

Jet Fan for Ventilating Tunnels, Jet Fan System and Method

The invention concerns a jet fan for ventilating tunnels, in particular road tunnels, a jet fan system and a method of manufacturing a jet fan for
5 ventilating tunnels.

Jet fans for ventilating tunnels are known in principle. Such jet fans ventilate and exhaust the air from tunnels, in particular road tunnels, so that high concentrations of exhaust gases in the tunnels can be avoided. Jet fans generate an air stream by means of a fan arranged in a fan shaft,
10 which enters the tunnel at one end and exits at another end of the tunnel. The entrances and exits of this air stream can also occur at different locations other than the ends of the tunnel, for example, through air inflows in the middle of the tunnel. To reduce noise emissions from the jet fans, they usually have silencers.

15 The air stream inside a tunnel has a velocity profile in which the flow rate at the floor, ceiling and side sections is limited and increases toward a center section of the tunnel. The highest flow rate can generally be achieved at the center of the tunnel. It would be advantageous in terms of flow to arrange the jet fan at the center of the tunnel. However, such an
20 arrangement would reduce the clearance height in the tunnel and is therefore not generally practicable, since either the height would not be sufficient or the height of the tunnel would have to be disproportionately increased.

As a result, jet fans are ordinarily arranged in the vicinity of the wall or
25 ceiling of the tunnel. However, the fan output is converted into an increasingly less effective air stream through the entire tunnel, the closer

the jet fan is arranged to the tunnel wall or tunnel ceiling. In particular, this means that the closer a jet fan is arranged to the tunnel wall or tunnel ceiling, the poorer its efficiency.

5 DE 19920513 A1 teaches a jet fan, which has a nozzle arrangement at the fan inlet and fan outlet. The jet fan draws in air more easily from the tunnel center and ejects the air stream accelerated by the fan in the direction of the tunnel center. This jet fan improves the ventilation of tunnels, but the clearance height is negatively influenced by the jet fan.

10 Since jet fans for ventilating tunnels reduce the clearance height, and for this reason may require a greater tunnel height to be provided, it is requirement that jet fans have as little as possible of an adverse effect on the clearance height. It is also a requirement that as few jet fans as possible be used to supply a defined air stream through the tunnel, since jet fans as such and their installation and maintenance as well as the
15 cables to be laid result in high costs.

It is therefore an object of the invention to provide a jet fan for ventilating tunnels, in particular road tunnels, a jet fan system for ventilating tunnels, in particular road tunnels, and a method for manufacturing a jet fan for ventilating tunnels, in particular road tunnels, which reduce or eliminate
20 one or more of the aforementioned drawbacks. In particular, it is an object of the invention to provide a solution that reduces the number of required jet fans inside a tunnel and/or the cost of jet fans for ventilating a tunnel.

According to a first aspect, this object is achieved by a jet fan for ventilating tunnels, in particular road tunnels, comprising a fan unit for
25 generating an air stream, a silencer arranged on the fan unit with a proximal section and a distal section adjacent to the proximal section,

characterized in that an angle is set between the distal section and the proximal section.

The invention is based on the knowledge that the silencers of a jet fan have a significant influence on the clearance height between the jet fan and the roadway. Since the efficiency of a jet fan diminishes the closer it is arranged to the tunnel ceiling or tunnel wall, known jet fans are either arranged at a greater distance from the tunnel ceiling or tunnel wall or the silencer is arranged at an angle relative to the fan unit so that the air stream is directed into center of the tunnel.

However, the clearance height between the jet fan and the roadway is reduced by the inclined arrangement of the silencer. As an alternative, a jet fan having substantially non-inclined silencers can be used, but the fan unit must then have a large diameter so that the clearance height is also reduced. There is also the possibility of increasing the number of jet fans, but this is generally not an appropriate solution from an economic perspective.

The jet fan just described cleverly enables arrangement of the jet fan directly beneath a tunnel ceiling and also enables high clearance height between the jet fan and a roadway, by setting an angle between the distal section and the proximal section such that the distal section is inclined relative to the fan unit and/or the proximal section. The proximal section can be arranged coaxial to the fan unit. The jet fan just described therefore combines the advantages of a jet fan without inclined silencers in terms of clearance height, and the advantages of a jet fan with inclined silencers in terms of an effective air stream.

The invention therefore enables a larger diameter jet fan to be provided without reducing the clearance height. A thrust produced by a jet fan is determined, among other things, from the fourth power of diameter. For example, a diameter increase of 12% results in an increase in thrust of 50%. As a result, by enlarging the jet fans by a standard size the number of jet fans for a tunnel can be reduced by 30 to 35%, thus significantly reducing the cost of venting. The inventor has also found that an enlargement by two standard sizes is also possible so that the number of jet fans for a tunnel can be reduced by 60%. The standard sizes in Germany, for example, are derived from a standard.

