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(54) **Title:** METHOD FOR MANUFACTURING A SOUND- ABSORBING SANDWICH PANEL FOR REDUCING NOISE OF AN AIRCRAFT ENGINE

(57) **Abstract:** The method for manufacturing a sound- absorbing panel (10) with a sandwich structure for reducing the noise impact of an aeronautic engine comprises the following steps in sequence: a) providing a first skin (12) in a thermoplastic polymeric material; b) making a plurality of micro-holes (18) through the first skin (12) by mechanical punching of the first skin (12); c) securing said first skin (12) to a central layer (14) by arranging a structural adhesive layer between the first skin (12) and the central layer (14) and/or by a thermal weld between the first skin (12) and the central layer (14); and d) securing said central layer (14) to a second skin (16) by arranging a structural adhesive layer between the central layer (14) and the second skin (16) and/or by a thermal weld between the central layer (14) and the second skin (16).

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Method for manufacturing a sound-absorbing sandwich panel for reducing noise of an aircraft engine

Technical Background

The present invention relates to a method for manufacturing a sound-absorbing panel for aeronautical use and a relative sound-absorbing panel.

State of the Art

The use of sound-absorbing panels is generally known in the aeronautical field, particularly when arranged on the engine nacelle around the engine in order to absorb the dispersed sound power thereof. Usually, these sound-absorbing panels have a so-called “sandwich” structure, or a structure comprising a pair of outer skins with a central layer in between. Typically, the central layer is made with a honeycomb structure, and the skin facing the engine is provided with a plurality of holes; in this way, the sound wave can enter into the central layer and remain confined in the volumes of the honeycomb structure, also called resonance chambers. The layers of outer skin are usually made of composite materials with a thermosetting matrix, such as epoxy resins, or of aluminium.

A sound-absorbing panel for aeronautical use is known, for example, from US 9,856,030 B2, Figure 1 of which shows a sound-absorbing panel having a first perforated skin, an intermediate layer with a honeycomb structure and a second skin.

Further examples of sound-absorbing panels for aeronautical use are shown, for example, in patent publications CN 105346152 A, GB 2,452,476 B, US 4,817,756 A, US 7,631,483 B2, US 7,640,961 B2, US 9,194,293 B2, US 2005/0060982 A1, US 2005/0082112 A1, US 2015/0315972 A1 and EP 2,017,077 A2. The latter document, in particular, shows the possibility of using different materials, but not that of using thermoplastic materials for making the perforated skin. In fact, the use of such thermoplastic materials is complicated by the difficulties of gluing layers in thermoplastic material to layers in a different material, such as in aluminium, in a material with a meta-aramid base, or in a composite material with a phenolic resin base reinforced with glass fibres.

In order to make the holes in the skin facing the engine, a laser drilling process is normally used, since the cheaper conventional mechanical punching process is not suitable for machining composite materials. In fact, the drilling of composite materials can involve a series of specific problems and defects of the material, such as delamination (namely, the separation of the layers of materials from one another) and fragmentation (namely the fraying of the reinforcement fibres in the area of the hole). In fact, mechanical drilling of a composite material causes the fracture of the fibre part of the material and the heat generated during machining becomes a problem for the resin phase of the material since composite materials, being poor conductors of heat, do not produce chips. Consequently, in order to achieve precise cuts, a specific approach must be adopted in terms of tools and methods, which means that making sound-absorbing panels in composite material is by no means an economical process.

Summary of the invention

The aim of the present invention is to provide a method for manufacturing sound-absorbing panels for aeronautical use that does not have the disadvantages of the state of the art.

These and other aims are fully achieved according to the present invention thanks to a manufacturing method as defined in the accompanying independent claim 1.

Advantageous embodiments of the invention are specified in the dependent claims, the content of which is deemed to form an integral part of the following description.

