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 DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
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 KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
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(54) Title: A PROCESS OF MANUFACTURING A CARBON FIBRE REINFORCED POLYMER ELEMENT, A PROCESS
 OF MANUFACTURING A CARBON FIBRE REINFORCED POLYMER LAMINATED PREFORM, A CARBON FIBRE REIN-
 FORCED POLYMER LAMINATED PREFORM AND A CARBON FIBRE REINFORCED POLYMER ELEMENT

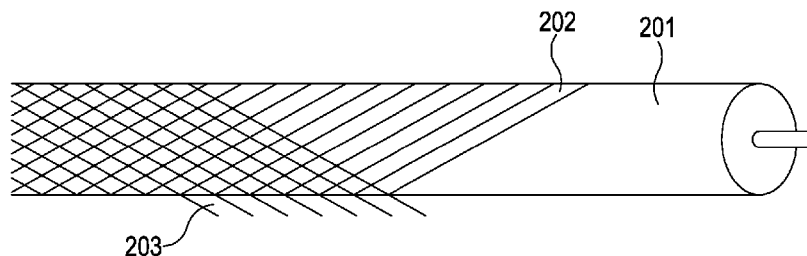


Figure 2

(57) Abstract: A process of manufacturing a carbon fibre reinforced polymer laminated preform is disclosed, the process comprising the steps of applying at least one layer of adhesive (202) onto a bladder (201); applying at least one layer of carbon fibre (203) onto the bladder (201). The invention also concerns a carbon fibre reinforced polymer laminated preform, a process of manufacturing a carbon fibre reinforced polymer element, and a carbon fibre reinforced polymer element.



A process of manufacturing a carbon fibre reinforced polymer element, a process of manufacturing a carbon fibre reinforced polymer laminated preform, a carbon fibre reinforced polymer laminated preform and a carbon fibre reinforced polymer element

The invention relates to manufacturing carbon fibre elements and to carbon fibre elements.

5 More specifically, the invention relates to a process of manufacturing a carbon fibre reinforced polymer element, a process of manufacturing a carbon fibre reinforced polymer laminated preform, a carbon fibre reinforced polymer laminated preform and a carbon fibre reinforced polymer element.

There are several processes for manufacturing composites, including composites comprising
10 carbon fibres, which are known in the art.

Resin transfer moulding (RTM) is a method of fabricating high-tech composite structures. RTM uses a closed mould commonly made of aluminium. A fibre "layup" such as graphite is placed into the mould. The mould is closed, sealed, heated, and placed under vacuum. Heated resin is injected into the mould to impregnate the fibre layup.

15 In high-pressure resin transfer moulding (HP-RTM) process, the first step is building up a fibre preform. A very low-viscosity, reactive resin is injected into the cavity at high pressure ensuring that each individual fibre is wetted and that there are not any air voids.

Many high-performance thermoset parts require heat and high consolidation pressure to cure — conditions that require the use of an autoclave. Autoclaves, generally, are expensive, result
20 in waste heating of space and the component. Manufacturers that are equipped with autoclaves usually have to cure a number of parts simultaneously.

The above solutions of the prior art however have several significant disadvantages. The known methods often require use of foam or rigid mandrels. In order to obtain a complex curvature

of the final element, a multi-axis robot typically has to be employed. The tooling or moulds used to obtain desired shapes are often highly pressurised and made of steel.

It is an object of the present invention to provide a technical solution to the issues outlined above, and which, in particular does not require heating of the tooling or mould, is cost-effective and reduces cycle times.

In accordance with a first aspect of the present invention, there is provided a process of manufacturing a carbon fibre reinforced polymer laminated preform, the process comprising the steps of: applying at least one layer of adhesive onto a bladder; applying at least one layer of carbon fibre onto the bladder.

In an embodiment, the process further comprises applying a plurality of layers of adhesive onto the bladder.

In an embodiment, the process further comprises applying a plurality of layers of carbon fibre onto the bladder.

In an embodiment, the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.

In an embodiment, one layer of adhesive is applied directly onto the bladder.

In an embodiment, applying the at least one layer of adhesive comprises spraying a layer of resin.

In an embodiment, applying the at least one layer of adhesive comprises winding a tape of resin film.

In an embodiment, the process further comprises inflating the bladder prior to applying at least one layer of adhesive or at least one layer of carbon fibre.

