(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 October 2009 (01.10.2009)

PCT

(10) International Publication Number
WO 2009/118548 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/GB2009/050242

(22) International Filing Date:
12 March 2009 (12.03.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0805268.0 25 March 2008 (25.03.2008) GB

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: COMPOSITE AIRCRAFT JOINT

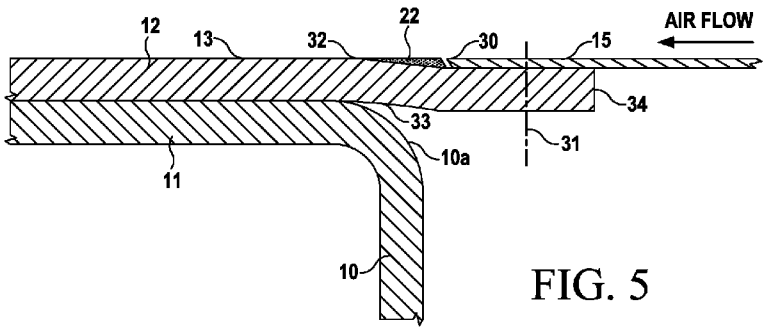

FIG. 5

(57) **Abstract**: The present invention relates to a joint between a laminar composite cover and a second cover (which may or may not be also formed from a composite material). The invention also relates to a method of manufacturing such a joint and a method of manufacturing a composite cover suitable for use in such a joint. The laminar composite cover comprises a stack of layers, substantially all of the layers being shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp. The second cover partially overlaps with the composite cover, and a clamp or fastener holds the covers together where they overlap. The covers have external sides which are substantially aligned with each other so as to form a smooth aerodynamic surface.

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COMPOSITE AIRCRAFT JOINT

FIELD OF THE INVENTION

The present invention relates to a joint on an aircraft between a laminar composite cover and a second cover (which may or may not be also formed from a composite material). The invention also relates to a method of manufacturing such a joint and a method of manufacturing a composite cover suitable for use in such a joint.

BACKGROUND OF THE INVENTION

Aircraft components including items such as wing skins and other covers are increasingly being made from composite materials, for example laminates. It is known to fasten the leading and trailing edge covers of a wing to the wing skin using butt-straps located along the joint between the leading and trailing edge covers and the wing skin. These butt-straps secure the covers in place and ensure that the leading and trailing edges of the covers are properly aligned with the corresponding trailing and leading edges of the wing skin.

Conventionally, a metallic butt-strap 1 is used as shown in cross-section in Fig. 1 and described in WO 2007/071905. The butt-strap is attached to the inner mould line (IML) face of the wing skin that generally faces towards the interior of the wing. Prior art butt-strap 1 has a stepped, z-shaped profile, with a short vertical portion 1a joining two horizontal plate portions 1b, c. In this example, plate 1b fits over a portion of the IML face of the aircraft's wing skin 2 such that the leading edge of skin 2 butts up against vertical portion 1a. This is bolted in place with bolt 3 that is countersunk into skin 2 on its outer-mould-line (OML) face.

Plate 1c is attached to the structure that is to be fixed to the leading edge of the cover. For example a D-nose leading edge skin 4 is shown attached to a wing cover leading edge 5 (Fig. 2). In order to reduce erosion of the composite skin 2 by airflow 6, the D-nose skin 4 is usually chosen to be sufficiently thick to overhang the leading edge 5 of skin 2. However, it is found that aerodynamic erosion still occurs and the increased thickness also increases drag. Aerodynamic erosion is often exacerbated when composite materials are used.

The prior-art butt-strap is also vulnerable to bird strike and similar collisions. Fig. 3 shows schematically how an impact on the leading-edge structure (not shown) attached by butt-strap 1 can lead to catastrophic forces on bolt 3. The present invention seeks to ameliorate at least some of the abovementioned problems.

