System and method for fabricating a composite material assembly

Abstract: A system and method for fabricating a composite material assembly. The components of the assembly originate from more than one mold while providing curing or solidifying under heat and vacuum in one step only, preferably with a composite material in a pre-preg form which does not require autoclave treatment. A removable insert is removed from a second mold prior to assembly of the first mold to the second mold. A section of a laminate extending over the removable insert overlaps over an adjacent laminate after closing and assembly of the first mold onto the second mold.
WO 2011/095834

LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG). Published: — with international search report (Art. 21(3))
SYSTEM AND METHOD FOR FABRICATING A COMPOSITE MATERIAL ASSEMBLY

FIELD OF THE INVENTION

The present invention generally relates to composite materials. The present invention more specifically relates to a system and method for fabricating a composite material assembly.

BACKGROUND OF THE INVENTION

Composite material assembly, and more particularly fuselage manufacturing through the use of multi-piece sections, typically requires pre-solidification and cure of each piece prior to assemble them with splices between individual sections or portions.

The limitations of this methodology are:
- a minimum two-step cure is required;
- additional mechanical fasteners are required at splicing joints on primary structure components;
- the methodology requires handling equipment and assembly jigs (for out-of-mold operations);
- long fuselage manufacturing time;
- over thickness at joints resulting in stress concentration;
- increases in weight of assembly; and
- surface preparation is required prior to bonding.

Various solutions for assembly of multi-piece sections have been proposed in the prior art.
US 7,459,048 discloses a method of manufacturing a unitary section of an aircraft fuselage including steps of disposing a thin layup mandrel element onto the outer shell surface of a cylindrical inner mandrel shell to form a mandrel with a layup surface. The method further includes steps of laying-up fibers onto the layup surface while the mandrel rotates to form a unitary pre-cured section of an aircraft fuselage.

WO 98/32589 discloses composite structures having a continuous skin formed using automated fiber placement methods. The multiple layers of fibers are placed on a fiber placement tool including a mandrel body surrounded by a bladder. Uncured composite structures are created by placing fibers around the fiber placement tool as discontinuous segments that are capable of moving or sliding in relation to each other in order to be expandable from within. The uncured stuctures are then expanded against the other surface of the molds by creating a vacuum between the bladder and the molds.

US 7,325,771 discloses structures and methods for joining composite fuselage sections using spliced joints attaching a first stiffener on a first composite part as well as a second stiffener on a second composite part through a fitting. A strap is then used to splice the first and second composite parts together.

US 2006/0251847 discloses a method of joining composite elements in which the bonding is done through the thickness of fiber composite laminates in order to reduce interlaminar stresses using non-interlocking and interlocking bonds.

US 2009/0148647 discloses a method of fabricating composite structures by joining a plurality of composite modules along their edges using scarf joints instead of using advance fiber placement machines that require high capital investment and operating costs.
However, there is still a need for a system and method for fabricating composite material assemblies that facilitate assembly of parts when forming structures while minimizing assembly equipment costs.

5 SUMMARY OF THE INVENTION

An object of the present invention is to propose a system and method that satisfies at least one of the above-mentioned needs.

According to the present invention, that object is accomplished with a system for fabricating a composite material assembly comprising:

- a first mold for receiving a first module made of composite material, the first mold comprising:
  - a first composite material laminate support structure having first and second opposite edges; and
  - a first attachment interface for attachment of the first mold to an adjacent mold; and
- a second mold for receiving a second module made of composite material, the second mold comprising:
  - a second composite material laminate support structure having first and second opposite edges;
  - a second attachment interface for attachment of the second mold to the first mold; and
- at least one removable insert extending beyond at least one of the first and second edges of the second mold,

wherein the first module comprises a first laminate covering the first laminate support structure, the second module comprises a second laminate covering the second laminate support structure and extending over the at least one removable insert, and wherein the at least one removable insert is removed from the second mold prior to
assembly of the first mold to the second mold, and a section of the second laminate extending over the at least one removable insert overlaps over the first laminate after closing and assembly of the first mold onto the second mold.