In an embodiment, applying at least one layer of carbon fibre comprises braiding a carbon fibre tow.

In an embodiment, the carbon fibre tow comprises dry carbon fibre.

In an embodiment, the carbon fibre tow is braided in a single linear direction.

In an embodiment, winding the tape of resin film begins before braiding of carbon fibre tow is finished.

In accordance with a second aspect of the present invention, there is provided a carbon fibre reinforced polymer laminated preform, the preform comprising: a bladder; at least one layer of adhesive; at least one layer of carbon fibre.

In an embodiment, the preform further comprises a plurality of layers of adhesive.

In an embodiment, the preform further comprises a plurality of layers of carbon fibre.

In an embodiment, the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.

In an embodiment, the at least one layer of adhesive comprises a tape of resin film.

In an embodiment, the at least one layer of carbon fibre comprises a carbon fibre tow.

In an embodiment, the carbon fibre tow comprises dry carbon fibre.

In accordance with a third aspect of the present invention, there is provided a process of manufacturing a carbon fibre reinforced polymer, CFRP, element, the process comprising steps of: positioning a preform within a mould defining a final shape of the CFRP element, the preform comprising carbon fibre and adhesive positioned onto a bladder; when the preform is positioned in the mould, introducing a heated and pressurised fluid into the bladder so as to infuse the adhesive into the carbon fibre, such that, the preform becomes cured to obtain the CFRP element.

In an embodiment, the preform is cured from inside of the bladder in an outward direction.

In an embodiment, the process further comprises the steps of: applying at least one layer of adhesive onto a bladder; applying at least one layer of carbon fibre onto the bladder such that the preform is obtained.

In an embodiment, the process further comprises applying a plurality of layers of adhesive onto the bladder.

In an embodiment, the process further comprises applying a plurality of layers of carbon fibre onto the bladder.

In an embodiment, the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.

In an embodiment, one layer of adhesive is applied directly onto the bladder.

5 In an embodiment, applying at least one layer of adhesive comprises spraying a layer of resin.

In an embodiment, applying at least one layer of adhesive comprises winding a tape of resin film.

In an embodiment, the process further comprises inflating the bladder prior to applying adhesive and carbon fibre.

10 In an embodiment, applying at least one layer of carbon fibre comprises braiding a carbon fibre tow.

In an embodiment, the carbon fibre tow comprises dry carbon fibre.

In an embodiment, the carbon fibre tow is braided in a single linear direction.

15 In an embodiment, winding the tape of resin film begins before the braiding of carbon fibre tow is finished.

In an embodiment, the mould comprises a first female portion and a second female portion, the portions representing a final geometry of an external surface of the CFRP element.

In an embodiment, the process further comprising applying vacuum to a cavity between the mould and the preform to remove air, subsequent to positioning the preform within the mould.

20 In an embodiment, positioning the preform comprises adjusting a shape of the bladder so as to fit the mould.

In an embodiment, the process further comprises removing the bladder from the preform subsequent to the introduction of heated and pressurised fluid into the preform.

25 In an embodiment, the process further comprises heating the fluid to a temperature of at least 120°C, pressurising the fluid to a pressure of substantially 3 bar and retaining the fluid in the bladder for substantially 3 hours.

In an embodiment, there is provided a carbon fibre reinforced polymer element obtainable by a process according to the third aspect.

Whilst the invention has been described above, it extends to any inventive combination of features set out above or in the following description. Although illustrative embodiments of the invention are described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments.

Furthermore, it is contemplated that a particular feature described either individually or as part of an embodiment can be combined with other individually described features, or parts of other embodiments, even if the other features and embodiments make no mention of the particular feature. Thus, the invention extends to such specific combinations not already described.

The invention may be performed in various ways, and, by way of example only, embodiments thereof will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates steps of a process of manufacturing a carbon fibre reinforced polymer laminated preform according to a first embodiment.

Figure 2 illustrates steps of the process of figure 1.

Figure 3 illustrates a carbon fibre reinforced polymer laminated preform according to a third embodiment.

Figure 4 illustrates steps of a process of manufacturing a carbon fibre reinforced polymer element according to a second embodiment.

Figure 5 illustrates steps of the process of figure 4.

Figure 6 illustrates an example carbon fibre reinforced polymer element obtainable by a process of figure 4.