SUMMARY OF THE INVENTION

A first aspect of the invention provides an aircraft joint comprising a laminar composite cover comprising a stack of layers, substantially all of the layers being shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp; a second cover which partially overlaps with the composite cover; and a clamp or fastener which holds the covers together where they overlap, wherein the covers have external sides which are substantially aligned with each other so as to form a smooth aerodynamic surface.

A further aspect of the invention provides a method of manufacturing an aircraft joint between a composite cover and a second cover, the method comprising: providing a laminar composite cover comprising a stack of layers, substantially all of the layers being shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp; partially overlapping a second cover with the composite cover; holding the covers together where they overlap with a clamp or fastener; and substantially aligning external sides of the covers with each other so as to form a smooth aerodynamic surface.

Typically a protector is provided on the external side of the composite cover which covers at least part of the ramp. The protector may be formed from a composite material, a rubber, or any other suitable material.

Typically the protector has a tapered shape which is relatively thick towards the bottom of the ramp and relatively thin towards the top of the ramp.

The second cover may comprise a leading edge or trailing edge cover of an aircraft structure such as a wing, a horizontal tail plane, a vertical tail plane, or a control surface such as an aileron or flap. In this case the composite cover is typically an upper or lower skin of a primary element such as a wing box, extending on an opposite side of a spar from the second cover.

Alternatively the second cover may comprise a manhole cover. In this case the composite cover is typically a lower skin of a wing.

The protector may be installed after the covers are overlapped, or more preferably before they are overlapped.

The protector may be attached by a layer of adhesive, by co-curing it with one of the covers, by a combination of such methods, or by any other suitable method.

Preferably the protector is pre-formed with a tapered shape before it is installed in position covering the ramp.

Preferably each ramp extends at an angle which is no steeper than 1 in 5 relative to the first and second covers. For instance each ramp may extend at an angle of 1 in 8, or 1 in 10, relative to the first and second covers.

A further aspect of the invention provides a method of manufacturing a composite cover, the method comprising: pre-forming a protector with a tapered shape; mounting the protector on a mould tool; laying a stack of layers of composite material on the protector on the mould tool whereby at least one of the layers forms a ramp; and curing the stack of layers of composite material. Typically each of the layers in the stack is formed with a ramp, typically forming the cover into a Z or joggle shape.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figures 1-3 illustrate prior art butt-strap configurations;

Figure 4 is a perspective view of the front spar of an aircraft wing;

Figure 5 is a cross-sectional side view of the joint between the wing skin and the leading-edge panel in the wing of Figure 4;

Figure 6 illustrates a method of constructing the wing skin of Figure 4;

Figure 7 shows the underside of the wing skin produced by the method illustrated in Figure 6;

Figure 8 is a side view of an alternative joint between a wing skin and leading-edge panel;

Figure 9 is a side view of the rubber edge protector by itself; and

Figure 10 is a sectional view showing a joggle joint between a wing skin and a manhole cover.

DETAILED DESCRIPTION OF EMBODIMENT(S)

A front spar of an aircraft wing is shown in Figure 4. The spar comprises a web 10, an upper flange 11 and a lower flange (not shown). The spar has a radius portion 10a where the web 10 meets the flange 11. A laminar composite skin 12 is attached to the upper flange 11 and extends aft of the spar to form the upper boundary of the wing box (the primary structural element of the wing). The skin 12 also overhangs the front of the spar slightly as shown in Figure 4.

The skin 12 has an external side 13 shown in Figure 4 and an internal side 14 shown in Figure 7.