According to the present invention, there is also provided a method for fabricating a composite material assembly comprising the steps of:

a) providing an assembly system comprising:
   - a first mold for receiving a first module made of composite material, the first mold comprising:
     - a first composite material laminate support structure having first and second opposite edges; and
     - a first attachment interface for attachment of the first mold to an adjacent mold;
   and
   - a second mold for receiving a second module made of composite material, the second mold comprising:
     - a second composite material laminate support structure having first and second opposite edges;
     - a second attachment interface for attachment of the second mold to the first mold; and
     - at least one removable insert extending beyond at least one of the first and second edges of the second mold;

b) laying down the first module on the first mold, the first module comprising a first laminate covering the first laminate support structure;
c) laying down the second module on the second mold, the second module comprising a second laminate covering the second laminate support structure and extending over the at least one removable insert;
d) removing the at least one removable insert from the second mold; and
e) assembling the first mold to the second mold while overlapping a section of the second laminate extending over the at least one removable insert over the first laminate.

The present invention provides means for manufacturing one-piece composite components originating from more than one mold while providing a structure that can be cured or solidified under heat and vacuum in one step only, preferably with a composite material in a pre-preg form which does not require autoclave treatment.

A non-restrictive description of a preferred embodiment of the invention will now be given with reference to the appended drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figures 1a to 1c are side cross-sectional views of the system according to a preferred embodiment of the present invention, showing an assembly sequence of a first monolithic laminate on a first mold onto a second monolithic laminate of a second mold with prior removal of a removable insert;

Figures 2a to 2c are side cross-sectional views of the system according to another preferred embodiment of the present invention, showing an assembly sequence of a first sandwich laminate on a first mold onto a second sandwich laminate of a second mold with prior removal of a removable insert, and a subsequent addition of a layup splice;

Figures 3a to 3e are front views of a build sequence of a tubular component using the system according to another preferred embodiment of the present invention, using one removable insert per mold;
Figures 4a to 4e are perspective views of the build sequence of the tubular component shown in Figures 3a to 3e;

Figures 5a to 5c are front views of initial steps of a build sequence of a tubular component using the system according to another preferred embodiment of the present invention, with an alternate distribution of removable inserts with respect to the molds, with no insert on a first mold, one (1) insert on a second mold and two (2) inserts on a third mold;

Figures 6a to 6c are perspective views of the build sequence of the tubular component shown in Figures 5a to 5c;

Figure 7 is a perspective view of a build sequence of a fuselage component using the system according to another preferred embodiment of the present invention and showing installation of composite layup materials by personnel; and

Figures 8a and 8b are schematic views of a stepped-lap joint interface and a scarf-joint interface respectively.

PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

An object of the present invention is to manufacture a composite material assembly, such as, but not limited to, a tubular profile structure from two or more longitudinal section components. The whole assembly can be cured in one step in order to form a one-piece tubular structure, such as, for example, a fuselage. Hence, the components that will constitute the whole assembly are joined before curing occurs and then the whole assembly is cured through co-curing of these components, producing an end product without any overly apparent seams.
Referring to Figures 1a to 1c, according to a first preferred embodiment of the present invention, a system 10 for fabricating a composite material assembly is disclosed. The system 10 includes a first mold 12 for receiving a first module 13 made of composite material. The first mold 12 has a first composite material laminate support structure 14 having first and second opposite edges 16, 18. The first mold 12 also has a first attachment interface 20 for attachment of the first mold 12 to an adjacent mold 22. The system 10 also comprises a second mold 22 for receiving a second module 23 made of composite material. The second mold 22 includes a second composite material laminate support structure 24 having first and second opposite edges 26, 28. The second mold 22 also has a second attachment interface 30 for attachment of the second mold 22 to the first mold 12.

The system 10 further comprises a removable insert 32 extending beyond the second edge 28 of the second mold 22. The insert 32 is shaped such that it would contact the first mold 12 if the first and second molds 12, 22 were attached together and would prevent attachment therebetween if the insert 32 was present.

