

(19)



(11)

EP 3 205 580 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
31.03.2021 Bulletin 2021/13

(51) Int Cl.:
B64D 15/04 (2006.01)

(21) Application number: **17154201.2**

(22) Date of filing: **01.02.2017**

(54) ANTI-ICING SYSTEM AND AIRCRAFT

ENTEISUNGSSYSTEM UND FLUGZEUG

SYSTÈME ANTIGIVRAGE ET AÉRONEF

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

- **Ishida, Toshiyuki**
Tokyo, 108-8215 (JP)
- **Morishita, Masatoshi**
Tokyo, 108-8215 (JP)
- **Kawai, Kazuhiro**
Tokyo, 108-8215 (JP)

(30) Priority: **12.02.2016 JP 2016024387**

(43) Date of publication of application:
16.08.2017 Bulletin 2017/33

(74) Representative: **Henkel & Partner mbB**
Patentanwaltskanzlei, Rechtsanwaltskanzlei
Maximiliansplatz 21
80333 München (DE)

(73) Proprietor: **Mitsubishi Aircraft Corporation**
Aichi 455-8555 (JP)

(56) References cited:
EP-A2- 2 481 672 DE-B- 1 213 256
GB-A- 486 549 JP-A- 2009 523 637
JP-A- 2011 183 922 US-A- 3 917 193

(72) Inventors:
• **Ichikawa, Gento**
Tokyo, 108-8215 (JP)
• **Uefuji, Yoichi**
Tokyo, 108-8215 (JP)

EP 3 205 580 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a combination of a leading edge for a wing of an aircraft and an anti-icing system that prevents icing on the leading edge of the aircraft, and to an aircraft including the combination.

Description of the Related Art

[0002] During flight of an aircraft, icing occurs on an outer surface of a leading edge in a traveling direction of the aircraft, such as a main wing, a tail wing, and an air intake, due to collision of supercooled droplets in the air. The icing phenomenon variously adversely affects flight of the aircraft. Therefore, an anti-icing system that prevents icing by various heating means are provided at positions that may be particularly affected by the icing phenomenon.

[0003] In an aircraft including a turbine engine, as one of the anti-icing systems, bleed air that is high-temperature high-pressure air extracted from an engine compressor has been widely used as a heating source. In such an anti-icing system, the bleed air is guided through a pipe, cooled to a predetermined temperature, and is blown to the inner surface of the leading edge, thereby performing heating. A member called piccolo tube that has, in the longitudinal direction, a plurality of ejection holes through which the bleed air is ejected is used as the pipe. For example, when being provided in the main wing, the piccolo tube is disposed near the leading edge along a wing length direction from an end connected to a fuselage toward a front end. As illustrated in FIG. 6B, the method makes it possible to provide high heat transfer coefficient at a blown point of the bleed air. This makes it possible to reduce an air supply amount and to suppress deterioration of fuel consumption, as compared with other methods.

[0004] In FIG. 6B, a dashed line indicates distribution of the heat transfer coefficient of the bleed air (HD), and a solid line indicates distribution of a collision amount of droplets (DD). FIG. 6B illustrates that the blown point at which the heat transfer coefficient by the bleed air reaches a peak and an outside airflow stagnation point (hereinafter, simply referred to as a stagnation point) Ps at which the collision amount of the droplets reaches a peak are coincident with each other.

[0005] As illustrated in FIG. 6B, the heat transfer coefficient is drastically decreased at positions away from the blown point at which the heat transfer coefficient reaches a peak. Therefore, temperature unevenness easily occurs at the blown point and positions away from the blown point. If the positions of the respective ejection holes of the piccolo tube are not appropriate, disadvantageously, heating may become insufficient or damage of the lead-

ing edge structure caused by overheating may be accelerated. Therefore, a method of focusing on particularly stringent icing flight condition and orienting the ejection holes to concentrate a heating amount to the stagnation point at which the collision amount of the droplets reaches a peak under the condition is typically used. When the flight condition, in particular, an angle of attack of the aircraft is varied and the position of the stagnation point is accordingly moved, however, the blown point, namely, a point to which the heating amount is concentrated is not coincident with the position at which the collision amount of the droplets reaches a peak as illustrated in FIG. 6C, which deteriorates efficiency of heating. This may cause increase of the air amount necessary for anti-icing or may accelerate damage of the leading edge structure caused by overheating.

[0006] Note that the vertical direction in FIGS. 6B and 6C indicates a horizontal direction of environment in which the aircraft flies. In addition, in FIGS. 6B and 6C, P1 indicates an upper limit position of the collision of the droplets, and P2 indicates a lower limit position of the collision of the droplets.

[0007] Therefore, JP 2011-183922 A suggests a method of configuring the inner surface side of the leading edge structure of the main wing as the double structure and averaging heat transfer coefficients. In addition, WO 2009-523637 A suggests means that promotes cooling by making a transition from a flow on an outer surface of the leading edge structure to turbulent flow, thereby preventing local overheating.

[0008] The suggestion by JP 2011-183922 A, however, uses the double structure that is complicated. In addition, since the double structure causes increase of the weight and heat loss to the parts other than the part to be heated is large, it is necessary to increase the amount of extracted air, which may result in deterioration of fuel consumption.

[0009] Moreover, the suggestion by WO 2009-523637 A uses the structure that makes transition to the turbulent flow. The structure may increase, for example, air resistance of a main wing and accordingly cause deterioration of fuel consumption. In addition, since the cooling of the leading edge is promoted, the necessary amount of the heated air may be increased.

[0010] US 3917193 A discloses an anti-icing apparatus for an aircraft wing that specifically intends to prevent ice from forming on a leading edge portion of a leading edge flap, which is movable between a retracted position in the wing and an operative position adjacent to the leading edge of the wing. The anti-icing apparatus includes a flap nose tube forming the nose of the flap, and a spray tube that has a longitudinal axis coaxial with the longitudinal axis of the tube and is provided with a plurality of orifices from which high temperature air is ejected in the direction of arrows toward the interior surface of the external tube. The orifices are distributed about the substantially entire circumference of the internal spray tube and air is ejected directly to the forward nose parts of the

leading edge portion but also to a direction opposite from the leading edge side.

[0011] DE 1213256 A discloses an anti-icing system with a hot air tube including a flow path for heated air that is provided with a slit through which the heated air flows out from the interior of the hot air tube onto a front edge inner side of the outer skin. The slot extends horizontally and there is no further ejection opening in another direction other than toward the most forward part of the leading edge portion.

[0012] GB 486549 A discloses an anti-icing system for an aircraft wing where a tubing extends along a leading edge portion of the wing of an aircraft from a rear end to a front end. The tubing is provided with a plurality of ejection holes provided along the longitudinal direction and the ejection holes are arranged such that heated air is ejected to blown points on the inner surface of the leading edge. The ejection direction in any case includes the most forward or leading edge part of the leading edge.

[0013] EP 2481672 A2 discloses an aircraft slat assembly with an anti-icing system including piccolo tubes housed in the slats. Each tube has spray holes for ejecting engine bleed air to the leading edge of the slat.

[0014] Therefore, an object of the present invention is to provide an anti-icing system that has a simple and light configuration and makes it possible to exert anti-icing performance by dealing with displacement of a stagnation point without increasing air resistance.

SUMMARY OF THE INVENTION

[0015] A combination of a leading edge for a wing of an aircraft and an anti-icing system according to the present invention blows heated air to a curved inner surface of the wing of the aircraft and has the features of claim 1. The anti-icing system includes: a piccolo tube that includes a flow path through which the heated air flows in a longitudinal direction from a rear end to a front end, and a plurality of ejection holes provided along the longitudinal direction to make the flow path communicate with an outside; and a supply source that supplies the heated air toward the piccolo tube. The heated air ejected from the ejection holes of the piccolo tube is ejected toward an upper limit position and a lower limit position of an outside airflow stagnation point that are virtually formed on the wing.