The detailed structure of the skin 12 during manufacture is shown in Figure 6. The skin 12 is formed by the following sequence of steps:

- an edge protector 22 is pre-formed with a wedge shape which tapers gradually from a relatively thick end to a relatively thin edge. The edge protector 22 may be pre-formed from a unidirectional extruded composite material; rubber; or by carbon fibres impregnated with epoxy resin and pultruded to shape. In the preferred case, the edge protector is pre-formed by a pultrusion process in which carbon fibres and epoxy resin are combined and pulled by rollers through a die with the desired cross-sectional shape. The die is heated so as to

cure or partially cure the epoxy resin, so that the edge protector 22 retains its shape

- a copper film 20 is laid onto a mould surface 28 which is formed with a step 29
- the edge protector 22 is placed on the copper film 20 as shown, with its thick end contacting the step in the copper film. The angled surface 23 of the edge protector 22 is fitted with a strip of film adhesive FM300 (not shown) either before or after it is laid onto the mould
- a first ply 24 of "prepreg" is laid onto the mould tool, adhering to the film adhesive. The ply 24 of "prepreg" comprises a unidirectional array of carbon fibre impregnated with an epoxy resin matrix.
- a stack of plies of "prepreg" material is laid onto the mould with the fibre direction varying across the stack as required, until a final ply 25 (which will form the internal surface of the skin 12) has been laid
- a vacuum bag (not shown), optionally in combination with other elements such as release films, is laid over the final ply 25
- the space between the vacuum bag and the mould is evacuated in an autoclave which is simultaneously heated to above the cure temperature of the epoxy resin so that the prepregs and edge protector 22 become fully cured
- the vacuum bag etc are removed, leaving the cured skin 12 as shown in Figure 7.

The stack of layers forms a Z-shaped so-called "joggle" profile with a ramp above the edge protector 22. Each one of the layers in the stack is shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions. For example one of the internal layers of the stack comprises a first horizontal portion 45 at the "top" of a ramp 46 (top and bottom being defined in this case relative to the orientation shown in Figure 5), and a second horizontal portion 47 at the "bottom" of the ramp 46.

Note that the ramp extends across the full stack thickness, so that the external and internal layers 24,25 are both formed with ramps 26,27 respectively along with all of the internal layers. The shape of the external side 13 of the skin (known as the "outer mould line" or OML) is precisely controlled since it engages the mould tool during the cure process.

Note that the number of layers in the stack is the same on both sides of the ramp. As a result there are no discontinued layers within the interior of the stack which would cause porosity problems.

After the skin 12 has been bolted to the spar, it is joined to a leading edge panel 15 by a lap joint shown most clearly in the cross-sectional view of Figure 5. The panel 15 may or may not be formed from a similar composite material.

The internal side of the panel 15 is partially overlapped with the external side 13 of the skin 12 as shown in Figure 5. The edge protector 22 and the external sides of the panel 15 and the skin 12 together form a substantially continuous external aerodynamic surface which is exposed to an airflow as shown. A fastener (such as a bolt) is then passed along a line 31 through the skin 12 and panel 15 where they overlap. The fastener can be removed to enable the joint to be disassembled for inspection or repair purposes.

The edge protector 22 is positioned between the ramp and the trailing edge 30 of the panel 15, and protects the edge 32 at the downstream top of the ramp 26 from erosion by particles carried by the airflow (which travels in the direction indicated in Figure 5). The gap between the edge protector 22 and the trailing edge 30 of the panel 15 is filled using Aero filler (not shown) at final assembly.

On the internal side of the cover 12, the "top" 33 of the ramp is positioned as close as possible to the spar 11, so the ramp partially overlaps with the radius portion 10a of the spar (top and bottom being defined in this case relative to the orientation shown in Figure 5). This enables the edge 34 of the cover 12 to be positioned relatively close to the spar.

Figures 8 and 9 illustrate an alternative form of edge protector. Most elements of the structure are the same as in Figure 5, and the same reference numerals are used for equivalent elements. In this case the edge protector is made of pre-formed rubber and

forms a seal between the skin 12 and the panel 15. The edge protector has a tapered wedge shaped portion 40 which covers the ramp, and a tail 41 shown most clearly in Figure 9 which forms a seal between the overlapping parts. The edge protector in this case may be attached to the panel 15 or to the skin 12 by a layer of adhesive (not shown) before they are overlapped to form the joint. A rib 42 is also shown in Figure 8, and the skin 12 and panel 15 are bolted to the rib 42.