The first module 13 comprises a first laminate 34 covering the first laminate support structure 14. The second module 23 comprises a second laminate 36 covering the second laminate support structure 24 and extending over the removable insert 32. As better shown in the transition between Figure 1a and Figure 1b, the removable insert 32 is removed from the second mold 22 prior to assembly of the first mold 12 to the second mold 22. As better shown in Figure 1b, a section 38 of the second laminate 36 extending over the removable insert 32 overlaps over the first laminate 34 after closing and assembly of the first mold 12 onto the second mold 22. At the initial closing of the molds 12, 22, the laminates 34, 36 are not cured or solidified, allowing the required tackiness, softness and flexibility to ensure proper intermesh and layup at the interface.
Preferably, the first laminate 34 has a first interface profile 40 shaped to fit into a complementary second interface profile 42 of the section of the second laminate 36 extending over the removable insert 32. The second laminate 36 can therefore overlap over the first laminate 34, and form a joint without an overly apparent seam, between the first and second modules 13, 23. Preferably, the interface profiles 40, 42 are chosen to form a stepped-lap joint. During initial placement of the laminates 34, 36 on the molds 12, 22, the removable insert 32 provides the extension surface that is required to form the stepped-lap joint.

Preferably, when the composite material assembly is a tubular component, the final assembly results from two or more joints. Given that the chosen type of joint for this application must minimize any over thickness in order to obtain a uniform structure thickness along the perimeter of circumference of the assembly, it is preferable to use a type of joint that requires superimposing two half-elements, preferably through a stepped-lap interface as mentioned above. In other embodiments of the present invention for fuselage applications, the stepped-lap interface, as shown in Figure 8A, at the sectional interface between modules could be changed for a scarf-type lamination, as shown in Figure 8B without affecting the required constant thickness of the fuselage structure.

As shown in Figure 1b, manufacturing of a joint in accordance with the present invention requires that one section 38 of the laminate 36 overhangs temporarily and is therefore not supported beyond the edge 38 of the mold 32. This overhanging configuration is required for the period of time between removal of the insert 32 and closing of the molds 12, 22 for forming the assembly.

In order to allow closing of the molds 12, 22, each of the half-elements of the complementary interface profiles 40, 42 to be stacked must avoid contact with each other during the closing movement of the molds 12, 22, as there can be a risk of localized pre-adherence, before the two half-elements are positioned correctly. Any
incorrect positioning of the two sides of the interface for the laminate could result in the formation of air pockets and result in an abnormal discontinuity in the structural laminate in the joint assembly zone.

In order to avoid this possibility of pre-adherence between the two half-elements of the joint prior to the final closed position of the molds 12, 22, the removable insert 32 preferably has a geometrical form shaped to position the overhanging section 38 of the laminate 36, with the interface profile 42, above its corresponding interface profile 40 on the other mold 12 without incurring any contact or pre-adherence, after the insert 32 is removed.

Preferably, the surface of the insert 32 on which the overhanging section 38 of the laminated interface is resting has an angular position of at least 10° and preferably between 10° and 15° with respect to a tangential direction of the second laminate 36 of the second mold 22, at the edge 28 of the second mold 22 where the removable insert 32 is positioned, towards an inner side of the second mold 22.

For fuselage applications, the required laminate construction for the fuselage can be a monolithic configuration, as shown in Figures 1a to 1c, or sandwich/core structure, as shown in Figures 2a to 2c, or a combination of the two. Preferably, in the case of a fuselage sandwich/core structure, as shown in Figures 2a to 2c, the initial laminated assembly produced with the removable insert 32 and the molds 12, 22 is the same but this laminated assembly may now be designated as an "outer skin" 74a. As shown in Figure 2b, the "outer skin" 74a receives a sandwich honeycomb core 72 followed by an "inner skin" 74b which could be of different construction. The inner skin laminate 74b is terminated also at its longitudinal edges 78, 79 by a stepped-lap geometry being in full contact with the sandwich core 72 surface. Preferably, the laminates are made of "out of autoclave" carbon - epoxy pre-preg and the sandwich/core structure comprises a Nomex™ honeycomb core, however, other materials may be used.
Preferably, the removable insert 32 is a structural element. However, the removable insert may be an inflatable structure, or any other retractable molding structure known to a person skilled in the art.