Figures 1 and 2 illustrate an example process 100 of manufacturing a carbon fibre reinforced polymer (CFRP) laminated preform. At step 101, a bladder is provided. At step 102, a layer 202 of adhesive is applied onto a bladder 201 which may be pre-inflated, to obtain a semiproduct. The application may be performed by winding a tape 202 of resin film or by spraying a layer of resin onto the bladder 201. At step 103, a layer of carbon fibre is applied onto the semiproduct to obtain a laminated preform 200. The application of the layer of carbon fibre may include braiding a carbon fibre tow 203 using a braider (not shown). In one example, fibres of the carbon fibre may be braided in their net shape orientations or layup at close to 180° to achieve a final curvature of substantially 90°. The bladder 201 may comprise a tube made of natural rubber or silicon, and is sufficiently rigid so that the braiding step results in a sustainable carbon fibre pattern on the bladder 201, and is elastic enough such that a curvature of the bladder 201 may be manipulated to achieve a desired shape of the preform, in particular to achieve concave sections of the preform. More than one layer 202, 204 of adhesive and more than one layer 203 of carbon fibre may be applied, in more than one order of application. For example, the layers 202, 203 and 204 could be alternately applied onto the bladder 201. The at least one layer 202, 204 of adhesive may comprise a tape of thermoplastic resin film 202, 204. The at least one layer 203 of carbon fibre tow 203 may comprise dry carbon fibre and may be braided in a single linear direction. Winding the layer 204 of adhesive may begin before braiding of carbon fibre tow 203 is finished.

The process 100 can be used to obtain an example CFRP laminated preform 200, as illustrated by figure 3. The preform 200 comprises a first layer 202 of adhesive wound onto an external surface 201a of the bladder 201. A carbon fibre tow 203 is braided onto the first layer 202 and a second layer 204 of adhesive is wound onto the carbon fibre tow 203. The first layer 202 of adhesive or second layer 204 of adhesive may comprise a tape of thermoplastic resin film. The carbon fibre tow 203 may comprise dry carbon fibre, wherein each specific weave is coated with an amount of epoxy while it is being made, before it has set or cured. By using a process 100, a near net shape braided preform 200 can be obtained.

Figures 4 and 5 illustrate an example process 300 of manufacturing a CFRP element. At step 301, the bladder 411 is inflated with gas or liquid which may be introduced into the bladder 411. At step 302, a first layer 412 of adhesive is wound onto the bladder 411 to obtain a first semiproduct. At step 303, a carbon fibre tow 413 is braided onto the first semiproduct to obtain a second semiproduct. At step 304, a second layer 414 of adhesive is wound onto the second semiproduct to obtain the preform 410. The first layer 412 of adhesive or second layer 414 of adhesive may comprise a tape of resin film, and the carbon fibre tow 413 may comprise dry carbon fibre 413. The carbon fibre tow 413 may be braided in a single linear direction. The step 304 of winding the second layer 414 of adhesive may begin before the step 303 braiding of carbon fibre tow is finished. At step 305, the preform 410 is positioned within a mould 420 which defines a final shape of the CFRP element. The mould 420 may comprise a first female portion 421 and a second female portion 422, the portions 421, 422 representing a final geometry of an external surface of the CFRP element. The mould 420 may be a lightweight and low cost shell mould tool, eliminating the need for a block tool (not shown). At step 306, a shape of the bladder 411 may then be adjusted so as to fit the interior of the mould 420. The preform 410 comprises carbon fibre 413 and adhesive 412, 414 positioned onto a bladder 411. At step 307, a vacuum may be applied to a cavity between the mould 420 and the preform 410 to remove air, subsequent to positioning the preform 410 within the mould 420. When the preform 410 is positioned in the mould 420, at step 308, a heated and pressurised fluid is introduced into the bladder 411 so as to infuse the adhesive 412, 414 into the carbon fibre 413, such that, the preform 410 becomes cured to obtain the CFRP element. In one example, the fluid has a temperature of at least 120°C and remains in the bladder for 3 hours, at a pressure of 3 bar. In particular, curing is performed in a direction which is from inside of the bladder 411 toward the outside. The preform 410 may comprise a first layer 412 of adhesive wound onto a bladder 411, a carbon fibre tow 413 braided onto the first layer 412 and a second layer 414 of adhesive wound onto the carbon fibre tow 413. The first layer 412 of adhesive or second layer 414 of adhesive may comprise a tape of resin film and the carbon fibre tow 413 may comprise dry carbon fibre. At step

309, the bladder 411 is removed from the preform 410 subsequent to the introduction of heated and pressurised fluid into the preform. As a result of the process 300, a carbon fibre reinforced polymer (CFRP) element may be obtained.