Preferably the rubber edge protector is pre-attached to the panel 15 instead of the skin 12. This creates a replaceable item if damaged or worn, with no impact on the primary strucuture.

Figure 10 shows a joggle joint between a laminar composite skin 50 and a manhole cover 54. The composite skin 50 is a bottom skin of an aircraft wing and carries a series of T-section stringers on its inner surface, part of one of such stringers 52 being shown in cross-section.

The manhole cover 54 is clamped to the skin 50 by a clamping plate 53. The manhole cover 54 and clamping plate 53 are both approximately oval when viewed from below the aircraft wing. The skin 50 is formed with an oval opening which receives the clamping plate 53. The clamping plate 53 has an annular flange 55 which engages the inner surface of the skin 50. A rubber sealing gasket 56, shown in dashed line, provides a fuel-tight seal between the flange 55 and the skin 50.

The manhole cover 54 is joined to the clamping plate 53 around its periphery by a series of fasteners 57. As the fasteners 57 are tightened they clamp the skin 50 between the two parts 53,54. A rubber sealing gasket 58, shown in dashed line, provides a fuel-tight seal between the manhole cover 54 and the skin 50. A tapered filler 59 is provided between the gasket 58 and the skin 50.

The skin 50 is formed with a joggled stack of layers in a similar manner to the skin 12 as shown in Figure 6. The clamping plate 53 and fasteners 57 together act as a clamp which holds the parts 50,54 together where they overlap. The fasteners 57 can be removed to enable the joint to be disassembled and provide access to the interior of the wing. The skin 50 and manhole cover 54 have external sides which are substantially aligned with each other so as to form a smooth aerodynamic surface.

In contrast with the previous embodiments in which the leading edge panel 15 has a constant thickness, the thickness of the manhole cover 54 tapers towards a relatively narrow edge 60, the taper following the angle of the ramp 61 in the joggle. The external side of the skin 50 is formed with an annular recess with a step 61 which accommodates the gasket 58 so that the gasket 58 lies flush with the external sides of the skin 50 and the manhole cover 54.

The gasket 58 and tapered filler 59 together act as an edge protector, protecting the edge 60 of the manhole cover 54, and the skin 50, from erosion by particles carried by the airflow.

Although the invention has been described above with reference to one or more preferred embodiments, it will be appreciated that various changes or modifications may be made without departing from the scope of the invention as defined in the appended claims.

Claims

1. An aircraft joint comprising: a laminar composite cover comprising a stack of layers, substantially all of the layers being shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp; a second cover which partially overlaps with the composite cover; and a clamp or fastener which holds the covers together where they overlap, wherein the covers have external sides which are substantially aligned with each other so as to form a smooth aerodynamic surface.

2. The joint of claim 1 further comprises a protector on the external side of the composite cover which covers at least part of the ramp.

3. The joint of claim 2 wherein the protector is formed from a composite material.

4. The joint of claim 2 or 3 wherein the protector has a tapered shape which is relatively thick towards the bottom of the ramp and relatively thin towards the top of the ramp.

5. The joint of any preceding claim wherein the second cover comprises a leading edge or trailing edge cover of an aircraft wing.

6. The joint of any preceding claim wherein the top of the ramp is positioned aft of the bottom of the ramp.

7. The joint of any preceding claim wherein the clamp or fastener comprises a fastener which passes through the covers where they overlap.

8. The joint of any preceding claim wherein each ramp extends at an angle which is no steeper than 1 in 5 relative to the first and second covers.

9. An aircraft structure comprising: a spar; a laminar composite cover attached to the spar; a second cover; and a joint according to any preceding claim between the laminar composite cover and the second cover.