In short, the invention is based on the idea of not using a first skin in composite material to be drilled according to the specific techniques of drilling composite materials, but rather a first skin in a thermoplastic polymeric material, through which a plurality of micro-holes are made initially in a conventional manner by means of a mechanical punch, and which is then secured to the other components of the sound-absorbing panel by means of a thermal welding and/or gluing process, possibly supported by a co-curing or co-polymerization or so-called *co-bonding* process (co-curing supported by interposing an adhesive layer).

By virtue of the possibility of making a plurality of micro-holes in a conventional manner, the cost of producing a sound-absorbing panel is, thus, significantly reduced.

Furthermore, thanks to the use of thermal welding and/or gluing, it is possible to glue a layer in thermoplastic material to materials of different types.

Brief description of the drawings

The characteristics and advantages of the present invention will emerge more clearly from the following detailed description, given by way of non-limiting example with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a sound-absorbing panel in partial cross-section; and

Figure 2 is a cross-sectional view of part of an engine nacelle having a sound-absorbing panel.

Detailed description

With reference to Figures 1 and 2, a sound-absorbing panel with a sandwich structure for reducing the noise impact of an aeronautical engine is generally indicated by 10. The sound-absorbing panel 10 substantially comprises a first skin 12, a central, or intermediate (also known as a *core*) layer 14 and a second skin 16.

The sound-absorbing panel 10 is capable of being used to form an insulating covering having as a whole a substantially cylindrical shape, or a shape suitable to at least partially surround a nacelle of an aeronautical engine. For example, in one embodiment, the sound insulation of the aeronautical engine is obtained by joining a plurality of sound-absorbing panels 10 having the shape of portions of cylindrical surfaces. In other embodiments, the sound-absorbing panel may have a substantially flat shape, or be slightly curved.

The first skin 12 has a generally thin, or film-like structure, or has a much smaller thickness than the two other dimensions and, when the sound-absorbing panel 10 is fitted for use, it is arranged to face the sound source; in particular, the first skin 12 is facing the engine, in a radially internal direction of the nacelle.

The first skin 12 may be made in different thermoplastic polymer materials. In some non-limiting embodiments described purely by way of example, the first skin 12 may be made in a thermoplastic polymer material in the list comprising: PEEK (polyether-ether-ketone), PEK (polyether-ketone), PEI (polyether-imide), nylon, PET (polyethylene terephthalate), PAEK (poly-aryl-ether-ketone), PPS (poly-para-phenyl-sulphide), PA (poly-amide), PPSU (poly-phenyl-sulfone), PC (poly-carbonate) and PP (polypropylene).

The first skin 12 may, preferably, have a thickness comprised between about 300 and about 1500 micrometres. Yet more preferably, the first skin 12 has a thickness comprised between about 500 and about 1200 micrometres.

The first skin 12 is provided with a plurality of micro through-holes 18, made by means of a conventional mechanical punching process, and distributed over its entire area. The micro-holes 18 are adapted to enable the passage of sound waves from the outside of the sound-absorbing panel 10 to its central layer 14. These micro-holes 18 may be variously distributed over the surface of the first skin 12.

Preferably, the micro-holes 18 are distributed in a regular and repetitive pattern, for example in offset rows as shown in Figure 1. Preferably, the micro-holes 18 cover a percentage of the area of the first skin 12 comprised between about 3% and about 50%, and more preferably comprised between about 3% and about 15%. Preferably, the diameter of the micro-holes 18 is comprised between about 100 micrometres and about 3000 micrometres. Yet more preferably, the micro-holes 18 have a diameter comprised between about 1000 and about 1500 micrometres. However, both the percentage of area covered by the micro-holes 18 and their diameter may be smaller or larger than described here purely by way of non-limiting example. The diameter and number of micro-holes 18 depends on the nature of the noise to be counteracted. For this reason, different micro-holes 18 will be used in different parts of an aeronautical engine. For example, while some diameters and opening percentages shall be used in the front part of the engine (depending on the noise that is propagating forwards), different percentages and diameters must be used in the engine's bypass duct, depending on the frequencies and propagation of the noise consistent with the airflow.