[0016] In the piccolo tube of one embodiment of the present invention, the plurality of ejection holes are straightly arranged in a first ejection hole line L1 and a second ejection hole line L2. The first ejection hole line L1 is disposed on relatively upper side, and the second ejection hole line L2 is disposed on lower side of the first ejection hole line L1. The heated air ejected from the first ejection hole line L1 is ejected toward the upper limit position, and the heated air ejected from the second ejection hole line L2 is ejected toward the lower limit position.

[0017] In the anti-icing system according to the present invention, the outside airflow stagnation point under a

condition that a collision amount of droplets becomes highest may be preferably disposed in a middle between an upper limit stagnation point and a lower limit stagnation point.

[0018] In the anti-icing system according to the present invention, the plurality of ejection holes are disposed such that the outside airflow stagnation point under a condition that a collision amount of droplets becomes highest is located in a middle between positions at which heat transfer coefficient by the heated air ejected from the first ejection hole line L1 and the second ejection hole line L2 reaches respective peaks.

[0019] In the piccolo tube according to the present invention, the plurality of ejection holes forming the first ejection hole line L1 and the plurality of ejection holes forming the second ejection hole line L2 may be preferably arranged in a staggered arrangement.

[0020] In the piccolo tube according to the present invention, the plurality of ejection holes forming the first ejection hole line L1 and the plurality of ejection holes forming the second ejection hole line L2 may be preferably arranged in the same phase in a circumferential direction of the piccolo tube.

[0021] The piccolo tube according to the present invention may preferably have a tapered shape from a rear end side to a front end side, and the first ejection hole line L1 and the second ejection hole line L2 may preferably form, on the front end side, a center angle θ_c smaller than a center angle θ_a that is formed by the first ejection hole line L1 and the second ejection hole line L2 on the rear end side.

[0022] In the piccolo tube of an illustrative example not falling within the scope of the present invention, each of the ejection holes is formed of a slit that vertically extends from an upper end opening part to a lower end opening part, the heated air ejected from the upper end opening part is ejected toward the upper limit position, and the heated air ejected from the lower end opening part is ejected toward the lower limit position.

[0023] An aircraft according to the present invention includes the combination of a leading edge for a wing of the aircraft and the anti-icing system described above.

[0024] In the aircraft according to the present invention, the anti-icing system may be preferably provided in a main wing.

[0025] The anti-icing system of the combination according to the present invention ejects the bleed air toward the upper limit position and the lower limit position of the outside airflow stagnation point. Therefore, even if the stagnation point reaches the upper limit position due to change of the attitude of the aircraft, the stagnation point is coincident with or near one of the positions at which the heat transfer coefficient reaches a peak. Likewise, even if the stagnation point reaches the lower limit position due to change of the attitude of the aircraft, the stagnation position is coincident with or near the other of the positions at which the heat transfer coefficient reaches a peak. This allows for efficient evaporation of mois-

ture in a region where the heat transfer coefficient is high, near the blown point, which makes it possible to reduce the amount of the bleed air necessary for anti-icing and overheating is prevented.

[0026] Further, when the position at which the collision amount of the droplets becomes the highest is located in the middle between the two positions at which the heat transfer coefficient reaches respective peaks, the most amount of the droplets collide with a region where the heating amount is small, and the droplets are not wholly evaporated. Therefore, the residual moisture forms a water film on the surface of the leading edge. The water film moves downward to reach the positions at which the heat transfer coefficient reaches the respective peaks. Consequently, the water film is evaporated and prevents overheating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027]

FIGS. 1A and 1B are diagrams each illustrating a schematic configuration of an anti-icing system according to an embodiment of the present invention, where FIG. 1A is a plan view of the anti-icing system including a main wing of an aircraft, and FIG. 1B is a cross-sectional diagram of the main wing;

FIGS. 2A to 2E are diagrams each illustrating a piccolo tube of FIGS. 1A and 1B, where FIG. 2A is a plan view, FIG. 2B is a partial front view, FIG. 2C is a cross-sectional diagram illustrating an upstream tube, FIG. 2D is a cross-sectional diagram illustrating a middle-stream tube, and FIG. 2E is a cross-sectional diagram illustrating a downstream tube;

FIGS. 3A to 3C are diagrams each illustrating relationship between heat transfer coefficient distribution of bleed air and droplet collision amount distribution in the anti-icing system of FIGS. 1A and 1B, where FIG. 3A is a diagram illustrating the relationship when a stagnation point is located lower than an upper limit position by a predetermined amount, FIG. 3B is a diagram illustrating the relationship when the stagnation point is located at a middle point, and FIG. 3C is a diagram illustrating the relationship when the stagnation point is located higher than a lower limit position by a predetermined amount;

FIG. 4 is a diagram to explain anti-icing action when the stagnation point is located at the position of FIG. 3B;

FIGS. 5A to 5D are diagrams each illustrating modifications of the piccolo tube of FIGS. 1A and 1B, where FIG. 5A is a front view of a piccolo tube in which ejection holes are arranged in a staggered arrangement, FIG. 5B is a front view of a piccolo tube

in which ejection holes are arranged in three lines, FIG. 5C is a front view of a piccolo tube in which ejection holes are each formed in a slit shape, and FIG. 5D is a diagram illustrating an example in which two piccolo tubes each having ejection holes arranged in one line are arranged, the examples shown in FIG. 5B, 5C and 5D not falling within the scope of the present invention; and

FIG. 6A is a diagram illustrating a state in which droplets collide with a main wing of an aircraft, FIG. 6B is a diagram illustrating heat transfer coefficient distribution and droplet collision amount distribution in a case where a blown point of bleed air and a stagnation point are coincident with each other in a piccolo tube that includes ejection holes arranged in one line, and FIG. 6C is a diagram illustrating the heat transfer coefficient distribution and the droplet collision amount distribution after the stagnation point is moved from the point of FIG. 6B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028] An embodiment of an anti-icing system according to the present invention is described below with reference to accompanying drawings.

[0029] As illustrated in FIGS. 1A and 1B, an anti-icing system 10 according to the present embodiment is provided inside a slat 3 of a main wing 1 of an aircraft, thereby preventing icing on an outer surface 7 of a leading edge 5 of the slat 3.

[0030] The slat 3 has an outer hull configured of a wing panel 4. The wing panel 4 may be made of, for example, an aluminum alloy, or a fiber reinforced resin such as carbon fiber reinforced plastics (CFRP) and glass fiber reinforced plastics (GFRP). As illustrated in FIG. 1B, a cross-sectional surface of the leading edge 5 along a wing length direction of the wing panel 4 has a curved shape derived from bending process. The anti-icing system 10 ejects bleed air that is heated air, toward an inner surface 6 of the leading edge 5, thereby preventing icing on the outer surface 7.

[0031] As illustrated in FIG. 1A, the anti-icing system 10 includes: a piccolo tube 11 that ejects the bleed air to the leading edge 5; an engine 18 that is a supply source of the bleed air; and an air supply tube 19 that connects the piccolo tube 11 with the engine 18 and guides the bleed air to the piccolo tube 11. The engine 18 is to obtain thrust force of the aircraft, and may be, for example, a jet engine mounted to a bottom surface of the main wing 1. The bleed air is the air extracted from a compressor of the jet engine, and has appropriate temperature because of previous cooling.

[0032] As illustrated in FIGS. 1A and 1B, the piccolo tube 11 is disposed, along the wing length direction of the main wing 1, at a position separated from the inner surface 6 of the leading edge 5 by a predetermined dis-

tance.

