem der vorhergehenden Ansprüche, wobei eine Aufwerfung (1) an der Düsenkante angebracht ist.
 4. Lüfteranordnung, die zwei Düsen aufweist, die beide gemäß einem vorhergehenden Anspruch konstruiert sind, und wobei auf jeder Seite eines Lüfters eine Düse installiert ist. 15

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Revendications

1. Ensemble ventilateur destiné à être installé dans un tunnel pour assurer une ventilation dans le tunnel, l'ensemble ventilateur comprenant : 25
 - un rotor de ventilateur (3) destiné à générer un flux de ventilation ; et
 - le flux d'entrée dans le rotor de ventilateur étant sensiblement parallèle au flux sortant provenant du rotor de ventilateur ; et
 - une buse couplée au ventilateur, la buse possédant un bord de fuite (6) au niveau de l'extrémité distale du ventilateur ; et
 - l'ensemble étant agencé ou pouvant être agencé de sorte qu'un flux de ventilation généré par le ventilateur passe à travers la buse avant de sortir de l'ensemble pour entrer dans un tunnel à ventiler ; et
 - la forme de buse étant agencée pour détourner l'écoulement au loin des surfaces de tunnel environnantes, 30
 - au moins un bord de l'alésage traversant de buse (12) étant selon un angle par rapport à l'axe de ventilateur (7) ; 35
 - ledit angle formé entre le bord de fuite de buse et l'axe de ventilateur n'étant pas perpendiculaire, et 40
 - ledit angle (16) formé entre le bord de fuite de buse et l'axe de la buse (8) étant compris dans la plage allant de 45 degrés à 85 degrés ; 45
 - caractérisé en ce que** le bord de fuite de buse possède la forme d'un cercle. 50
2. Ensemble ventilateur selon la revendication 1, au moins un bord de l'alésage traversant de buse étant parallèle à l'axe de ventilateur. 55