10. A method of manufacturing an aircraft joint between a composite cover and a second cover, the method comprising: providing a laminar composite cover comprising a stack of layers, substantially all of the layers being shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp; partially overlapping a second cover with the composite cover; holding the covers together where they overlap with a clamp or fastener; and substantially aligning external sides of the covers with each other so as to form a smooth aerodynamic surface.

11. The method of claim 10 further comprising attaching a protector to one of the covers before the covers are overlapped.

12. The method of claim 11 further comprising pre-forming the protector with a tapered shape before it is attached to the cover.

13. The method of claim 11 or 12 wherein the protector is co-cured with the composite cover.

14. The method of any of claims 11 to 13 further comprising pre-forming the protector by pulling and/or extruding material through a die with a desired cross-sectional shape.

15. A method of manufacturing a composite cover, the method comprising: pre-forming a protector with a tapered shape; mounting the protector on a mould tool; laying a stack of layers of composite material on the protector on the mould tool whereby at least one of the layers forms a ramp; and curing the stack of layers of composite material.

16. The method of claim 15, wherein the protector is co-cured with the stack of layers of composite material.

17. The method of claim 15 or 16 further comprising at least partially curing the protector before it is mounted on the mould tool.

18. The method of any of claims 15 to 17 wherein the protector is pre-formed by pulling and/or extruding material through a die with a tapered cross-sectional shape.

19. The method of any of claims 15 to 17 wherein substantially all of the layers are shaped to form a joggle, each joggle comprising a first portion, a second portion where the layer extends substantially parallel with the first portion, and a ramp between the first and second portions where the layer extends at an angle to the first and second portions, the number of layers being substantially the same on both sides of the ramp.

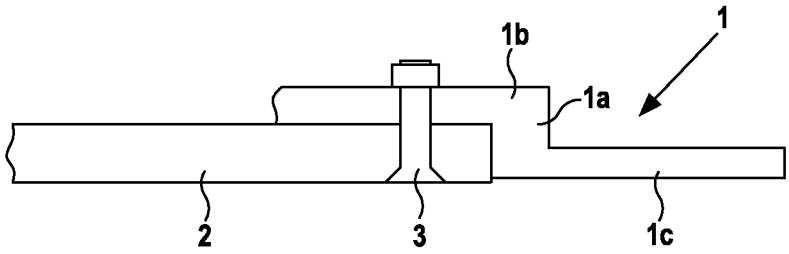

FIG. 1
(PRIOR ART)

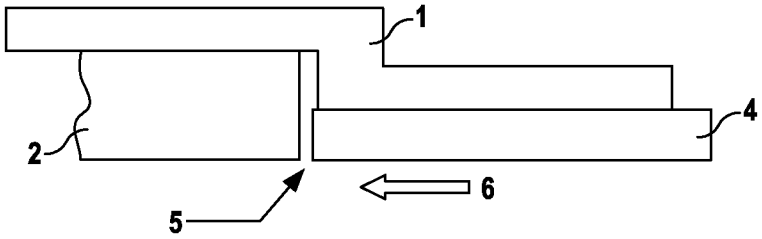

FIG. 2
(PRIOR ART)

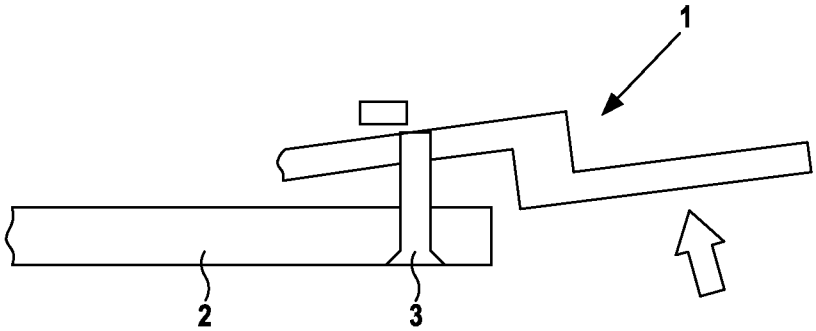

FIG. 3
(PRIOR ART)