[0033] As illustrated in FIG. 2A, the piccolo tube 11 has a tapered shape configured of three parts, namely, an upstream tube 12, a middle-stream tube 13, and a downstream tube 14 that are disposed in order from a rear end, as upstream side, continuous with the air supply tube 19 toward a front end. Note that upstream, middle-stream, and downstream are expression used for discriminating the three parts from one another, and merely express relative relation of the three parts.

[0034] As illustrated in FIGS. 2C to 2E, the upstream tube 12, the middle-stream tube 13, and the downstream tube 14 are each configured of a hollow cylindrical tubular member, and the respective hollow parts thereof configure a flow path 15 through which the bleed air flows.

[0035] As illustrated in FIGS. 2C to 2E, the upstream tube 12, the middle-stream tube 13, and the downstream tube 14 have different inner diameters from one another. This causes respective opening areas A12, A13, and A14 of the flow path 15 in the upstream tube 12, the middle-stream tube 13, and the downstream tube 14 to be decreased in a stepwise manner along a flowing direction of the bleed air. The piccolo tube 11 is configured by connecting, through welding or other process, the upstream tube 12, the middle-stream tube 13, and the downstream tube 14 that are prepared as separate tubes. $A12 > A13 > A14$

[0036] A plurality of ejection holes 16 that open to face the inner surface 6 of the leading edge 5 are provided in the piccolo tube 11. The ejection holes 16 make the flow path 15 communicate with the outside. As illustrated in FIGS. 2A and 2B, the plurality of ejection holes 16 are provided side by side with predetermined intervals in the longitudinal direction of the piccolo tube 11. The bleed air that has flowed into the piccolo tube 11 from the air supply tube 19 is ejected as high-temperature high-speed jet flow from the ejection holes 16 toward the inner surface 6 of the leading edge 5.

[0037] As illustrated in FIGS. 2A and 2B, in the piccolo tube 11 according to the present embodiment, the plurality of ejection holes 16 are arranged in two straight lines in the longitudinal direction. The two lines are disposed on the piccolo tube 11 in a circumferential direction thereof. Arranging the ejection holes 16 in the two lines makes it possible to cause the bleed air to be blown to a wide range of the inner surface, and to reduce a flow rate of the bleed air ejected from one ejection hole 16. This prevents heat transfer coefficient from becoming excessively large and prevents overheating of the members. Note that, as illustrated in FIG. 2B, the lines formed of the plurality of ejection holes 16 are respectively referred to as a first ejection hole line L1 and a second ejection hole line L2. Note that the ejection holes 16 are disposed in the same phase in the circumferential direction of the piccolo tube 11.

[0038] As illustrated in FIGS. 2A and 2B, the first ejection hole line L1 and the second ejection hole line L2 are disposed one above the other, and are formed from the

upstream tube 12 to the downstream tube 14. As illustrated in FIG. 2C, in the upstream tube 12, the first ejection hole line L1 disposed on relatively upper side and the second ejection hole line L2 disposed on relatively lower side are so provided as to form a center angle $\theta12$ (θa). Likewise, in the middle-stream tube 13 and the downstream tube 14, the first ejection hole line L1 and the second ejection hole line L2 are so provided as to form a center angle $\theta13$ (θb) and a center angle $\theta14$ (θc), respectively. This allows the piccolo tube 11 to generate a line of blown points of the bleed air by the first ejection hole line L1 and a line of blown points of the bleed air by the second ejection hole line L2. The bleed air ejected from the first ejection hole line L1 is ejected toward an outside airflow stagnation point P1 at an upper limit position (hereinafter, simply referred to as a stagnation point) described later, and the bleed air ejected from the second ejection hole line L2 is ejected toward an outside airflow stagnation point P2 at a lower limit position (hereinafter, simply referred to as a stagnation point) described later.

[0039] In this case, in the piccolo tube 11, the center angle between the first ejection hole line L1 and the second ejection hole line L2 that is formed from the upstream tube 12 to the downstream tube 14 is decreased in order of $\theta12$, $\theta13$, and $\theta14$. This is to adjust the distance to the corresponding inner surface 6 of the slat 3. As illustrated in FIG. 2A, the center angle is made small as the distance to the inner surface 6 is large, whereas the center angle is made large as the distance to the inner surface 6 is small, which allows for alignment of the positions of the inner surface 6 to which the bleed air reaches.

[0040] The above-described relationship, however, is a mere example, and the present invention is not limited to the positional relationship.

[0041] The plurality of ejection holes 16 according to the present embodiment are provided in two lines, the first ejection hole line L1 and the second ejection hole line L2, and the respective positions thereof are specified from the relationship with the stagnation point in the leading edge 5 of the slat 3 as well. This is described below with reference to FIGS. 3A to 3C, and FIGS. 6A and 6B.

[0042] When the aircraft flies and droplets D collide with the leading edge 5 of the slat 3 as illustrated in FIG. 6A, a collision amount of the droplets becomes the highest at a point at which the speed becomes zero in a flow field of the droplets D, namely, at the stagnation point Ps. The collision amount of the droplets D is decreased with the increase of the distance from the stagnation point Ps. Further, the droplets do not collide with the leading edge 5 at a position outside of a collision upper limit and a collision lower limit that are distanced from the stagnation point Ps by a specified length. In this way, the amount of the droplets D colliding with the slat 3 is determined based on the stagnation point. Note that the stagnation point Ps is virtually formed, and is determined based on a cross-sectional surface and the position of the slat 3 and an angle of attack of the aircraft.

[0043] In other words, it is premised in FIGS. 6A and 6B that the aircraft is flying horizontally as an example; however, the position of the stagnation point Ps is changed as the attitude of the aircraft is changed (the angle of attack is varied). Since the aircraft flies within a specific range of the angle of attack, the stagnation point Ps is also displaced within a specific range. The stagnation point Ps is displaced within a range between a stagnation point P1 and a stagnation point P2. The stagnation point P1 is the uppermost position of occurrence, namely, the upper limit position. The stagnation point P2 is the lowermost position of occurrence, namely, the lower limit position. The stagnation point P1 and the stagnation point P2 are illustrated in FIGS. 3A to 3C.

[0044] FIG. 3A is a diagram illustrating a state in which the stagnation point Ps is close to the stagnation point P1 as the upper limit position. FIG. 3B is a diagram illustrating a state in which the stagnation point Ps is located in the middle between the stagnation point P1 and the stagnation point P2. FIG. 3C is a diagram illustrating a state in which the stagnation point Ps is close to the stagnation point P2 as the lower limit position. The range between the stagnation point P1 and the stagnation point P2 is referred to as a stagnation point displacement range.

[0045] In the present embodiment, as illustrated in FIGS. 3A to 3C, the first ejection hole line L1 is disposed in the stagnation point displacement range inner than the upper limit stagnation point P1, and the second ejection hole line L2 is disposed in the stagnation point displacement range inner than the lower limit stagnation point P2.

[0046] The distribution of the heat transfer coefficient by the bleed air ejected from the first ejection hole line L1 and the second ejection hole line L2 has two peaks H1 and H2 as illustrated in FIGS. 3A to 3C. A position at which the heat transfer coefficient reaches the peak H1 is located inside of the stagnation point P1 by a slight distance, and a position at which the heat transfer coefficient reaches the peak H2 is located inside of the stagnation point P2 by a slight distance.

[Effects]

[0047] In the anti-icing system 10 according to the present invention, the positional relationship between the first ejection hole line L1 and the stagnation point P1 and the positional relationship between the second ejection hole line L2 and the stagnation point P2, namely, the positional relationship between the peak H1 and the stagnation point P1 and the positional relationship between the peak H2 and the stagnation point P2 each have the above-described relationship. Therefore, even if the stagnation point Ps reaches the stagnation point P1 as the upper limit position, due to change of the attitude of the aircraft, the stagnation point P1 is coincident with or near the position at which the heat transfer coefficient reaches the peak H1 as illustrated in FIG. 3A. Likewise, even if the stagnation point Ps reaches the stagnation

point P2 as the lower limit position, due to change of the attitude of the aircraft, the stagnation point P2 is coincident with or near the position at which the heat transfer coefficient reaches the peak H2 as illustrated in FIG. 3C.