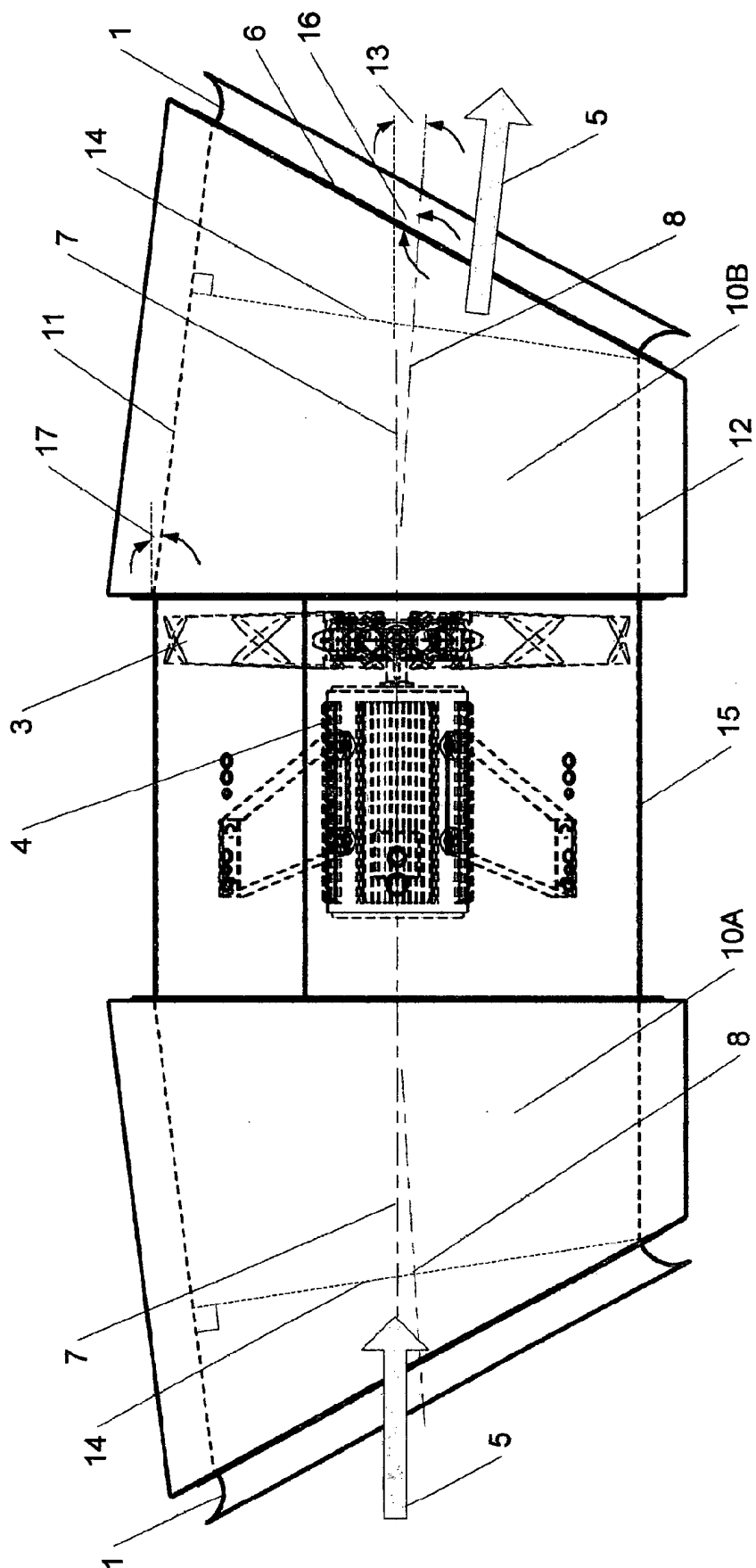


Fig. 1

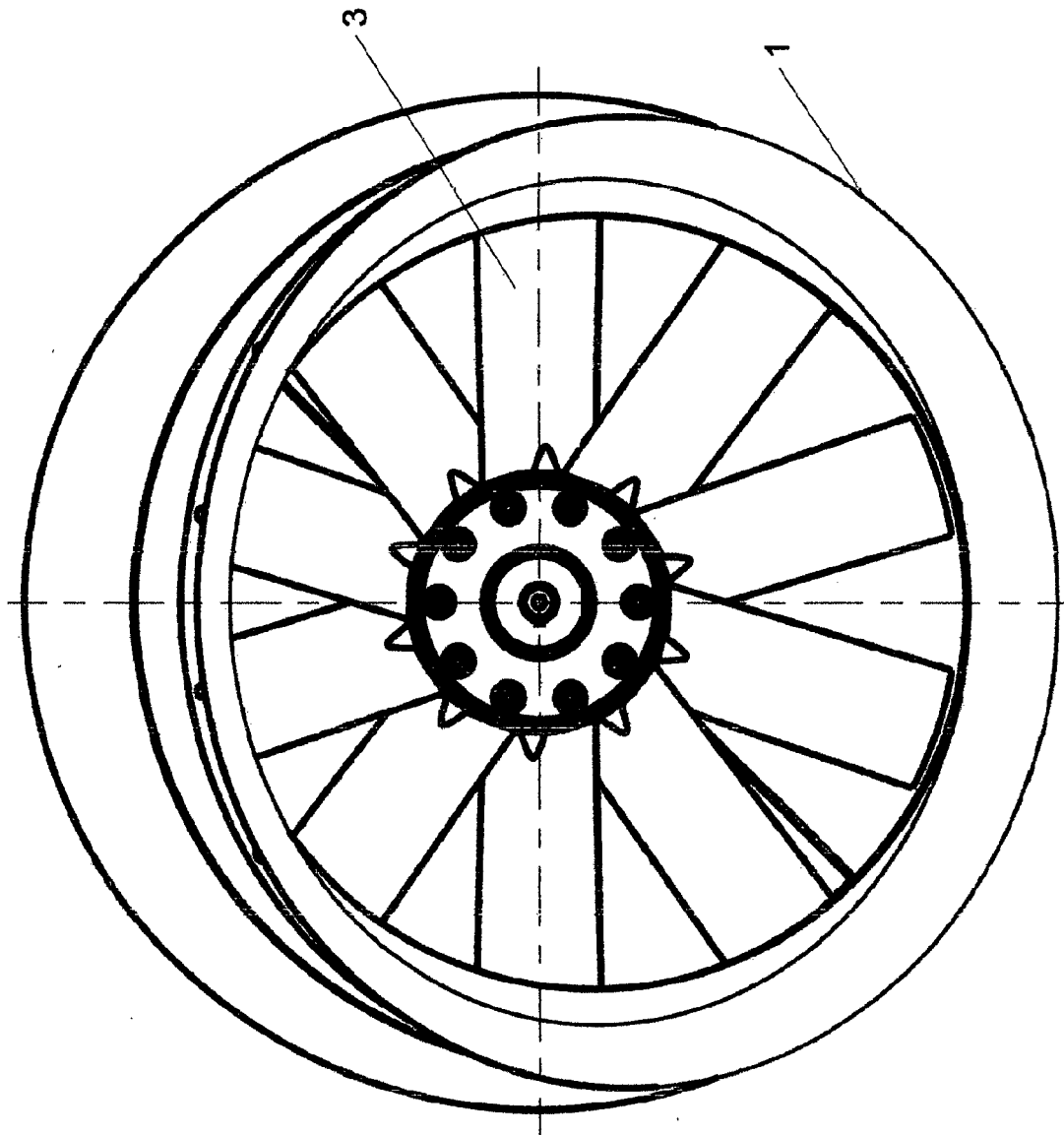


Fig. 2