Figure 6 illustrates an example CFRP element 500 obtainable by the process 300, which may be used with airbags, planar fixing pads, harness routings and other automotive applications. The element 500 may be hollow and may comprise a plurality of cross-sections 510a, 510b, 510c, wherein each cross section may be of different shape and size so as to achieve a complex curvature of the entire element 500. As an example, at least one of the cross sections 510a, 510b, 510c may be concave. At least one section of the element 500 may be locally reinforced. The element 500 comprises an improved class A surface and improved carbon fibre orientation.

Claims

1. A process of manufacturing a carbon fibre reinforced polymer laminated preform, the process comprising the steps of:
 - applying at least one layer of adhesive onto a bladder;
 - 5 applying at least one layer of carbon fibre onto the bladder.
2. A process according to claim 1, further comprising applying a plurality of layers of adhesive onto the bladder.
3. A process according to any preceding claim, further comprising applying a plurality of layers of carbon fibre onto the bladder.
- 10 4. A process according to claim 3 when appended to claim 2, wherein the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.
5. A process according to any preceding claim, wherein one layer of adhesive is applied directly onto the bladder.
6. A process according to any of the preceding claims, wherein applying the at least one layer of
15 adhesive comprises spraying a layer of resin.
7. A process according to any of the preceding claims, wherein applying the at least one layer of adhesive comprises winding a tape of resin film.
8. A process according to any preceding claim, further comprising inflating the bladder prior to applying at least one layer of adhesive or at least one layer of carbon fibre.
- 20 9. A process according to any preceding claim, wherein applying at least one layer of carbon fibre comprises braiding a carbon fibre tow.
10. A process according to claim 9, wherein the carbon fibre tow comprises dry carbon fibre.
11. A process according to any of the claims 9 to 10, wherein the carbon fibre tow is braided in a single linear direction.
- 25 12. A process according to claims 9 to 11 when appended to claim 7, wherein winding the tape of resin film begins before braiding of carbon fibre tow is finished.

13. A carbon fibre reinforced polymer laminated preform, the preform comprising:
- a bladder;
 - at least one layer of adhesive;
 - at least one layer of carbon fibre.
- 5 14. A preform according to claim 13, further comprising a plurality of layers of adhesive.
15. A preform according to any of the preceding claims 13 to 14, further comprising a plurality of layers of carbon fibre.
16. A preform according to claim 15 when appended to claim 14, wherein the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.
- 10 17. A preform according to any of the preceding claims 13 to 16, wherein the at least one layer of adhesive comprises a tape of resin film.
18. A preform according to claim 13 to 17, wherein the at least one layer of carbon fibre comprises a carbon fibre tow.
19. A preform according to claim 18, wherein the carbon fibre tow comprises dry carbon fibre.
- 15 20. A process of manufacturing a carbon fibre reinforced polymer, CFRP, element, the process comprising steps of:
- positioning a preform within a mould defining a final shape of the CFRP element, the preform comprising carbon fibre and adhesive positioned onto a bladder;
 - when the preform is positioned in the mould, introducing a heated and pressurised fluid into

20 the bladder so as to infuse the adhesive into the carbon fibre, such that, the preform becomes cured to obtain the CFRP element.
21. A process according to claim 20, wherein the preform is cured from inside of the bladder in an outward direction.
22. A process according to any of the claims 20 to 21, further comprising the steps of:
- 25 applying at least one layer of adhesive onto a bladder;

applying at least one layer of carbon fibre onto the bladder, such that the preform is obtained.

23. A process according to claim 22, further comprising applying a plurality of layers of adhesive onto the bladder.

5 24. A process according to any of the preceding claims 22 to 23, further comprising applying a plurality of layers of carbon fibre onto the bladder.

25. A process according to claim 24 when appended to claim 23, wherein the layers of adhesive and layers of carbon fibre are alternately applied onto the bladder.

10 26. A process according to any of the preceding claims 22 to 25, wherein one layer of adhesive is applied directly onto the bladder.

27. A process according to any of the preceding claims 22 to 26, wherein applying at least one layer of adhesive comprises spraying a layer of resin.