The thickness of the first skin 12, the number of micro-holes 18 and the diameter thereof are calculated depending on the nature (level and frequencies) of the noise to be reduced through of a set of mathematical models validated with experimental tests owned by the Applicant. The ideal skin 12 is then assessed for mechanical resistance and maintainability and reparability requirements. The optimum range is defined by drawing a compromise between acoustic performance, which would require a minimum thickness, and resistance performance.

In general, the dimensional ranges described here preferably with respect to the diameter of the micro-holes 18, the percentage of micro-holes 18 on the first skin 12, and the thickness of the first skin 12 are particularly suitable for applications in civil aircraft.

The central layer 14 may be made in several materials. Purely by way of non-limiting example, the central layer 14 can be made in a thermoplastic polymer material, or in aluminium, or even in a composite material with a phenolic resin matrix reinforced with glass fibres, or in a material with meta-aramid, such as Nomex®. The central layer 14 preferably has a known honeycomb structure.

In any event, the central layer 14 is made in such a way to define a vertical separation of volumes, as shown for example in Figure 1. Together with the first skin 12 and the second skin 16, these volumes define a plurality of resonance chambers 20. In another embodiment, the central layer 14 may have a three-dimensional structure formed by a plurality of walls that are mutually converging and/or intersecting, adapted t distance the first skin 12 from the second skin 16, and to define, between them, a plurality of cavities, or resonance chambers 20, of variable geometry, each in communication with the outside of the sound-absorbing panel 10 through at least one micro-hole 18 of the first skin 12. In this particularly preferable latter embodiment, also the central layer 14 is made in a thermoplastic material.

The second skin 16 has a generally thin, or film-like structure, or has a much smaller thickness than the two other dimensions and, when the sound-absorbing panel 10 is fitted for use, it faces the side opposite the sound source; in particular, the second skin 16 faces the side opposite the engine, that is to say in a radially external direction in relation to the nacelle. The second skin 16 may be equal or equivalent to the first skin 12 in terms of thickness, area and shape, but has no micro-holes. The second skin 16 may be made, purely by way of non-limiting example, in a polymeric material, or in a composite material, for example with an epoxy resin matrix reinforced with fibres, for example carbon fibres. Non-limiting examples of materials suitable for making the second skin 16 are: epoxy resin and epoxy resin reinforced with fibres, bismaleimide resin and bismaleimide resin reinforced with fibres, cyanate esters and cyanate esters reinforced with fibres, and polyimide and polyimide reinforced with fibres. Advantageously, the second skin 16, the central layer 14 and the first skin 12 are all made with the same thermoplastic material.

By virtue of the presence of micro through-holes 18, the sound can pass through the first skin 12 and reach the inside of the sound-absorbing panel 10, entering the resonance chambers 20, where it remains confined due to the continuous and un-holed surface of the second skin 16, thus enabling a significant reduction in the sound power dispersed.

As shown in particular in Figure 2, the sound-absorbing panel 10 may be fitted in an engine nacelle 22, for example on an internal side 24 of one of its air intakes 26. In particular, Figure 2 also shows a blade 28 of an engine turbine and a longitudinal axis x of the engine. As is clearly shown, the sound-absorbing panel 10 is mounted with the first skin 12 arranged towards the noise source sound source, i.e. towards the engine, and with the second skin 16 arranged on the opposite side.

According to the invention, the sound-absorbing panel 10 is obtained by securing together, two by two, the first skin 12 and the central layer 14, and the central layer 14 and the second skin 16 respectively. In particular, the method for manufacturing a sound-absorbing panel 10 according to the invention comprises the following steps in sequence:

a) providing a first skin 12 in a thermoplastic polymeric material;

b) making a plurality of micro-holes 18 through the first skin 12 by mechanical punching;

c) securing said first skin 12 to a central layer 14 by arranging a structural adhesive layer between the first skin 12 and the central layer 14 and/or by a thermal weld between the first skin 12 and the central layer 14; and

d) securing said central layer 14 to a second skin 16 by arranging a structural adhesive layer between the central layer 14 and the second skin 16 and/or by a thermal weld between the central layer 14 and the second skin 16.