Therefore, according to the present embodiment, when the flight condition is changed (the angle of attack is varied), the position of the stagnation point is also changed. Thus, the position at which the collision amount of the droplets reaches a peak is also moved but is constantly located near one of the upper blown point or the lower blown point. This allows for efficient evaporation of moisture in a region where the heat transfer coefficient is high, near the blown point, which makes it possible to reduce the amount of the bleed air necessary for anti-icing and to prevent overheating.

[0048] Next, as illustrated in FIG. 3B, a case is assumed in which the stagnation point Ps, namely, the position at which the collision amount of the droplets becomes the highest is located in the middle between the positions at which the heat transfer coefficient reaches the respective peaks H1 and H2, namely, at a position at which the heat transfer coefficient distribution reaches a trough.

[0049] Overheating easily occurs because a more amount of the bleed air is necessary under the condition that the collision amount of the droplets becomes the highest. When the position (the stagnation point) at which the collision amount of the droplets reaches a peak is set to the position at which the heat transfer coefficient reaches the trough, however, a most amount of the droplets collides with a region where the heating amount is small and the droplets are not wholly evaporated, as illustrated in FIG. 4. Therefore, the residual moisture forms a water film WF on the surface of the leading edge 5 of the slat 3. The water film WF moves downward to reach the positions at which the heat transfer coefficient distribution reaches the respective peaks H1 and H2. Therefore, the water film WF is evaporated (S) to prevent overheating caused by the peaks H1 and H2.

[0050] Further, in the anti-icing system 10, it is sufficient to arrange the plurality of ejection holes 16 in the two lines on the piccolo tube 11, and to specify the arrangement position of the ejection holes 16 from the relationship with the stagnation point Ps. Therefore, it is possible to realize uniform heating without using a complicated internal structure as with the structure used in JP 2011-183922 A. This results in reduction in the weight of the system. Further, the internal structure is simple and it is possible for the anti-icing system 10 to prevent heat loss of heating of the double wall adopted in JP 2011-183922 A, which makes it possible to reduce the supply amount of the bleed air and to improve fuel consumption of the engine. Furthermore, unlike the National Publication of WO 2009-523637 A, it is unnecessary for the anti-icing system 10 to include a projection on an outer surface, which eliminates the increase of air resistance and the deterioration of the fuel consumption.

[0051] For example, the ejection holes 16 are disposed

in the same phase in the circumferential direction of the piccolo tube 11 in the above-described embodiment; however, the present invention is not limited thereto. For example, as illustrated in FIG. 5A, the plurality of ejection holes 16 may be arranged in a staggered arrangement. Arranging the ejection holes 16 in the staggered arrangement makes it possible to suppress unevenness of heating. In an illustrative example not falling within the scope of the present invention, the ejection holes 16 may be arranged in three lines as illustrated in FIG. 5B, in order to suppress unevenness of heating.

[0052] Further, higher heat transfer coefficient is applied to the stagnation point P1 and the stagnation point P2 by arranging, in the two lines, the ejection holes 16 each having a circular opening in the above-described embodiment; however, the present invention is not limited thereto. In an example not falling within the scope of the invention, as illustrated in FIG. 5C, ejection holes 26 each having an opening that extends along the circumferential direction may be provided. Each of the ejection holes 26 is formed of a slit that vertically extends from an upper end opening part to a lower end opening part. The bleed air ejected from the upper end opening part is ejected toward the stagnation point P1 as the upper limit position, and the bleed air ejected from the lower end opening part is ejected toward the stagnation point P2 as the lower limit position. The heat transfer coefficient in the circumferential direction by the bleed air ejected from the ejection holes 26 does not have a peak as with the peaks H1 and H2 in its distribution but may apply a predetermined heat transfer coefficient to the stagnation point P1 and the stagnation point P2.

[0053] Moreover, in a further illustrative example not within the scope of the invention as illustrated in FIG. 5D, two piccolo tubes 11 each having the ejection holes 16 arranged in one line may be disposed.

Claims

1. A combination of a leading edge (5) for a wing (1) of an aircraft and an anti-icing system (10) that is arranged to blow heated air to a curved inner surface (6) of the leading edge (5), the anti-icing system (10) comprising:

a piccolo tube (11) that includes a flow path (15) through which the heated air can flow in a longitudinal direction from a rear end to a front end, and a plurality of ejection holes (16) provided along the longitudinal direction to make the flow path (15) communicate with an outside and to eject the heated air as jet flows toward the inner surface (6) of the leading edge (5); and a supply source (18) that is arranged to supply the heated air toward the piccolo tube (11), wherein the plurality of ejection holes (16) of the piccolo tube (11) are straightly arranged in only

two lines consisting of a first ejection hole line L1 and a second ejection hole line L2, the first ejection hole line L1 being disposed on a relatively upper side and the second ejection hole line L2 being disposed on a lower side of the first ejection hole line L1 such that the jet flows of the heated air ejected from the ejection holes (16) of the first ejection hole line L1 generate, in operation, a first line of blown points on the inner surface (6) of the leading edge (5) corresponding to an outside airflow stagnation point (P1) on an upper side of the leading edge (5), such that the jet flows of the heated air ejected from the ejection holes (16) of the second ejection hole line L2 generate, in operation, a second line of blown points on the inner surface (6) of the leading edge (5) corresponding to an outside airflow stagnation point (P2) on a lower side of the leading edge (5), and such that no jet flows of the heated air are ejected to blown points on the inner surface (6) of the leading edge (5) between the first and second lines of blown points, and

wherein the outside airflow stagnation points (P1,P2) on the upper and lower sides of the leading edge (5) are virtually determined based on a cross-sectional surface of the wing and a specific assumed angle of attack of the aircraft.

2. The combination of a leading edge (5) for a wing (1) of an aircraft and an anti-icing system (10) according to claim 1, wherein the plurality of ejection holes (16) forming the first ejection hole line L1 and the plurality of ejection holes (16) forming the second ejection hole line L2 are arranged in a staggered arrangement.
3. The combination of a leading edge (5) for a wing (1) of an aircraft and an anti-icing system (10) according to claim 1, wherein the plurality of ejection holes (16) forming the first ejection hole line L1 and the plurality of ejection holes (16) forming the second ejection hole line L2 are disposed in the same phase in a circumferential direction of the piccolo tube (11).
4. The combination of a leading edge (5) for a wing (1) of an aircraft and an anti-icing system (10) according to claim 1 to 3, wherein the piccolo tube (11) has a tapered shape from the rear end side to the front end side, and the first ejection hole line L1 and the second ejection hole line L2 form, on the front end side and in a cross sectional view of the piccolo tube (11), a center angle θ_c smaller than a center angle θ_a that is formed by the first ejection hole line L1 and the second ejection hole line L2 on the rear end side.
5. An aircraft comprising the combination of a leading

edge (5) for a wing (1) of the aircraft and an anti-icing system (10) according to any one of claims 1 to 4.