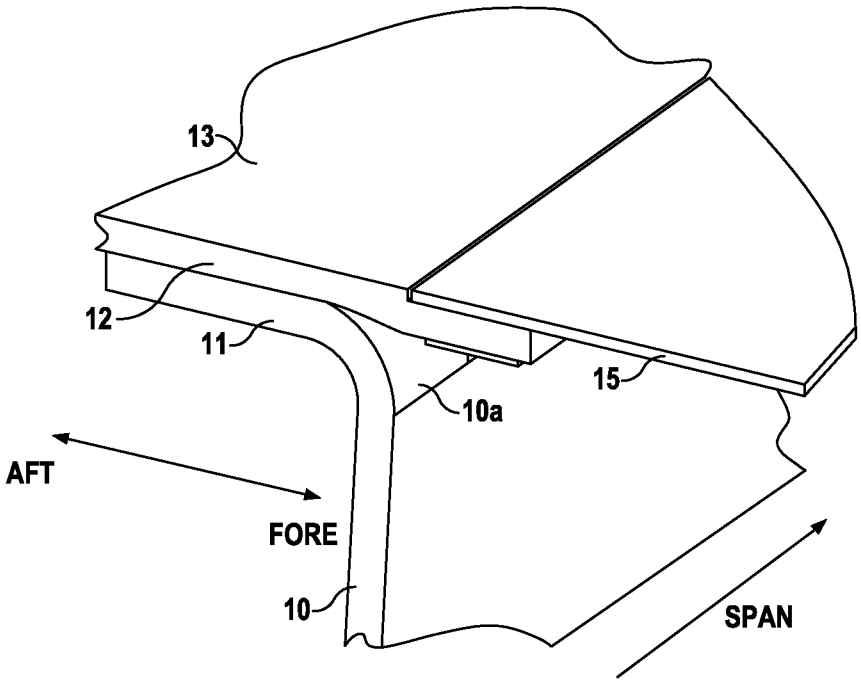
13
12
11
15
10a
AFT
FORE
10
SPAN

FIG. 4

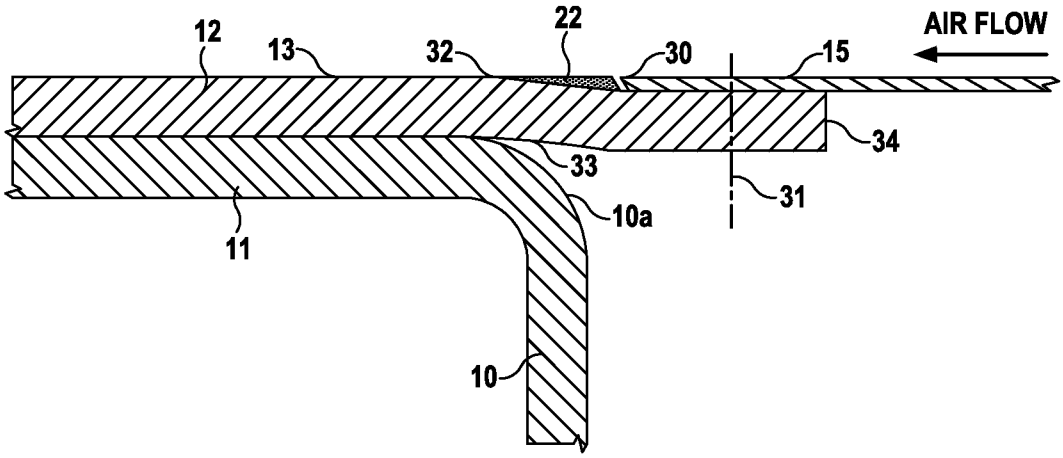
12
13
32
22
30
15
AIR FLOW
34
33
31
10a
11
10