So, initially, a first skin 12 in a thermoplastic polymeric material is provided. This first skin 12 can, for example, be made by means of a process of thermoforming on mould of a thermoplastic polymeric film, or by means of a similar known process for obtaining a first thin skin 12 in a thermoplastic polymeric material.

Through said first skin 12 of thermoplastic polymeric material, a plurality of micro through-holes 18 are made by mechanical punching, or by an equivalent conventional mechanical process. This process is well known and will not be described in further detail. Advantageously, the mechanical punching for making the plurality of micro-holes 18 passing through the first skin 12 may be performed before the process of thermoforming the first skin 12. Alternatively, the mechanical punching for making the plurality of micro-holes 18 passing through the first skin 12 may be performed even after the process of thermoforming the first skin 12. The central layer 14 and second skin 16 are secured, in that order, to said first skin 12.

Advantageously, in an embodiment of the method according to the invention, at least two adjacent components between the first skin 12, the central layer 14 and the second skin 16 - and, preferably, all three components - are made in an uncured material, and the above step c) and/or step d) further comprise the step of:

e) having the first skin 12, the central layer 14, and the second skin 16 undergo a curing process in autoclave with vacuum bag, according to a specific pressure and temperature cycle, for co-curing the uncured components.

When the union between the components of the sound-absorbing panel 10 is achieved by co-curing, said first skin 12 is arranged, in a known way, on a curing bed. Then, onto the first skin 12, the central layer 14 is arranged resting thereon. Finally, on the central layer 14, the second skin 16 is arranged. At this point, covering may take place with the typical bagging materials used in a curing process in autoclave with vacuum bag, materials such as a nylon film for high temperatures, a surface ventilation fabric in nylon or polyester and a separating film for high temperatures. They may be arranged, for example, manually in sequence on top of one another. Upon completion of the covering step, the application of vacuum onto the outermost layer of the curing bag may be performed in order to guarantee the adaptation of the bagging materials to the surfaces of the sound-absorbing panel 10, avoiding wrinkling and air bubbles. Finally, the assembly comprising the first panel 12, the central layer 14 and the second panel 16 undergoes a co-polymerization, or co-curing, process; this process involves the application of a specific temperature and pressure cycle (typically, around 180°C and 6 bar), known and therefore not described in further detail. On completing the co-curing process, the first panel 12, the central layer 14 and the second panel 16 are connected to form a single sound-absorbing panel 10.

It is possible to glue thermoplastic materials to other components in aluminium, in a material with a meta-aramid base, or in a composite material with a phenolic resin base reinforced with glass fibres by suitable preparation of the surface to be glued and/or by the use of coatings (so-called *primers*).

Indeed, when performing step c) and/or step d), in order to secure together two-by-two the first skin 12 and the central layer 14 and/or the central layer 14 and the second skin 16 respectively, a structural adhesive layer may be arranged between the first skin 12 and the central layer 14 and/or between the central layer 14 and the second skin 16 respectively. For example, the adhesive film Loctite EA 9658 Aero (also known as Hysol EA 9658) may be used as a structural adhesive.

It is possible to use the structural adhesive directly to secure together two-by-two the first skin 12 and the central layer 14 and/or the central layer 14 and the second skin 16 by means of a simple gluing method or, alternatively it is possible to use the structural adhesive in the context of a co-curing or co-polymerization process, by means of a so-called co-bonding process.

Furthermore, when performing step c) and/or step d), it is also possible to perform a thermal weld between the first skin 12 and the central layer 14, in order to secure said first skin 12 to the central layer 14, and/or, between the central layer 14 and the second skin 16 respectively, in order to secure said central layer 14 to the second skin 16, both independently and together with the gluing process just described.