6. The aircraft according to claim 5, wherein the anti-icing system (10) is provided in a main wing (1).

Patentansprüche

1. Eine Kombination aus einer Vorderkante (5) für eine Tragfläche (1) eines Luftfahrzeugs und einem Vereisungsschutzsystem (10), das so angeordnet ist, dass es erwärmte Luft auf eine gekrümmte Innenoberfläche (6) der Vorderkante (5) bläst, wobei das Vereisungsschutzsystem (10) umfasst:

ein Piccolo-Rohr (11), das einen Strömungsweg (15) enthält, durch den die erwärmte Luft in einer Längsrichtung von einem hinteren Ende zu einem vorderen Ende strömen kann, und eine Vielzahl von Ausstoßlöchern (16), die entlang der Längsrichtung vorgesehen sind, um den Strömungsweg (15) mit einer Außenseite in Verbindung zu bringen und die erwärmte Luft als Strahlströme zu der Innenoberfläche (6) der Vorderkante (5) auszustoßen, und eine Versorgungsquelle (18), die angeordnet ist, um die erwärmte Luft in Richtung des Piccolo-Rohrs (11) zuzuführen,

wobei die Vielzahl von Ausstoßlöchern (16) des Piccolo-Rohrs (11) geradlinig in nur zwei Linien angeordnet sind, die aus einer ersten Ausstoßlochlinie L1 und einer zweiten Ausstoßlochlinie L2 bestehen, wobei die erste Ausstoßlochlinie L1 auf einer relativ oberen Seite und die zweite Ausstoßlochlinie L2 auf einer unteren Seite der ersten Ausstoßlochlinie L1 angeordnet ist, so dass die Strahlströme der erwärmten Luft, die aus den Ausstoßlöchern (16) der ersten Ausstoßlochlinie L1 ausgestoßen werden, im Betrieb eine erste Linie von Blaspunkten auf der Innenoberfläche (6) der Vorderkante (5), die einem Außenluftstrom-Stagnationspunkt (P1) auf einer Oberseite der Vorderkante (5) entspricht, erzeugen, so dass die Strahlströme der erwärmten Luft, die aus den Ausstoßlöchern (16) der zweiten Ausstoßlochlinie L2 ausgestoßen werden, im Betrieb eine zweite Linie von Ausblaspunkten auf der Innenoberfläche (6) der Vorderkante (5), die einem Außenluftstrom-Stagnationspunkt (P2) auf einer unteren Seite der Vorderkante (5) entspricht, erzeugen, und so, dass keine Strahlströme der erwärmten Luft zu Ausblaspunkten auf der Innenoberfläche (6) der Vorderkante (5) zwischen der ersten und der zweiten Linie von Ausblaspunkten ausgestoßen werden, und

wobei die Außenluftstrom-Stagnationspunkte

(P1,P2) auf den oberen und unteren Seiten der Vorderkante (5) virtuell auf der Grundlage einer Querschnittsoberfläche der Tragfläche und eines spezifischen angenommenen Anstellwinkels des Luftfahrzeugs bestimmt werden.

2. Die Kombination aus einer Vorderkante (5) für eine Tragfläche (1) eines Luftfahrzeugs und einem Vereisungsschutzsystem (10) nach Anspruch 1, wobei die Vielzahl von Ausstoßlöchern (16), die die erste Ausstoßlochlinie L1 bilden, und die Vielzahl von Ausstoßlöchern (16), die die zweite Ausstoßlochlinie L2 bilden, in einer versetzten Anordnung angeordnet sind.

3. Die Kombination aus einer Vorderkante (5) für eine Tragfläche (1) eines Luftfahrzeugs und einem Vereisungsschutzsystem (10) nach Anspruch 1, wobei die Vielzahl von Ausstoßlöchern (16), die die erste Ausstoßlochlinie L1 bilden, und die Vielzahl von Ausstoßlöchern (16), die die zweite Ausstoßlochlinie L2 bilden, in einer Umfangsrichtung des Piccolo-Rohrs (11) in derselben Phase angeordnet sind.

4. Die Kombination aus einer Vorderkante (5) für eine Tragfläche (1) eines Luftfahrzeugs und einem Vereisungsschutzsystem (10) nach einem der Ansprüche 1 bis 3, wobei das Piccolo-Rohr (11) eine sich von der hinteren Endseite zur vorderen Endseite verjüngende Form aufweist, und die erste Ausstoßlochlinie L1 und die zweite Ausstoßlochlinie L2 an der vorderen Endseite und in einer Querschnittsansicht des Piccolrohrs (11) einen Mittenwinkel θ_c bilden, der kleiner ist als ein Mittenwinkel θ_a , der durch die erste Ausstoßlochlinie L1 und die zweite Ausstoßlochlinie L2 an der hinteren Endseite gebildet wird.

5. Ein Luftfahrzeug mit der Kombination aus einer Vorderkante (5) für eine Tragfläche (1) des Luftfahrzeugs und einem Vereisungsschutzsystem (10) nach einem der Ansprüche 1 bis 4.

6. Das Luftfahrzeug nach Anspruch 5, wobei das Vereisungsschutzsystem (10) in einer Haupt-Tragfläche (1) vorgesehen ist.

Revendications

1. Combinaison d'un bord (5) d'attaque d'une aile (1) d'un aéronef et d'un système (10) d'antigivrage, qui est agencé pour insuffler de l'air chauffé sur une surface (6) intérieure incurvée du bord (5) d'attaque, le système d'anti-dégivrage comprenant :

un tube (11) piccolo, qui a un trajet (15) d'écou-

lement par lequel l'air chauffé peut passer dans une direction longitudinale d'une extrémité arrière à une extrémité avant, et une pluralité de trous (16) d'éjection prévue le long de la direction longitudinale, pour faire que le trajet (15) d'écoulement communique avec une sortie pour éjecter l'air chauffé, sous la forme d'écoulement en jets, vers la surface (6) intérieure du bord (5) d'attaque; et

une source (18) d'alimentation, qui est agencée pour envoyer l'air chauffé vers le tube (11) piccolo, dans laquelle la pluralité de trous (16) d'éjection du tube (11) piccolo sont disposés en ligne droite en seulement deux lignes, consistant en une première ligne L1 de trous d'éjection et en une deuxième ligne L2 de trous d'éjection, la première ligne L1 de trous d'éjection étant disposée d'un côté plus haut relativement et la deuxième ligne L2 de trous d'éjection étant disposée d'un côté plus bas de la première ligne L1 de trous d'éjection, de manière à ce que les écoulements en jets de l'air chauffé éjectés des trous (16) d'éjection de la première ligne L1 de trous d'éjection produisent, en fonctionnement, une première ligne de points insufflés sur la surface (6) intérieure du bord (5) d'attaque correspondant à un point (P1) de stagnation d'écoulement de l'air à l'extérieur, d'un côté plus haut du bord (5) d'attaque, de manière à ce que les écoulements en jets de l'air chauffé éjectés des trous (16) d'éjection de la deuxième ligne (12) de trous d'éjection produisent, en fonctionnement, une deuxième ligne de points insufflés sur la surface (6) intérieure du bord (5) d'attaque correspondant à un point (P2) de stagnation d'écoulement de l'air à l'extérieur, d'un côté plus bas du bord (5) d'attaque et de manière à ce qu'aucun écoulement en jet de l'air chauffé soit éjecté vers les points insufflés sur la surface (6) intérieure du bord (5) d'attaque entre les première et deuxième lignes de points insufflés, et dans laquelle les points (P1,P2) de stagnation d'écoulement de l'air à l'extérieur, des côtés plus haut et plus bas du bord (5) d'attaque, sont déterminés virtuellement sur la base d'une surface de section transversale de l'aile et d'un angle d'attaque spécifique assumé de l'aéronef.

2. Combinaison d'un bord (5) d'attaque d'une aile (1) d'un aéronef et d'un système (10) d'antigivrage suivant la revendication 1, dans laquelle la pluralité de trous (16) d'éjection formant la première ligne L1 des trous d'éjection et la pluralité de trous (16) d'éjection formant la deuxième ligne L2 de trous d'éjection sont disposées suivant un agencement en quinconce.
3. Combinaison d'un bord (5) d'attaque d'une aile (1)

d'un aéronef et d'un système (10) d'antigivrage suivant la revendication 1, dans laquelle la pluralité de trous (16) d'éjection formant la première ligne L1 de trous d'éjection et la pluralité de trous (16) d'éjection formant la deuxième ligne L2 de trous d'éjection sont disposées dans la même phase, dans une direction circumférentielle du tube (11) piccolo.