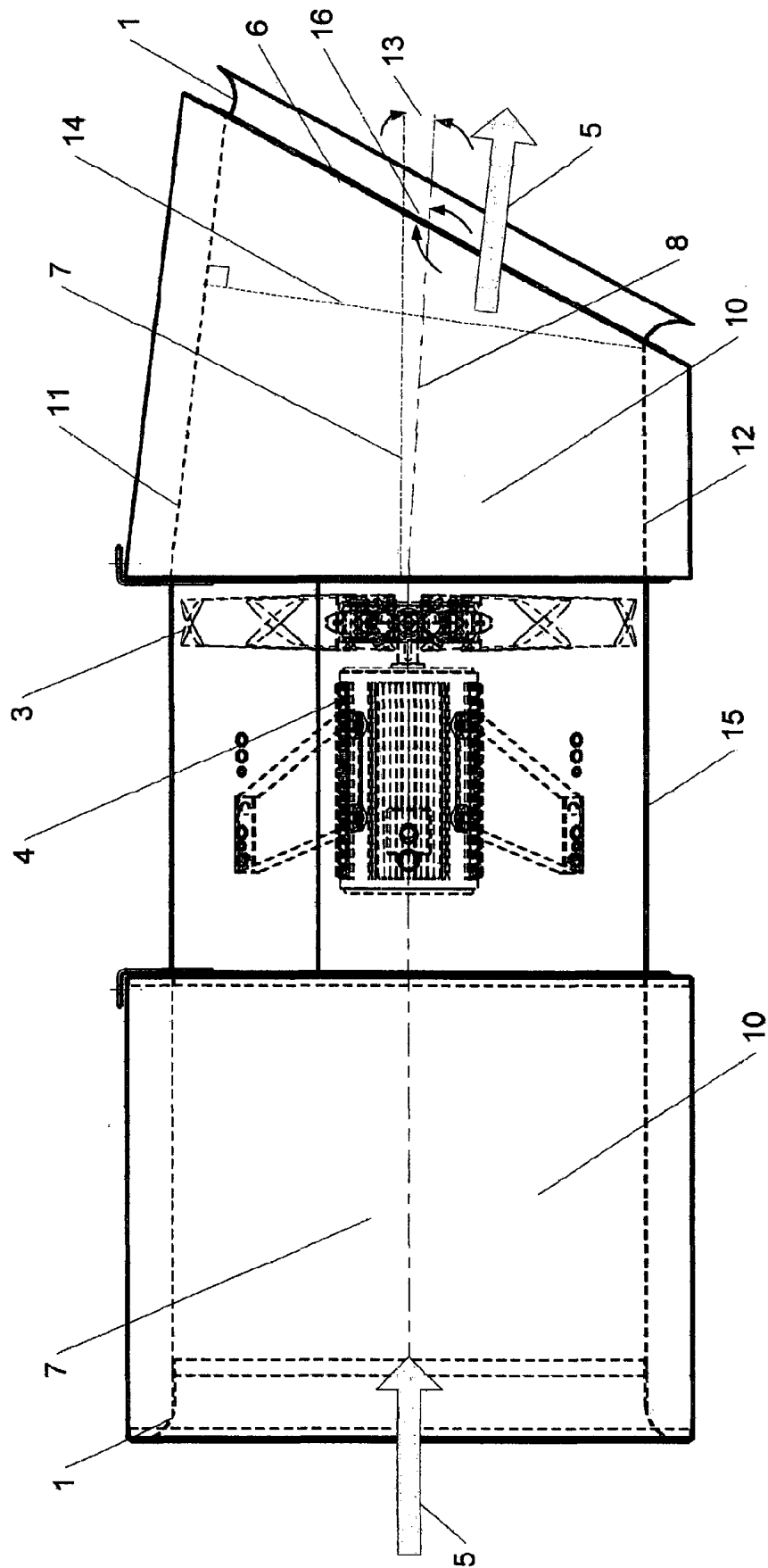


Fig. 3

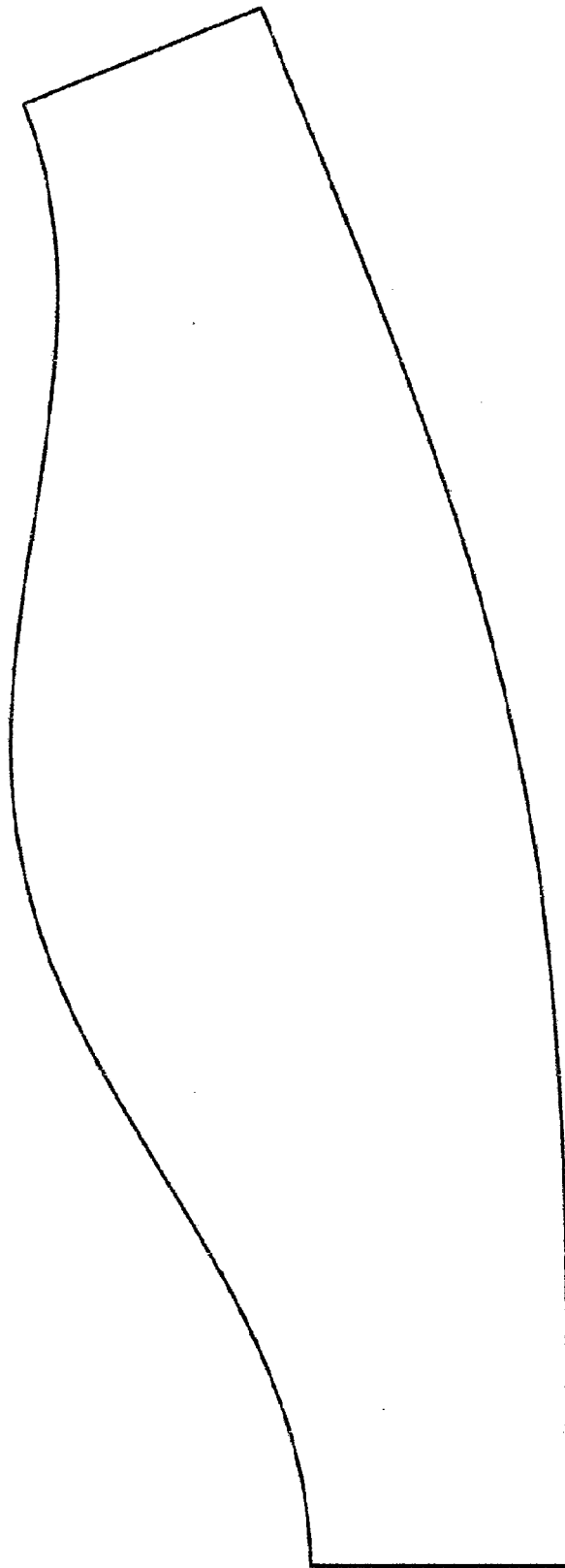


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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