The use of a thermal welding process to secure said first skin 12 made of thermoplastic material to others or to the same thermoplastic materials, in practice enables fillers to be used that have various and also variable geometric cavities and forms, where conventional fillers limit the form of the cavity to a repetitive single geometry.

Clearly, the method according to the invention is deemed equivalent when the order of arrangement of the first skin 12, the central layer 14 and the second 16 is reversed. In this case, the method remains unchanged except for reversing the order of steps b), c) and d), thus arranging the second skin 16 first then securing the central layer 14 thereto and, lastly, securing the first skin 12 to the central layer 14.

As regards the thermoplastic polymeric materials used in the method for manufacturing the various components of the sound-absorbing panel, the specific embodiments presented shall be considered as being given purely by way of non-limiting examples. In particular, thermoplastic materials that have an operating temperature comprised between about -70°C and about 120°C, sufficient resistance to external contaminants (oil, fuel and de-icing fluids), sufficient structural resistance and sufficient resistance to impact, according to the usual requirements of aeronautical components, are suitable for use in the method according to the invention.

In the most preferable embodiment of the manufacturing method according to the invention, the first skin 12, the central layer 14 and the second skin 16 are all made in the same thermoplastic polymeric material, and are secured together by means of a thermal welding process, and with the use of a structural adhesive layer. In this case, a first thermal weld may be performed to secure the first skin 12 and the central layer 14 together, and a second thermal weld may be performed to secure the central layer 14 and the second skin 16 together.

In another preferable embodiment of the manufacturing method according to the invention, the first skin 12 is made in a thermoplastic polymeric material, the central layer 14 is made in a composite material reinforced with glass fibre, and the second skin 16 is made in a composite material with an epoxy resin base and reinforced with carbon fibres. In this embodiment, the first skin 12, the central layer 14 and the second skin 16 are secured together two by two by simple gluing, that is to say by arranging respective layers of structural adhesive layers interposed between the first skin 12 and the central layer 14 and between the central layer 14 and the second skin 16 respectively.

In general, a sound-absorbing panel obtained by means of a method according to the invention may be used in any aeronautical environment in which it is necessary to attenuate a sound impact or reduce a transmission of noise, as is necessary in particular in an engine nacelle.

As illustrated by the above description, the manufacturing method according to the present invention offers various advantages.

Firstly, by virtue of the possibility of using a simple mechanical process like punching in order to make the micro-holes, the cost and time required to produce the sound-absorbing panel are considerably reduced.

Furthermore, by virtue of the use of a polymeric material to make the first skin with micro-holes, the weight of the sound-absorbing panel is reduced, with clear advantages for aeronautical applications.

Lastly, the simplicity of the mechanical technique for making the micro-holes enables maximum flexibility in varying the hole-making pattern, both in terms of dimension of the micro-holes and in terms of the position and number thereof.

Finally, by virtue of the use of thermoplastic materials preferably also in making the central layer, it is possible to obtain complex forms and different acoustic cavities.

Without undermining the principle of the invention, the embodiments and details of manufacture may be extensively varied compared to what has been described and illustrated purely by way of non-limiting example, without departing from the scope of the invention as defined in the accompanying claims.

CLAIMS

1. Method for manufacturing a sound-absorbing panel (10) with a sandwich structure for reducing the noise impact of an aeronautic engine, comprising the following steps in sequence:

a) providing a first skin (12) in a thermoplastic polymeric material;

b) making a plurality of micro-holes (18) through the first skin (12) by mechanical punching of the first skin (12);

c) securing said first skin (12) to a central layer (14) by arranging a structural adhesive layer between the first skin (12) and the central layer (14) and/or by a thermal weld between the first skin (12) and the central layer (14); and

d) securing said central layer (14) to a second skin (16) by arranging a structural adhesive layer between the central layer (14) and the second skin (16) and/or by a thermal weld between the central layer (14) and the second skin (16).