4. Combinaison d'un bord (5) d'attaque d'une aile (1) d'un aéronef et d'un système (10) d'antigivrage suivant l'une des revendications 1 à 3, dans laquelle le tube (11) piccolo a une forme conique du côté de l'extrémité arrière au côté de l'extrémité avant et la première ligne L1 de trous d'éjection et la deuxième ligne L2 de trous d'éjection forment, du côté de l'extrémité avant et en vue en section transversale du tube (11) piccolo, un angle θ_c au centre plus petit qu'un angle θ_a , qui est formé par la première ligne L1 de trous d'éjection et par la deuxième ligne L2 de trous d'éjection du côté de l'extrémité arrière.
5. Aéronef comprenant la combinaison d'un bord (5) d'attaque d'une aile (1) de l'aéronef et d'un système (10) d'antigivrage suivant l'une quelconque des revendications 1 à 4.
6. Aéronef suivant la revendication 5, dans lequel le système (10) d'antigivrage est prévu dans une aile (1) principale.

FIG. 1A

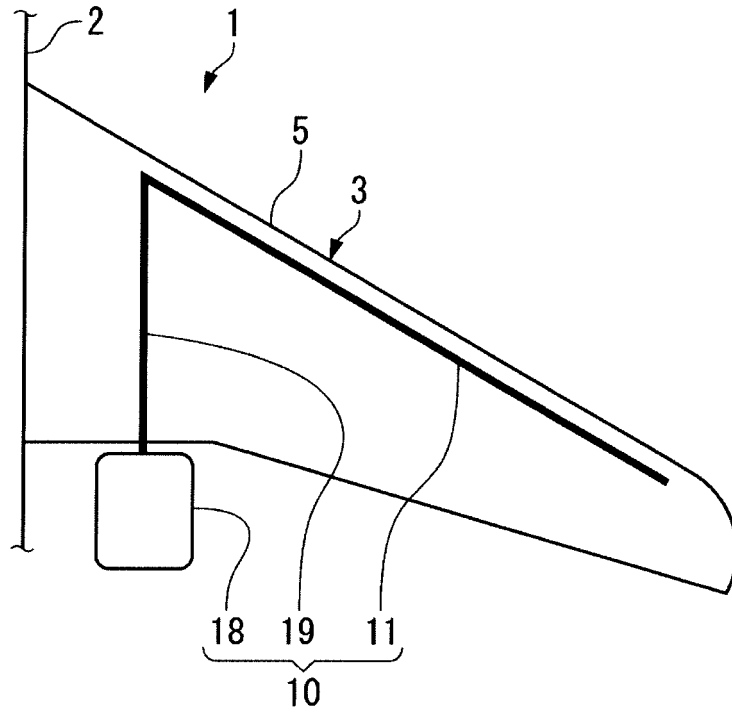


FIG. 1B

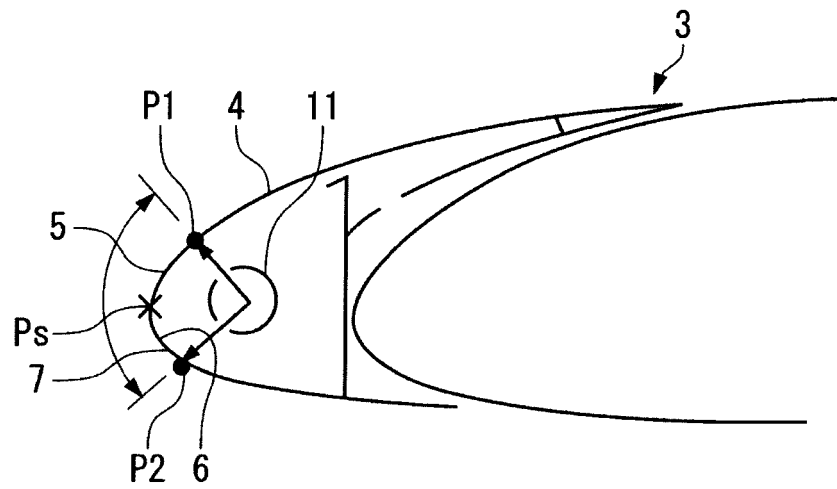


FIG. 2A

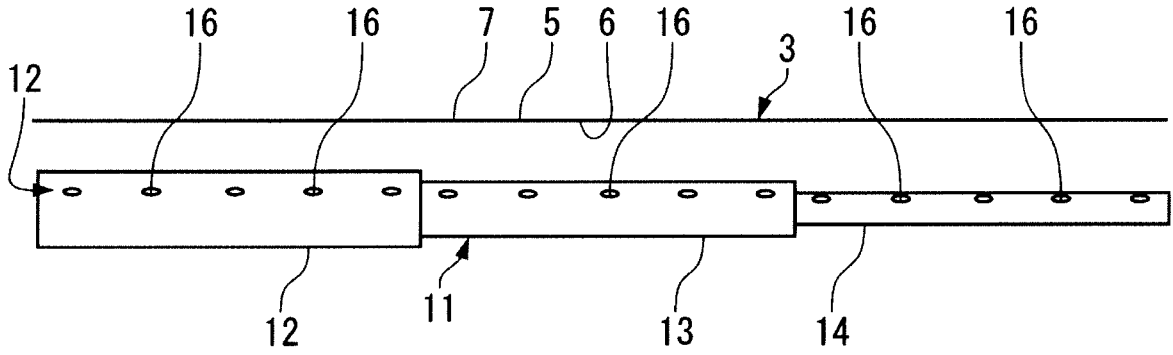


FIG. 2B

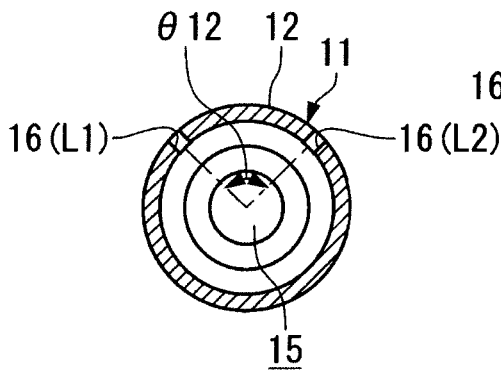
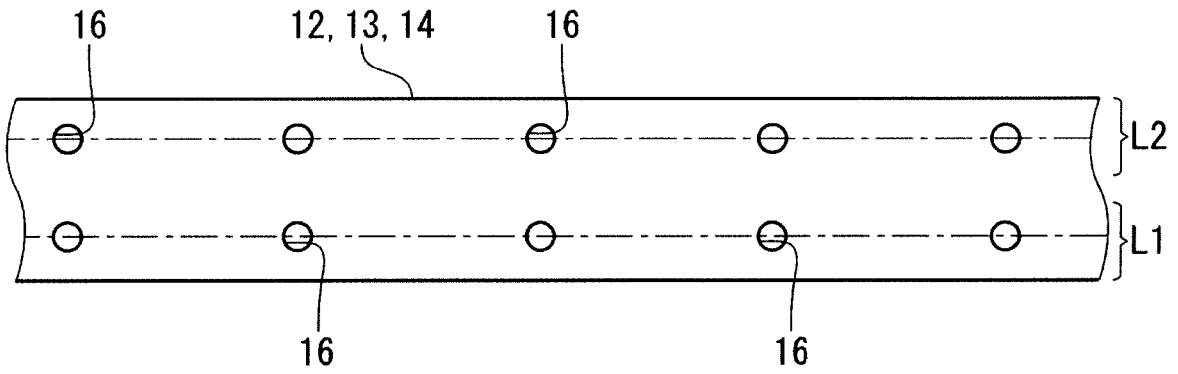