28. A process according to any of the preceding claims 22 or 27, wherein applying at least one layer of adhesive comprises winding a tape of resin film.

15 29. A process according to any of the preceding claims 22 to 28, further comprising inflating the bladder prior to applying adhesive and carbon fibre.

30. A process according to any of the claims 22 to 29, wherein applying at least one layer of carbon fibre comprises braiding a carbon fibre tow.

31. A process according to claim 30, wherein the carbon fibre tow comprises dry carbon fibre.

20 32. A process according to any of the claims 30 to 31, wherein the carbon fibre tow is braided in a single linear direction.

33. A process according to claims 30 to 32 when appended to claim 28, wherein winding the tape of resin film begins before the braiding of carbon fibre tow is finished.

25 34. A process according to any of the preceding claims 20 to 33, wherein the mould comprises a first female portion and a second female portion, the portions representing a final geometry of an external surface of the CFRP element.

35. A process according to any of the preceding claims 20 to 34, further comprising applying vacuum to a cavity between the mould and the preform to remove air, subsequent to positioning the preform within the mould.
36. A process according to any of the preceding claims 20 to 35, wherein positioning the preform
5 comprises adjusting a shape of the bladder so as to fit the mould.
37. A process according to any of the preceding claims 20 to 36, further comprising removing the bladder from the preform subsequent to the introduction of heated and pressurised fluid into the preform.
38. A process according to any of the preceding claims 20 to 37, further comprising heating the fluid
10 to a temperature of at least 120°C, pressurising the fluid to a pressure of substantially 3 bar and retaining the fluid in the bladder for substantially 3 hours.
39. A carbon fibre reinforced polymer element obtainable by a process according to any of the preceding claims 20 to 38.