2. Manufacturing method according to claim 1, wherein at least two among the first skin (12), the central layer (14) and the second skin (16) comprise uncured polymerizable material, and wherein step c) and/or step d) further comprise the step of:

e) having the first skin (12), the central layer (14), and the second skin (16) undergo a curing process in autoclave with vacuum bag, according to a specific pressure and temperature cycle, for co-curing the uncured components.

3. Manufacturing method according to claim 1 or to claim 2, further comprising the step of:

a0) having the first skin (12) undergo a process of thermoforming on mold.

4. Manufacturing method according to claim 3, wherein step a0) follows step b).

5. Sound-absorbing panel (10) obtained by a method according to any one of the preceding claims.

6. Sound-absorbing panel according to claim 5, wherein the central layer (14) is made

in a thermoplastic material, or in aluminium, or in a material with a meta-aramid base, or in a composite material with a phenolic resin base reinforced with glass fibres.

7. Sound-absorbing panel according to claim 5 or to claim 6, wherein the central layer (14) has a honeycomb structure.

8. Sound-absorbing panel according to any one of claims 5 to 7, wherein the second skin (16) is made in a polymeric material or in a composite material with a thermosetting polymeric matrix and a fibre reinforcement.

9. Sound-absorbing panel according to any one of claims 5 to 8, wherein the first skin (12) is made in a thermoplastic polymer material in the list comprising: PEEK (polyether-ether-ketone), PEK (polyether-ketone), PEI (polyether-imide), nylon, PET (polyethylene terephthalate), PAEK (poly-aryl-ether-ketone), PPS (poly-para-phenyl-sulphide), PA (poly-amide), PPSU (poly-phenyl-sulfone), PC (poly-carbonate) and PP (polypropylene).

10. Sound-absorbing panel according to any one of claims 5 to 9, wherein the first skin (12) has a thickness comprised between about 300 and about 1500 micrometres, more preferably between about 500 and about 1200 micrometres.

11. Sound-absorbing panel according to any one of claims 5 to 10, wherein the micro-holes (18) cover a percentage of the area of the first skin (12) comprised between about 3% and about 50%, more preferably comprised between about 3% and about 15%.

12. Sound-absorbing panel according to any one of claims 5 to 11, wherein the diameter of the micro-holes (18) is comprised between about 100 micrometres and about 3000 micrometres, preferably between about 1000 and about 1500 micrometres.

13. Sound-absorbing panel according to any one of claims 6 to 11, wherein the central layer (14) is made in a thermoplastic material and has a three-dimensional structure formed by a plurality of walls that are mutually converging and/or intersecting, adapted to distance the first skin (12) from the second skin (16), and to define, between them, a plurality of

resonance chambers (20) of variable geometry, each resonance chamber (20) being in communication with the outside of the sound-absorbing panel (10) through at least one microhole (18) of the first skin (12).