FIG. 2C

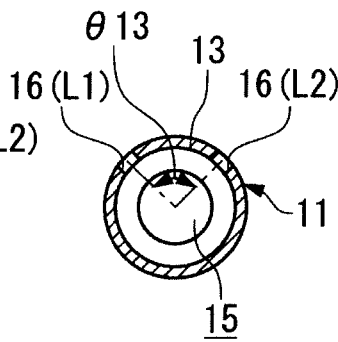


FIG. 2D

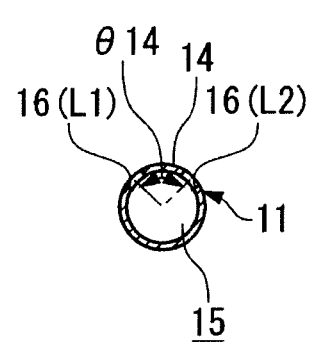


FIG. 2E

FIG. 3A

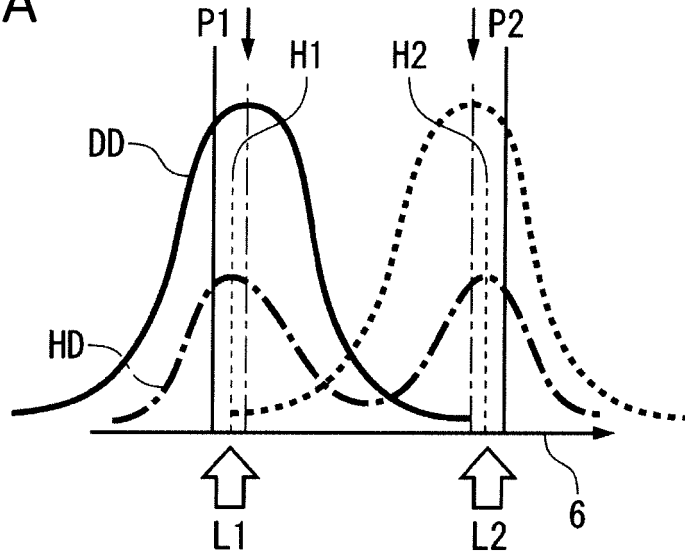


FIG. 3B

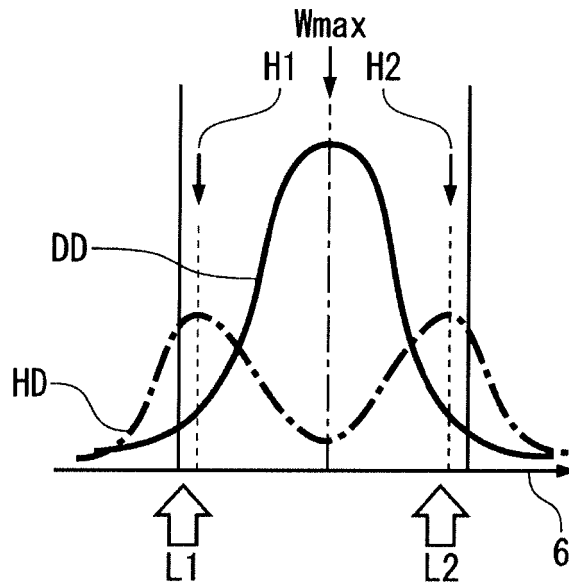


FIG. 3C

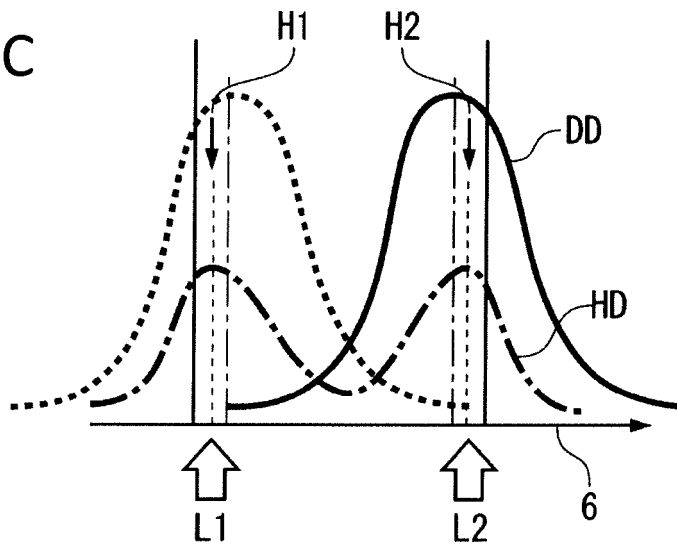
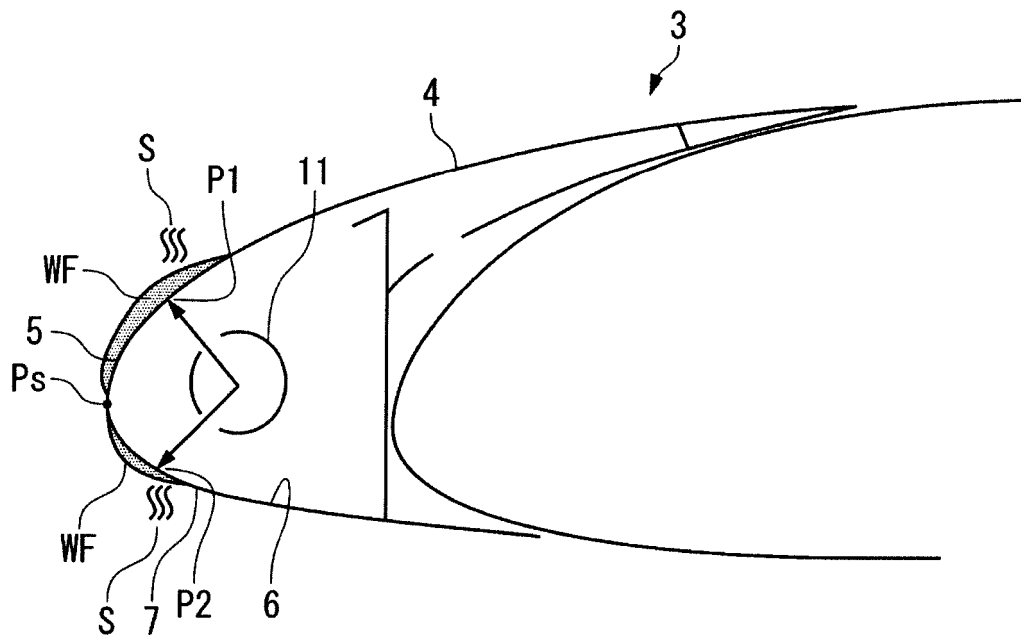