FIG. 5

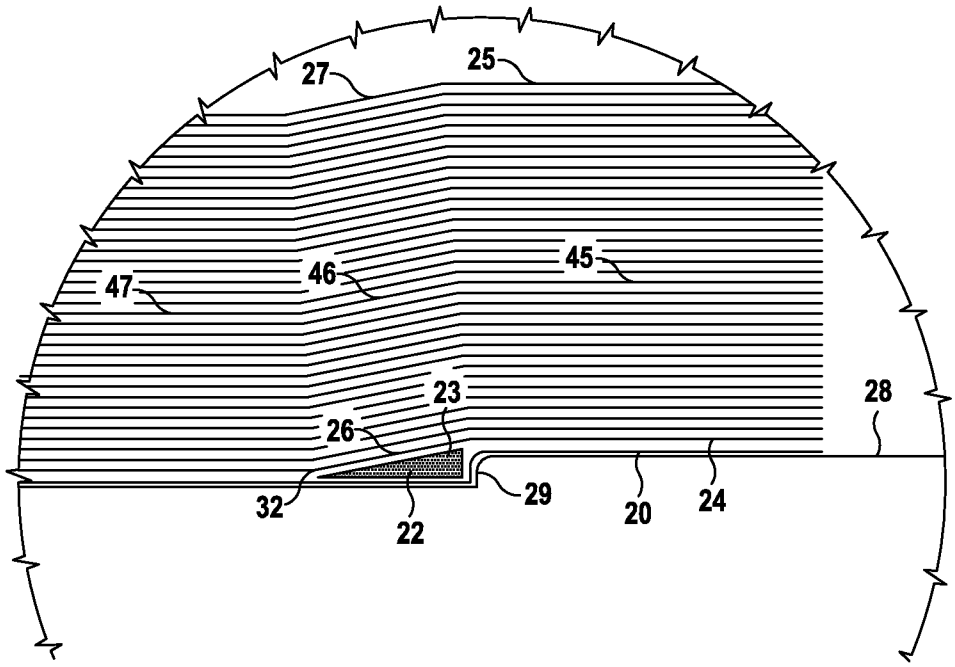

FIG. 6

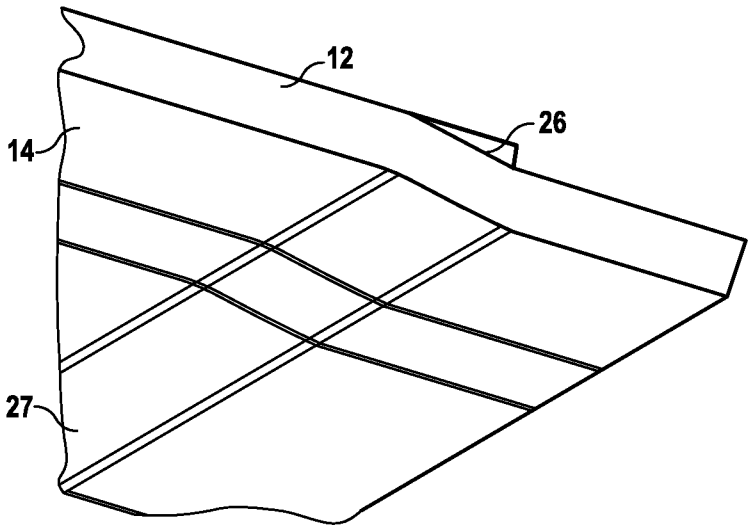

FIG. 7