It must also be considered that there are official noise level requirements for tunnels. For a given thrust, the length of the silencer is generally established within a narrow design window. The silencers known in the prior art, which are inclined relative to the roadway, were restricted with respect to their length in order to guarantee sufficient clearance height. The invention now makes it possible to provide the silencers in any length, since lengthening of the proximal section does not lead to a reduction in clearance height.

The jet fan includes the fan unit for generating an air stream. The fan unit ordinarily has a fan shaft in which a propeller is mounted rotatably. The propeller is ordinarily coupled to an electric drive that rotates the propeller. The fan unit ordinarily has an inlet and an outlet in the flow direction. Since it can be advantageous to reverse the flow direction, the inlet can also act as an outlet and the outlet as an inlet. A silencer is preferably arranged at the inlet and/or outlet. A silencer is arranged at least at the inlet or at the outlet.

The silencer has at least one proximal section and a distal section. The proximal section preferably faces the fan unit, the distal section facing away from the fan unit. An angle is set between the distal section and the proximal section so that the distal section in particular is oriented at an
5 incline relative to the proximal section.

The angle, for example, can be an exterior angle and/or an interior angle. It is particularly preferred that a passage axis of the proximal section and a passage axis of the distal section form a passage angle and/or are not aligned parallel. The proximal section of the silencer can be designed as a
10 cylindrical shell element. Moreover, the distal section can also be designed as a cylindrical shell element. The silencer can be designed in one or two parts.

According to a preferred variant embodiment of the jet fan, it is provided that the distal section is designed to guide an air stream generated by the
15 fan unit from a radially outer section of the tunnel into a substantially central section of the tunnel. Moreover, the distal section can be designed so that an air stream generated by the fan unit is guided from a substantially central section of the tunnel into the fan unit. Since the flow direction through the fan unit is reversible, the distal section, on the one
20 hand, can be used for exhausting or for drawing in air. An advantageous air flow on the interior of a tunnel is achieved by this design of the distal section.

Another preferred modification of the jet fan is characterized in that the proximal section defines a proximal flow direction and the distal section
25 defines a distal flow direction, in which case the proximal flow direction forms a flow angle with the distal flow direction. The proximal flow direction can be aligned during operation substantially parallel to a tunnel

longitudinal axis. The distal flow direction is preferably directed during operation of the jet fan from a tunnel ceiling or a tunnel wall in the direction of a center section of the tunnel. As a result, the flow angle is set between the proximal flow direction and the distal flow direction.

- 5 It is also preferred that the fan unit defines a fan flow direction in which the fan flow direction and/or the proximal flow direction encloses the flow angle with the distal flow direction. The flow angle corresponds in particular to the angle.

- 10 The aforementioned flow directions, i.e., the proximal flow direction, the distal flow direction and the fan flow direction, are understood to mean a main flow direction. The main flow direction is defined by the fact that it represents the basic flow direction within the jet fan. Naturally, in the vicinity of an inner wall of the jet fan or on elements arranged within the jet fan, flows may occur that are partially transverse or even opposite the
15 main flow direction. Such local flow directions occurring within the jet fan, however, are generally understood to mean the previously mentioned flow directions.

- In a further preferred variant embodiment, it is provided that a fan flow direction of the fan unit and the proximal flow direction are aligned
20 substantially parallel to each other. A slight projection length transverse to the tunnel axis is thus advantageously ensured.

- It is particularly preferred that the flow angle is between 2° and 15°, in particular between 4° and 10°, preferably between 6° and 8°. The inventors have found that at precisely such flow angles good flow could be
25 achieved in the interior of a tunnel with a limited number of jet fans.

- It is also preferred that the proximal section defines a proximal passage axis and the distal section a distal passage axis, the proximal passage axis forming a passage angle with the distal passage axis. It is also preferred that the fan unit defines a fan passage axis and the fan passage axis and the proximal passage axis are aligned substantially parallel to each other, in which case they can also be aligned coaxially in a preferred modification. It is also preferred that the proximal passage axis and the distal passage axis form an angle between 2° and 15° , in particular between 4° and 10° , preferably between 6° and 8° .
- 10 In another preferred variant embodiment of the jet fan it is provided that the proximal section is arranged between the distal section and the fan unit.
- 15 It is in particular preferred that the proximal section is arranged in the fan flow direction and/or in the proximal flow direction and/or in the distal flow direction between the distal section and the fan unit. The air stream through the jet fan is advantageously influenced by such an arrangement.
- Another preferred modification of the jet fan is characterized in that the
- 20 silencer is designed in two parts with a first silencer unit and a second silencer unit, the first silencer unit having the proximal section and the second silencer unit the distal section. A simple and cost-effective construction of this jet fan, which positively influences the air stream, can be ensured by a jet fan designed in this way.