FIG. 4



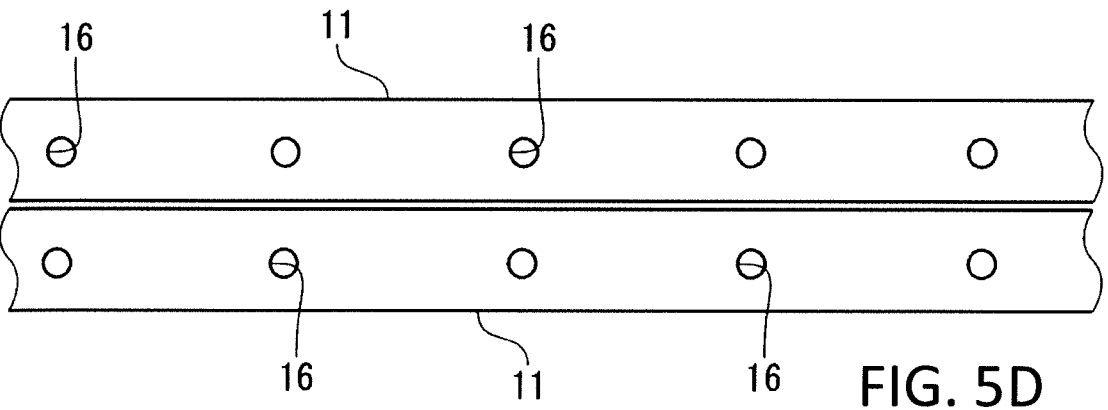
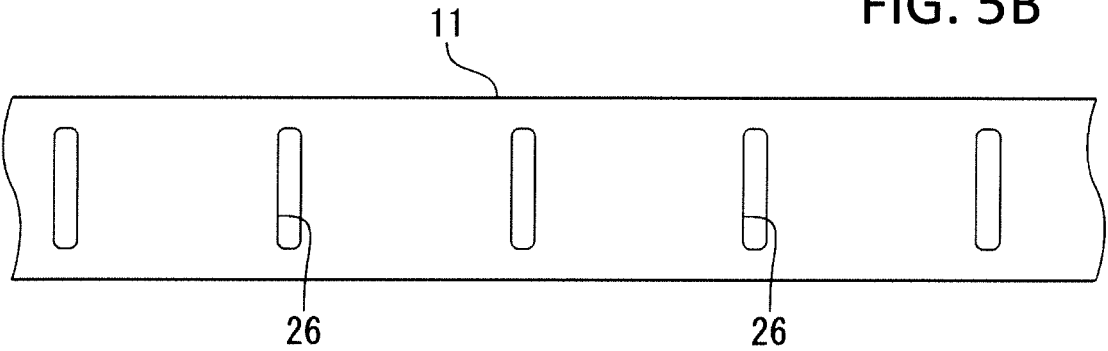
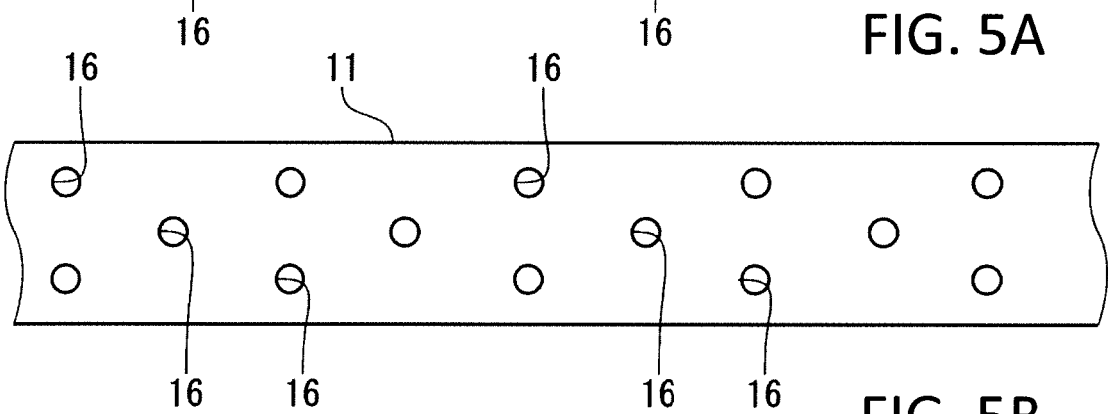
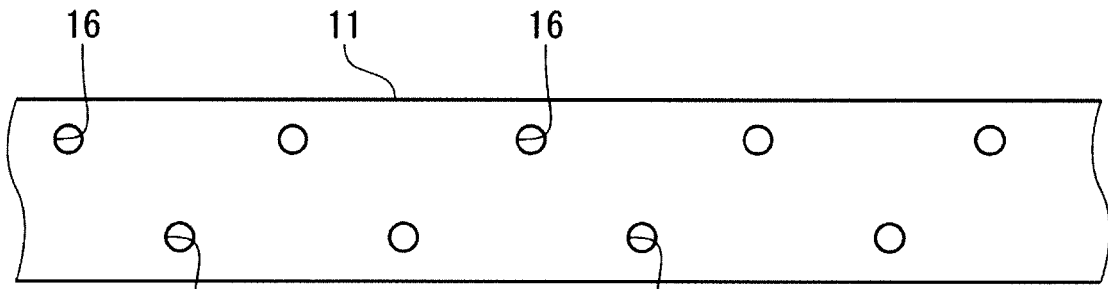


FIG. 6A

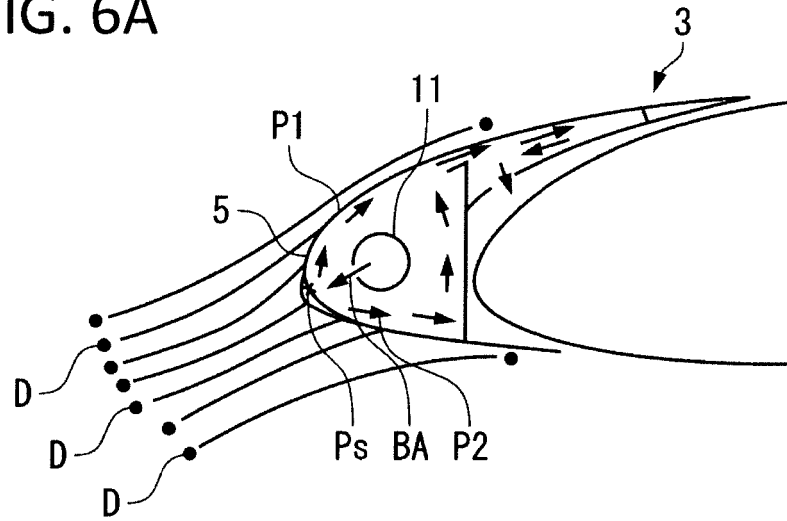


FIG. 6B

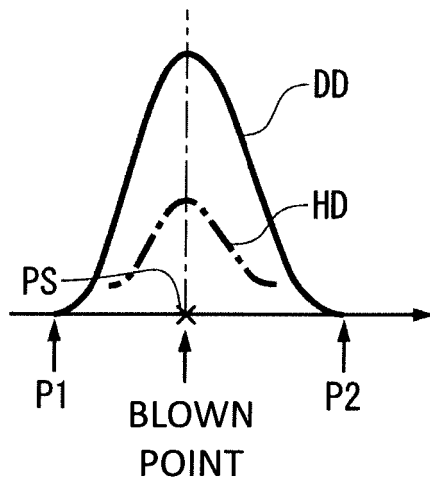
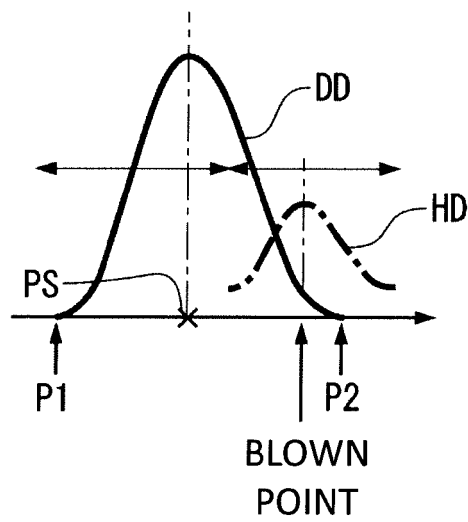


FIG. 6C



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2011183922 A [0007] [0008] [0050]
- WO 2009523637 A [0007] [0009] [0050]
- US 3917193 A [0010]
- DE 1213256 A [0011]
- GB 486549 A [0012]
- EP 2481672 A2 [0013]