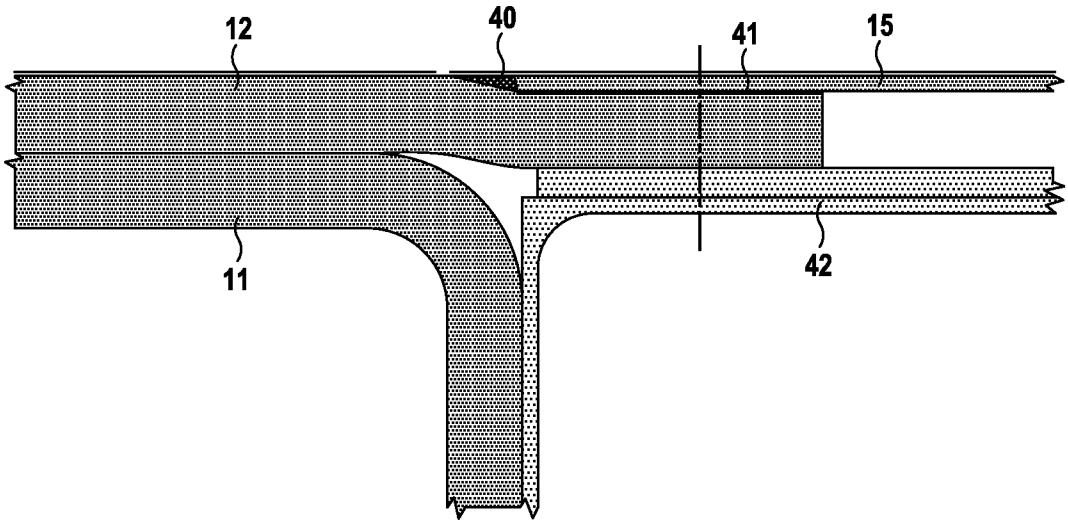

FIG. 8

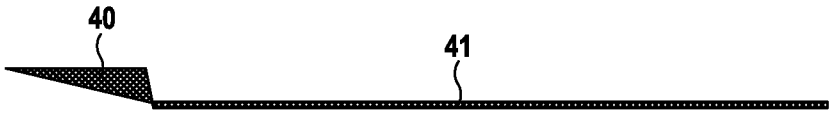

FIG. 9

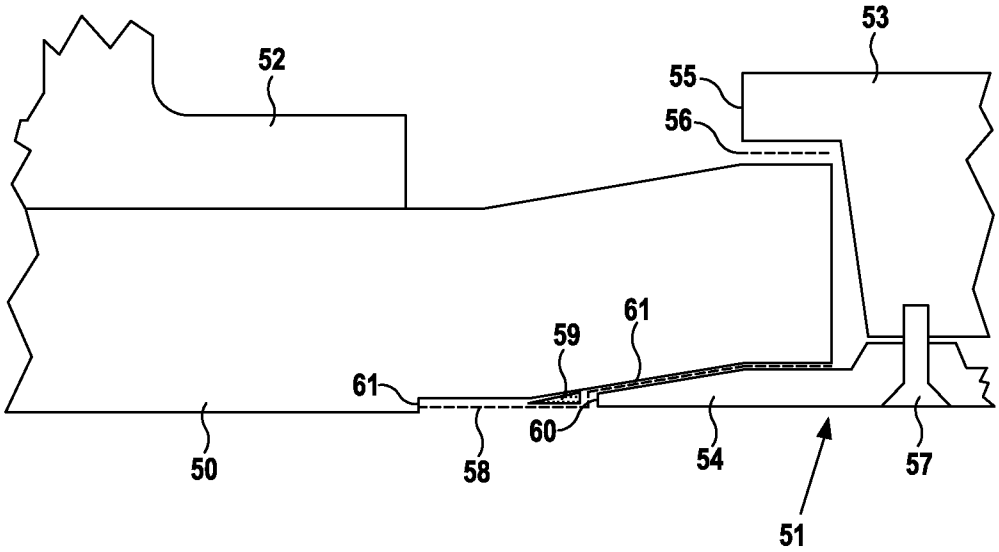

FIG. 10