Another preferred variant embodiment of the jet fan is characterized in that the proximal section extends in the proximal flow direction with a proximal extension and the distal section extends in the distal flow direction with a distal extension, the distal extension being smaller than the proximal extension. The ratio of distal extension to proximal extension in this preferred variant embodiment is less than 1.

In another preferred variant embodiment of the jet fan it is provided that the ratio of the distal extension to the proximal extension is between 0.05 and 0.4, in particular between 0.1 and 0.3. The inventors have found that with precisely this ratio a further improvement in flow conditions can be achieved in the interior of the tunnel.

The jet fan can also be modified in that the fan unit and/or silencer has or have a flow diameter and the ratio of distal extension to flow diameter is between 0.2 and 0.75, in particular between 0.45 and 0.55, and/or the ratio of proximal extension to flow diameter is between 1 and 4, in particular between 2 and 3.

The flow diameter is in particular a dimension of the cross section whose surface orthogonal is aligned parallel to the flow direction and/or to the passage axis. The flow diameter of the fan unit is generally to be understood while ignoring elements and/or systems incorporated within the fan unit.

In another preferred variant embodiment of the jet fan, it is provided that it includes a second silencer, which preferably has the same features as the [sic; first] silencer, in which the [sic; first] silencer is arranged on a first end and the second silencer is arranged on a second end of the fan unit opposite the first end in the fan flow direction. The noise emissions of the

jet fan are further reduced by the [sic; first] silencer and the second silencer. In particular, a mirror-symmetrical jet fan is therefore made possible so that reversal of the flow direction is advantageously made possible.

- 5 In another preferred variant it is provided that the jet fan includes a fastening unit, which is arranged and designed to fasten the jet fan on a tunnel ceiling and/or a tunnel wall so that a projection length is less than 1.3 times, in particular less than 1.1 times the flow diameter. It is also preferred that a distal flow direction is directed to an outlet side of the jet
10 fan in a substantially center section of the tunnel.

It can also be preferred that the jet fan has a nozzle element, which includes a surface segment that extends from an inlet to an outlet with a cross section in the form of an annular segment and defines a nozzle flow direction in which the surface segment has an opening section on the
15 peripheral side adjacent to the exit, and also includes connection devices that are designed to connect the nozzle element to the silencer and/or the second silencer.

According to another aspect, the object mentioned in the introduction is achieved by a jet fan system for ventilating tunnels, in particular road
20 tunnels, comprising at least one jet fan according to one of the variant embodiments just described, in which the at least one jet fan has a supply cable that connects the jet fan to a power supply.

The invention is based on the knowledge that about one third of the total costs of the jet fan system are attributable to the electrical equipment, for
25 example, switchboxes, cables, etc. Because of this, it is advantageous to reduce the total number of jet fans for a jet fan system, since the total

cable length to be laid is reduced. Since an additional third of the total costs are due to installation and assembly, this is an additional cost item that is reduced.

According to another aspect, the object mentioned in the introduction is
5 achieved by a method for manufacturing a jet fan for ventilating tunnels, in particular road tunnels, comprising the steps of: providing a fan unit for generating an air stream, providing a silencer with a proximal section and a distal section adjacent to the proximal section, in which the distal and the proximal section form an angle with each other, and fastening the
10 silencer to the fan unit, in which case the proximal section faces the fan unit and the distal section faces away from the fan unit.

The method and its possible modifications have features and method steps that make them particularly suitable for use in the previously described jet fan and its modifications. The description already provided
15 concerning the corresponding features and modifications of the jet fan are also referred to for additional advantages, embodiments and design details of the additional aspects and their possible modifications.

Preferred illustrative embodiments are explained with reference to the accompanying figures. In the figures:

20 Figure 1: shows a schematic two-dimensional sectional view of an illustrative embodiment of a jet fan;

Figure 2: shows a schematic three-dimensional side view of a jet fan in the prior art and a jet fan according to the invention;

Figure 3: shows a schematic three-dimensional side view of a jet fan in the prior art and a jet fan according to the invention; and

Figure 4: shows a schematic view of a method.