14. Aircraft engine nacelle (22) comprising a sound-absorbing panel (10) according to any one of claims 5 to 13.

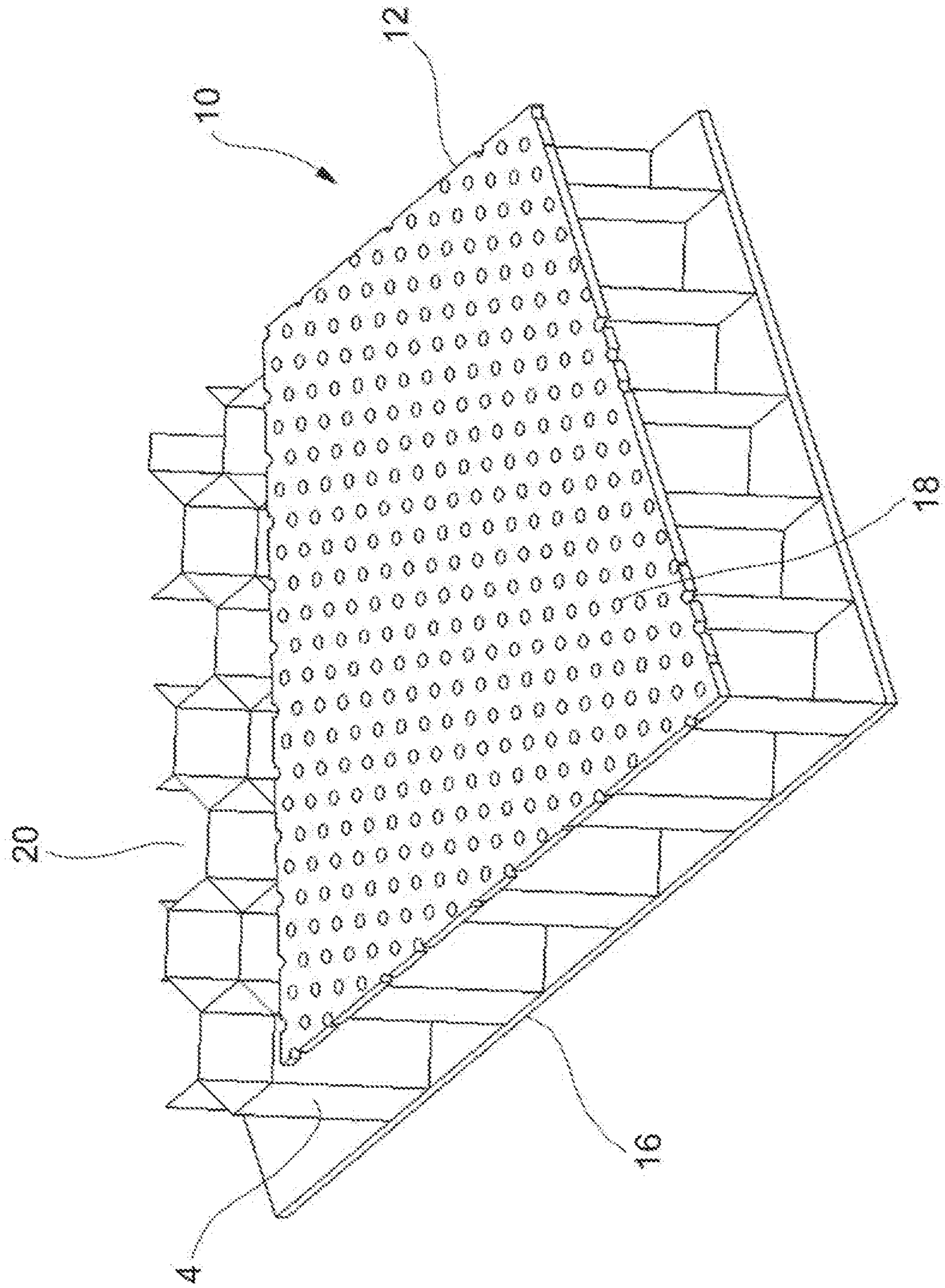

FIG.1

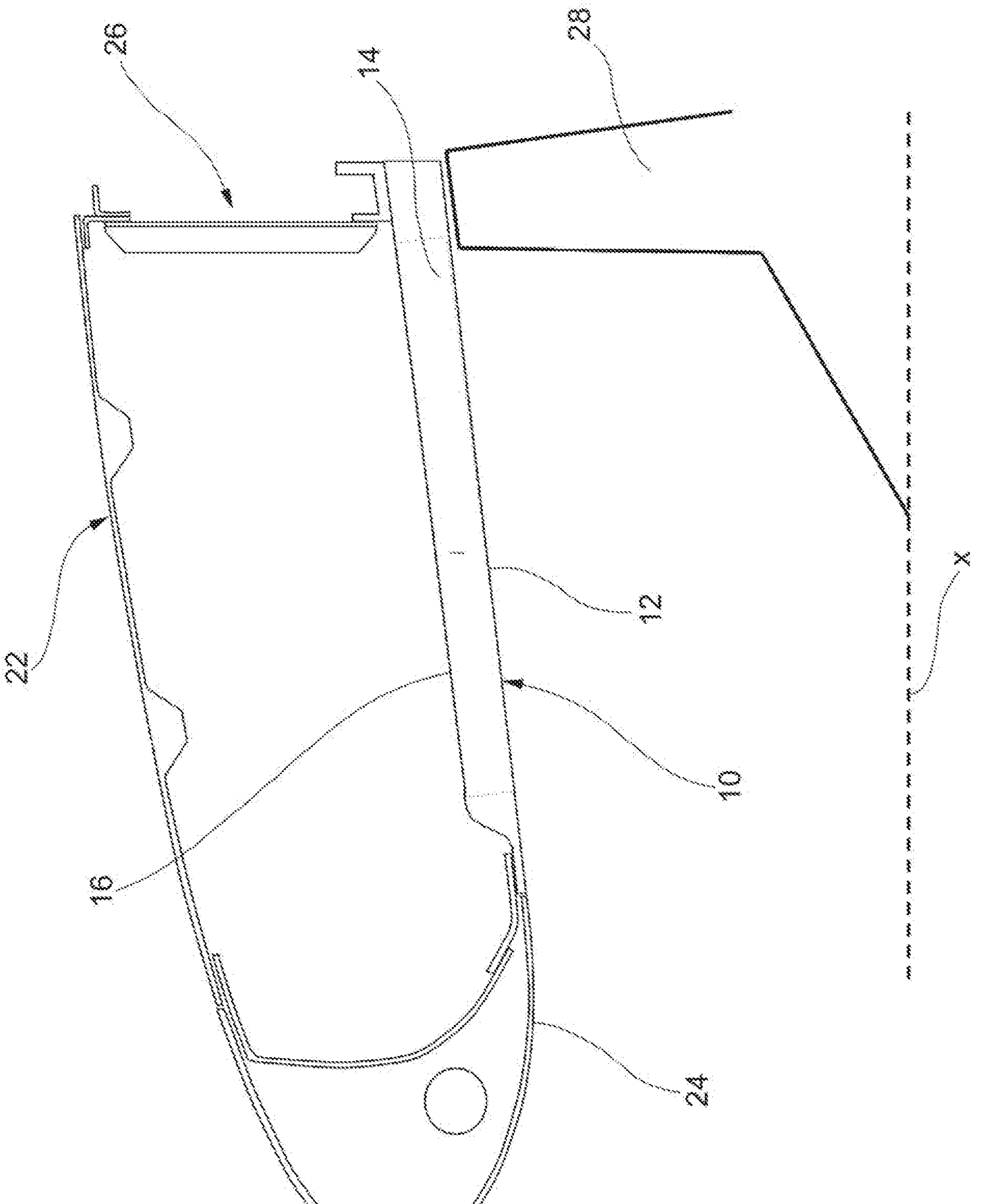

FIG.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/052900

A. CLASSIFICATION OF SUBJECT MATTER
INV. B32B3/12 B32B3/26 B32B7/12 B32B15/085 B32B15/088
B32B15/09 B32B15/20 B32B27/28 B32B27/32 B32B27/34
B32B27/36 B32B27/08 B32B27/38 B32B27/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2 017 077 A2 (ALENIA AERMACCHI SPA [IT]) 21 January 2009 (2009-01-21) paragraphs [0001], [0002], [0005], [0009] - [0014], [0017], [0018], [0021] - [0024] claims 1,4-6 -----	1-14
A	US 4 759 513 A (BIRBRAGHER FERNANDO [US]) 26 July 1988 (1988-07-26) page 2, column 3, line 1 claims 1,5 -----	1-14
A	US 2013/075193 A1 (VAVALLE ARMANDO [GB]) 28 March 2013 (2013-03-28) abstract paragraphs [0001] - [0003], [0005] - [0012], [0017], [0045], [0055] - [0058], [0160], [0190] -----	1-14
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 June 2020	03/07/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Yu, Sze Man

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/052900

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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