Preferably, the attachment interfaces 20, 30 are hinge-type interfaces. However, other types of attachment interfaces may be used. Moreover, the attachment interfaces 20, 30 may comprise a cam assembly in order to provide a sufficient amount of clearance for the overhanging section 38 of the laminate 36 to avoid inadvertent contact and pre-adherence with the other side of the interface.

Preferably, the system 10 further comprises a flexible elastomeric seal at a joint interface between the first and second molds 12, 22. The flexible elastomeric seal provides vacuum integrity of the mold assembly needed for the curing procedure.

Preferably, a release agent is applied to the first and second molds 12, 22 prior to laying down of the first and second modules 13, 23 thereon. The release agent is preferably one of three types: (i) liquid or paste, (ii) in the form of a plastic film and (iii) of a permanent type such as a Teflon™ coating and one skilled in the art can select the appropriate one for its particular need. Additionally, other types of release agents may be considered. The release agent is applied in each mold to allow remolding of other modules after a curing step.

Preferably, the first and second molds 12, 22 are portions of a cylindrical structure. The system can therefore be used to form a curved assembly as shown in Figures 3a to 3e and Figures 4a to 4e. Preferably, the molds have a geometric shape adapted to form a tubular-profiled structure and comprises at least two 180° sections or preferably three 120° sections.
Referring to Figure 3a, when the molds are made of three sections, a central mold 12 rests on the ground with the two other molds 22, 52 placed adjacently.

Preferably, when the assembly molds 12, 22, 52 comprise three sections to form a cylindrical structure, the removable inserts can be positioned in different manners. In a preferred embodiment of the present invention, one insert is associated with each mold 12, 22, 52, as shown in Figures 3a to 3e, since such a configuration allows for the manufacture of three (3) identical molds/inserts. However, other configurations can be considered. For example, no insert can be associated with the first mold 12, one insert can be associated with the second mold 22, and two inserts can be associated with the third mold 52, as shown in Figures 5a to 5c.

The closing sequence of the different molds 12, 22, 52 is not influenced by the positioning and distribution of the inserts among the different molds because a clearance zone has been designed into the shape of the molds in order to position, within this clearance zone, the overhanging section 38 of the laminate 36 to avoid contact between the two sides of the interface of the assembled laminate interface during closing of the molds.

Preferably, for assembly of cylindrical fuselage components, among other applications, three molds 12, 22, 52 are provided. As better shown in Figures 5a to 5c, the system 10 for fabricating a composite material assembly comprises a third mold 52 for receiving a third module made of composite material. The third mold 52 includes a third composite material laminate support structure 54 having first and second opposite edges 56, 58. The third mold also has a pair of opposite third and fourth attachment interfaces 60, 62 for attachment of the third mold 52 to the first and second molds 12, 22. The third mold 52 also has second and third removable inserts 64, 65 extending beyond the first and second edges 56, 58 of the third composite material laminate support structure 54. The first mold 12 comprises a fifth attachment interface 66 for attachment of the first mold 12 to the third mold 52. The
second mold 22 comprises a sixth attachment interface 68 for attachment of the second mold 22 to the third mold 52. A third laminate 70 covers the third layup structure 54 and extends over the second and third removable inserts 64, 65. The first, second and third removable inserts 32, 64, 65 are removed from the second and third molds 22, 52 prior to assembly of the first, second and third molds 12, 22, 52. A section 71 of the third laminate extending over the second removable insert 64 overlaps over the first laminate 34 after closing and assembly of the third mold 52 onto the first mold 12. Another section 73 of the third laminate extending over the third removable insert 65 overlaps over the second laminate 36 after closing and assembly of the third mold 52 onto the second mold 22. As mentioned above, the distribution of the inserts 32, 64, 65 among the different molds as shown in Figures 5a to 5e may vary for a selected assembly closure sequence and correspond, for example, to the distribution of inserts 32, 64, 65 shown in Figures 3a to 3e. In Figures 5a to 5e, the distribution of the inserts is such that first mold 12 resting on the ground has no inserts and sections 71, 38 overlap over the first laminate which may be a more practical sequence of assembly of the laminates in certain assembly configurations.