- 5 In the figures, identical or substantially functionally equivalent or similar elements are designated by the same reference numbers.

The jet fan 100 extends from an inlet 102 to an outlet 104. In this illustrative embodiment, the air flows into the jet fan 100 at inlet 102 and flows out again at outlet 104. The flow direction of the jet fan 100,
 10 however, can also be reversed, so that the air enters the jet fan 100 at outlet 104 and emerges from the jet fan 100 at inlet 102. The jet fan 100 has a fan unit 106, a first silencer 110 and a second silencer 130. The fan unit 106 defines a fan flow direction 108. When the jet fan 100 is operated as intended, the fan flow direction 108 is aligned substantially parallel to a
 15 tunnel longitudinal axis.

The first silencer 110 has a proximal section 112 with a proximal flow direction 114 and a distal section 116 with a distal flow direction 118. An angle 122 is set between the distal section 116 and the proximal section 112. Because of this angle 122, an angle is also set between the proximal
 20 flow direction 114 and the distal flow direction 118, namely flow angle 120. In the present illustrative embodiment, the sum of the flow angle 120 and the angle 122 set on the outer surface between the distal section 116 and the proximal section 112 is 180 degrees of arc.

The second silencer 130 is arranged on a side of the jet fan 100 facing
 25 away from the first silencer 110 in the fan flow direction 108. The second

silencer 130, similar to the first silencer 110, has a proximal section 132 and a distal section 134 between which an angle 136 is set.

The jet fan 100 can be fastened with a fastening unit 138 to a tunnel wall or tunnel ceiling. By designing the silencer with distal sections 116, 134 and proximal sections 112, 132, it is made possible for the fan unit 106 and the proximal section 112, 132 to be arranged close to the wall or ceiling. Despite this arrangement close to the ceiling or close to the wall, a large thrust is generated on the air stream by the jet fan 100 due to the bent distal sections 116, 134. As a result, the jet fan 100 can be designed with a smaller flow diameter or the total number of jet fans in the tunnel can be reduced.

This advantage becomes apparent from the illustration in Figures 2 and 3. A jet fan 200 known in the prior art is shown on the left side of Figure 2. This jet fan 200 is arranged on a tunnel ceiling 202 above a roadway 204. A clearance height 206 is obtained by the distance between the tunnel 202 and the roadway 204, and by the projection length 208. The clearance height 206 defines the passage height of the tunnel with a safety margin. The conventional jet fan 200 must have a greater distance from the tunnel ceiling 202 in order for its efficiency to not be too low.

Due to the distance from the tunnel ceiling 202, the clearance height 206 is significantly reduced. In the present example, at a total height between the roadway 204 and ceiling 202 of four to five flow diameters, the clearance height is only 2.5 to 3.5 times the flow diameter.

In contrast to this, with the jet fan 210 shown on the right side, a greater clearance height 216 of three to four times the flow diameter could be achieved. Moreover, the jet fan 210 can be spaced closer to the tunnel

ceiling 212. The projection length 218 is smaller because of the smaller spacing from the tunnel ceiling 212 in comparison with the arrangement of jet fan 210, namely about 0.4 times the flow diameter.

Figure 3 also shows a comparison between two jet fans, namely the conventional jet fan 200 and the jet fan 210 according to the invention. Owing to the smaller distance from the tunnel ceiling 212, a larger diameter can be chosen for the jet fan 210 so that the same projection length 208, 218 is achieved. Because of the greater flow diameter of jet fan 210, however, a greater thrust can be achieved, so that a smaller number of jet fans 210 need be arranged in the tunnel. This significantly reduces the assembly and installation work as well as the total cable lengths to be laid. As a result, the costs for ventilating the tunnel are reduced.

A schematic view of a method is shown in Figure 4. A fan unit 106 for generating an air stream is provided in step 300. A silencer 110, 130 with a proximal section 112, 132 and a distal section 116, 134 adjacent to the proximal section 112, 132 is provided in step 302, in which case the distal section 116, 134 and the proximal section 112, 132 enclose angles 122, 136 with each other. In step 304, the silencer 110, 130 is fastened to the fan unit 106, in which the proximal section 112, 132 faces the fan unit 106 and the distal section 116, 134 faces away from the fan unit 106. The proximal section 112, 132 can have fastening devices for fastening to the fan unit 106.