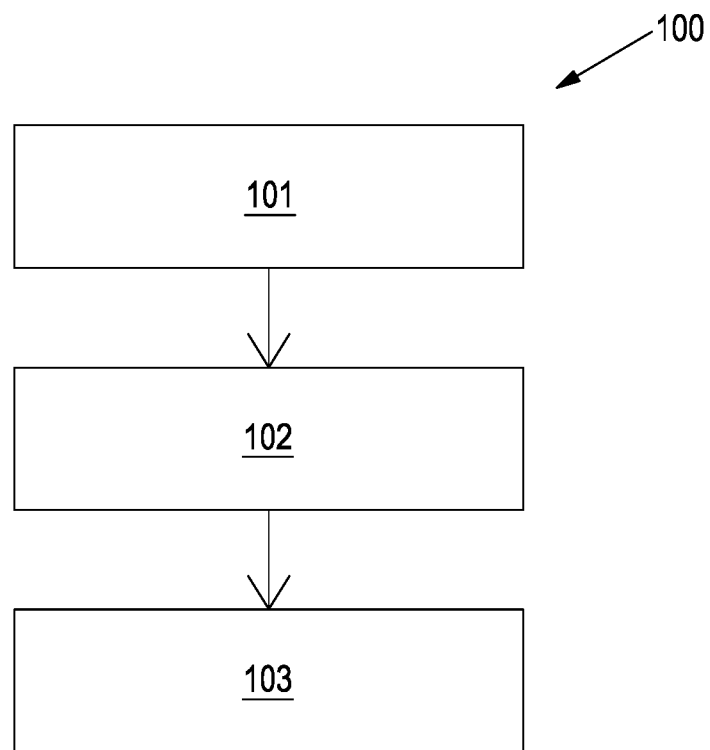


Figure 1

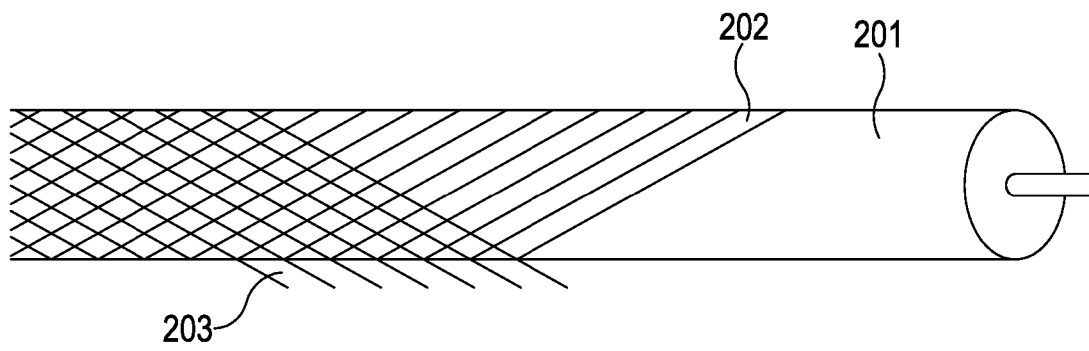


Figure 2

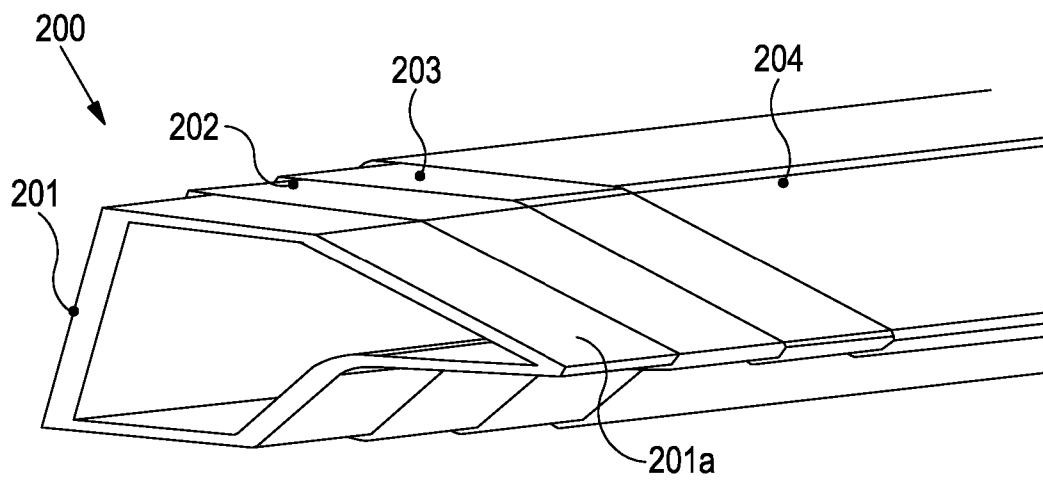


Figure 3

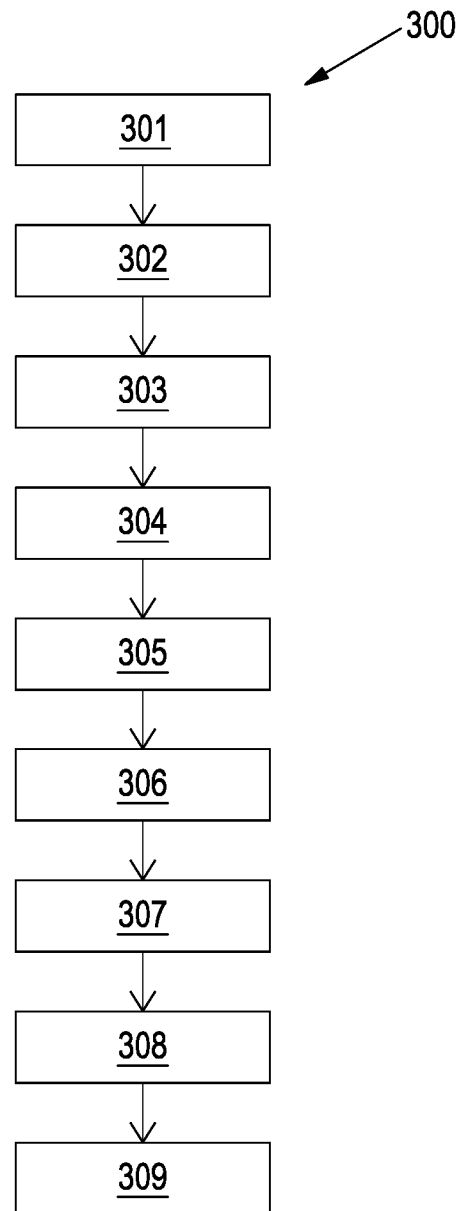


Figure 4

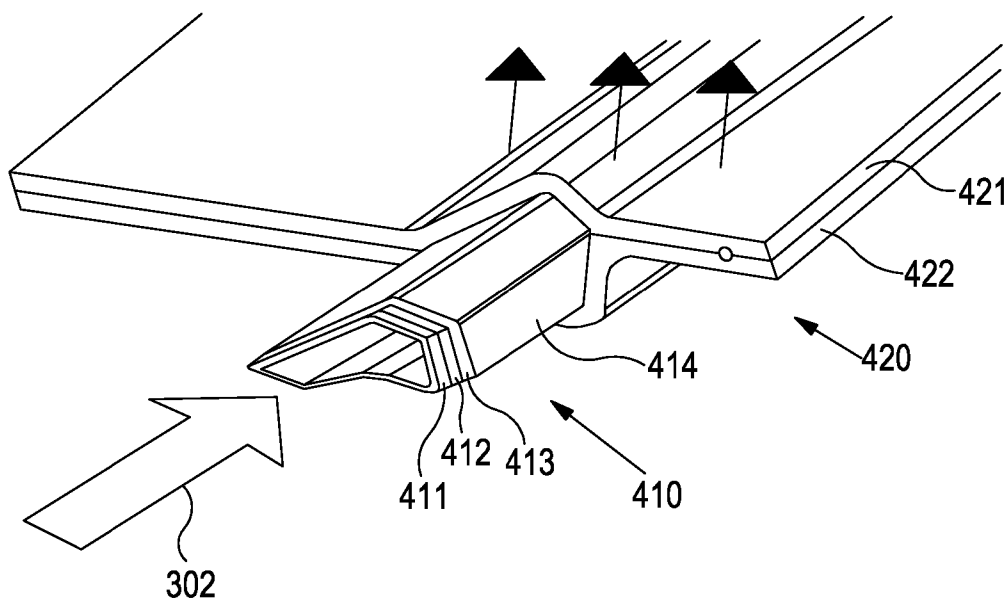


Figure 5

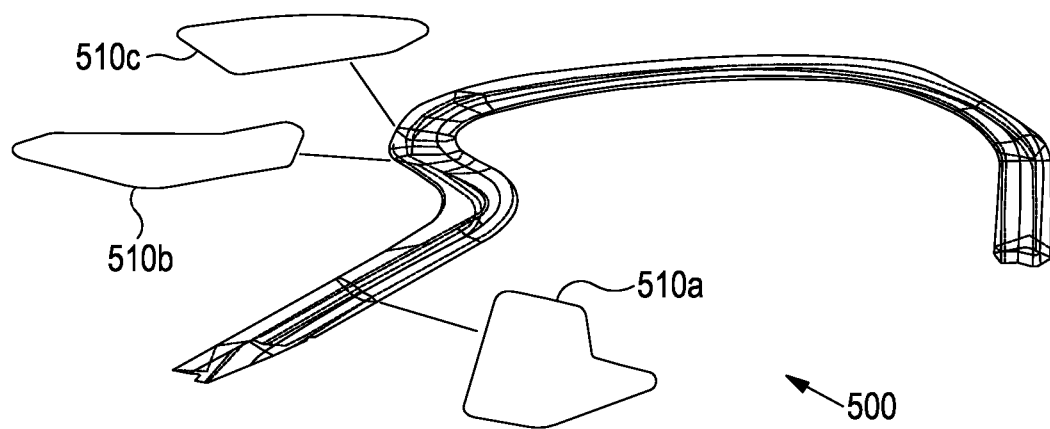


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2019/051886

A. CLASSIFICATION OF SUBJECT MATTER		
INV. B29D23/00	B29C53/82	B29B11/16
ADD. B29C53/56	B29C70/22	B29K307/04
		B29C70/30
		B29K105/08
		B29C33/50
		B29L23/00
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) B29B B29C		
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		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/294421 A1 (FUJIKI SOHEI [JP] ET AL) 25 November 2010 (2010-11-25) paragraphs [0043], [0044], [0059] figures 1-5 -----	1-19
X	EP 1 275 491 A1 (ECOLE POLYTECH [CH]) 15 January 2003 (2003-01-15)	1-19
Y	paragraphs [0001], [0024] - [0027], [0029] figures 1-3, 7, 8 -----	20-39
Y	FR 1 207 015 A (CASIMIR-ANDRÉ LOUBIÈRE) 12 February 1960 (1960-02-12) page 1, column 1, line 1 - line 18 page 2, column 2, line 6 - line 30 page 3, column 2, line 26 - line 56 figures 1-12 -----	20-39
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 28 August 2019		Date of mailing of the international search report 04/09/2019
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Dias, Filipe

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/051886

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
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