According to the present invention, there is also provided a method for fabricating a composite material assembly comprising the steps of:

a) providing an assembly system 10, as shown in Figures 1a to 1c comprising:
- a first mold 12 for receiving a first module 13 made of composite material, the first mold 12 comprising:
  - a first composite material laminate support structure 14 having first and second opposite edges 16, 18; and
  - a first attachment interface 20 for attachment of the first mold 12 to an adjacent mold 22; and
- a second mold 22 for receiving a second module 23 made of composite material, the second mold 22 comprising:
  - a second composite material laminate support structure 24 having first and second opposite edges 26, 28;
  - a second attachment interface 30 for attachment of the second mold 22 to the first mold 12; and
  - at least one removable insert 32 extending beyond the edge 28;

b) laying down the first module 13 on the first mold 12, the first module 13 comprising a first laminate 34 covering the first laminate support structure 14;

c) laying down the second module 23 on the second mold 22, the second module 23 comprising a second laminate 36 covering the second laminate support structure 24 and extending over the removable insert 32;

d) removing the removable insert 32 from the second mold 22;

e) assembling the first mold 12 with the second mold 22 while overlapping a section 38 of the second laminate 36 extending over the removable insert 32 over the first laminate 34.

Preferably, the method further comprises the step of f) curing the assembled first and second modules 13, 23 in an oven. When the method according to the present invention is used to manufacture a fuselage assembly, considering the fact that the entire composite structure of the fuselage has been realized in a complete uncured state and that the composite structure is fully assembled in a tubular profile, the entire fuselage assembly inside the closed mold has to be solidified by putting it under vacuum and heat inside a curing oven. Under only one "heat and pressure cycle" the pre-preg laminate and adhesive will cure and solidify to generate a one-piece tubular section of fuselage without an overly apparent seam. It is however understood by one skilled in the art that any appropriate curing process is possible pursuant to the invention.
Preferably, the one-piece section of fuselage produced using the system or method may integrate or comprise floor attachment members, a cockpit windshield, cabin windows and passenger door surrounding structures. All of these features may be all cured in one step only. The system and method according to the present invention can be used for any portion of a flying vehicle which possesses a tubular profile with a need to be co-cured for reducing any overly apparent seam, such as any cabin of an aircraft.

Referring to Figure 7, the system and method according to the present invention can be used for manufacturing of one-piece fuselage sections and facilitate the layup of composite pre-preg material on the molds 12, 22, 52 in an almost horizontal position, thus reducing the counter effect of gravity when compared to a tubular or cylindrical molds.

Although preferred embodiments of the present invention have been described in detail herein and illustrated in the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments and that various changes and modifications may be effected therein without departing from the scope or spirit of the present invention.
CLAIMS

1. A system for fabricating a composite material assembly comprising:
   - a first mold for receiving a first module made of composite material, said first mold comprising:
     - a first composite material laminate support structure having first and second opposite edges; and
     - a first attachment interface for attachment of the first mold to an adjacent mold;
   and
   - a second mold for receiving a second module made of composite material, said second mold comprising:
     - a second composite material laminate support structure having first and second opposite edges;
     - a second attachment interface for attachment of the second mold to the first mold; and
     - at least one removable insert extending beyond at least one of said first and second edges of the second mold,
   wherein the first module comprises a first laminate covering the first laminate support structure, the second module comprises a second laminate covering the second laminate support structure and extending over the at least one removable insert, and wherein the at least one removable insert is removed from the second mold prior to assembly of the first mold to the second mold, and a section of the second laminate extending over the at least one removable insert overlaps over the first laminate after closing and assembly of the first mold onto the second mold.

2. The system according to claim 1, wherein the first and second molds are portions of a cylindrical structure.
3. The system according to claim 1 or 2, wherein the first laminate has a first interface profile shaped to fit into a complementary second interface profile of the section of the second laminate extending over the at least one removable insert and overlapping over the first laminate, for forming a joint between the first and second modules.

4. The system according to any one of claims 1 to 3, wherein the at least one removable insert comprises a laminate overhang support surface, said laminate overhang support surface being oriented at an offset angle of at least 10° with respect to a tangential direction of the second laminate of the second mold, at the at least one of said first and second edges of the second mold where the at least one removable insert is positioned, towards an inner side of the second mold.