LIST OF REFERENCE NUMBERS

	100	Jet fan
	102	Inlet
	104	Outlet
5	106	Fan unit
	108	Fan flow direction
	110	First silencer
	112	Proximal section
	114	Proximal flow direction
10	116	Distal section
	118	Distal flow direction
	120	Flow angle
	122	Angle
	130	Second silencer
15	132	Proximal section
	134	Distal section
	136	Angle
	138	Fastening unit
	200	First jet fan
20	202	Tunnel ceiling
	204	Roadway
	206	Clearance height
	208	Projection length
	210	Second jet fan
25	212	Tunnel ceiling
	214	Roadway
	216	Clearance height
	218	Projection length

CLAIMS

1. A jet fan (100, 210) for ventilating tunnels, in particular road tunnels, comprising
 - a fan unit (106) for generating an air stream,
 - 5 - a silencer (110, 130) arranged on the fan unit (106) with a proximal section (112) and a distal section (116) adjacent to the proximal section (112),
 - characterized in that an angle (120, 122) is set between the distal section (116) and the proximal section (112).
- 10 2. The jet fan (100, 210) according to claim 1, wherein

the distal section (116) is designed to guide an air stream generated by the fan unit (106) from a radially outer section of the tunnel into a substantially center section of the tunnel and/or from a substantially center section of the tunnel into the fan unit (106).
- 15 3. The jet fan (100, 210) according to one of the preceding claims, wherein

the proximal section (112) defines a proximal flow direction (114) and a distal section (116) defines a distal flow direction (118), wherein the proximal flow direction forms a flow angle (120) with the distal flow
20 direction.

4. The jet fan (100, 210) according to one of the preceding claims,
wherein

a fan flow direction (108) of the fan unit (106) and the proximal flow
direction (114) are aligned substantially parallel to each other.
5. The jet fan (100, 210) according to one of the preceding claims,
wherein

the flow angle (120) is between 2° and 15°, in particular between 4°
and 10°, preferably between 6° and 8°.
6. The jet fan (100, 210) according to one of the preceding claims,
wherein

the proximal section (112) is arranged between the distal section
(116) and the fan unit (106),
7. The jet fan (100, 210) according to one of the preceding claims,
wherein

the silencer (110, 130) is designed in two parts with a first silencer
unit and a second silencer unit, the first silencer unit having the
proximal section (112) and the second silencer unit having the distal
section (116).
8. The jet fan (100, 210) according to one of the preceding claims,
wherein

the proximal section (112) extends in the proximal flow direction
(114) with a proximal extension and the distal section (116) extends

in the distal flow direction (118) with a distal extension, the distal extension being smaller than the proximal extension.

9. The jet fan (100, 210) according to one of the preceding claims, wherein
 - 5 the ratio of distal extension to proximal extension is between 0.05 and 0.4, in particular between 0.1 and 0.3.
10. The jet fan (100, 210) according to one of the preceding claims, wherein
 - 10
 - the fan unit (106) and/or the silencer (110, 130) has or have a flow diameter and
 - the ratio of the distal extension to the flow diameter is between 0.2 and 0.75, in particular between 0.45 and 0.55 and/or
 - the ratio of the proximal extension to the flow diameter is between 1 and 4, in particular between 2 and 3.
- 15 11. The jet fan (100, 210) according to any one of the preceding claims, comprising

a second silencer (110, 130), which preferably has the same features as the [sic; first] silencer (110, 130), wherein the [sic; first] silencer (110, 130) is arranged on a first end and the second silencer (110, 130) is arranged on a second end of the fan unit (106) in the fan flow direction opposite the first end.
- 20 12. The jet fan (100, 210) according to any one of the preceding claims, comprising a fastening unit (138), which is arranged and formed

- to fasten the jet fan (100, 210) on a tunnel ceiling and/or tunnel wall so that a projection length is less than 1.3 times, in particular less than 1.1 times the flow diameter, and/or
 - that the distal flow direction (118) on an outlet side of the jet fan is directed into a substantially center section of the tunnel.
- 5
13. A jet fan system for ventilating tunnels, in particular road tunnels, comprising
- at least one jet fan (100, 210) according to one of the preceding claims,
 - wherein the at least one jet fan (100, 210) has a supply cable that connects the jet fan (100, 210) to a power supply.
- 10
14. A method for manufacturing a jet fan (100, 210) for ventilating tunnels, in particular road tunnels, comprising the steps of:
- providing a fan unit (106) for generating an air stream,
 - providing a silencer (110, 130) with a proximal section (112) and a distal section (116) adjacent to the proximal section (112), wherein an angle (120, 122) is set between the distal section (116) and the proximal section (112) and
 - fastening the silencer (110, 130) to the fan unit (106), wherein the proximal section (112) faces the fan unit (106) and the distal section (116) faces away from the fan unit (106).
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- 20