5. The system according to claim 4, wherein the offset angle is between 10° and 15°.

6. The system according to any one of claims 1 to 5, further comprising a flexible elastomeric seal at a joint interface between the first and second molds.

7. The system according to any one of claims 1 to 6, wherein a release agent is applied to the first and second molds prior to laying down of the first and second modules thereon.

8. The system according to any one of claims 1 to 7, wherein the first and second modules are in an uncured state during assembly.

9. The system according to any one of claims 1 to 8, further comprising:
   -a third mold for receiving a third module made of composite material, said third mold comprising:
a third composite material laminate support structure having first and second opposite edges;
a pair of opposite third and fourth attachment interfaces for attachment of the third mold to the first and second molds; and
a second and third removable inserts extending respectively beyond the first and second edges of the third mold,
wherein the first mold comprises a fifth attachment interface for attachment of the first mold to the third mold, the second mold comprises a sixth attachment interface for attachment of the second mold to the third mold, the third module comprises a third laminate covering the third laminate support structure and extending over the second and third removable inserts, and wherein the first, second and third removable inserts are removed from the second and third molds prior to assembly of the first, second and third molds, a first section of the third laminate extending over the second removable insert overlaps over the first laminate after closing and assembly of the third mold onto the first mold, a second section of the third laminate extending over the third removable insert overlaps over the second laminate after closing and assembly of the second mold onto the third mold, and wherein the first, second and third molds form a closed cylindrical structure.

10. The system according to any one of claims 1 to 9, wherein the first and second laminates are outer mold line skins.

11. The system according to claim 10, further comprising an inner mold line skin placed over the outer mold line skins and a core interposed between the inner and outer mold line skins.

12. A method for fabricating a composite material assembly comprising the steps of:
a) providing an assembly system comprising:
- a first mold for receiving a first module made of composite material, said first mold comprising:
  - a first composite material laminate support structure having first and second opposite edges; and
  - a first attachment interface for attachment of the first mold to an adjacent mold;
and
- a second mold for receiving a second module made of composite material, said second mold comprising:
  - a second composite material laminate support structure having first and second opposite edges;
  - a second attachment interface for attachment of the second mold to the first mold; and
  - at least one removable insert extending beyond at least one of said first and second edges of the second mold;

b) laying down the first module on the first mold, the first module comprising a first laminate covering the first laminate support structure;
c) laying down the second module on the second mold, the second module comprising a second laminate covering the second laminate support structure and extending over the at least one removable insert;
d) removing the at least one removable insert from the second mold;
e) assembling the first mold with the second mold while overlapping a section of the second laminate extending over the at least one removable insert over the first laminate.

13. The method according to claim 12, wherein the first and second molds are portions of a cylindrical structure.

14. The method according to claim 12 or 13, wherein the first laminate has a first interface profile shaped to fit into a complementary second interface profile of the
section of the second laminate extending over the at least one removable insert and overlapping over the first laminate, for forming a joint between the first and second modules.

15. The method according to any one of claims 12 to 14, wherein the at least one removable insert comprises a laminate overhang support surface, said laminate overhang support surface being oriented at an offset angle of at least 10° with respect to a tangential direction of the second laminate of the second mold, at the at least one of said first and second edges of the second mold where the at least one removable insert is positioned, towards an inner side of the second mold.

16. The method according to claim 15, wherein the offset angle is between 10° and 15°.

17. The method according to any one of claims 12 to 16, wherein the assembly system further comprises a flexible elastomeric seal at a joint interface between the first and second molds.

18. The method according to any one of claims 12 to 17, further comprising the step of, prior to step b), applying a release agent to the first and second molds prior to layup of the first and second modules thereon.

19. The method according to any one of claims 12 to 18, further comprising the step of f) curing the assembled first and second modules.

20. An aircraft fuselage comprising a composite material assembly fabricated according to any one of claims 12 to 19.

21. The aircraft fuselage according to claim 20, wherein the fuselage is a solid laminate.
22. The aircraft fuselage according to claim 20, wherein the fuselage is a sandwich structure.

23. The aircraft fuselage according to claim 20, wherein the fuselage is a combination of a solid laminate in some locations and a sandwich structure in other locations.

24. The aircraft fuselage according to any one of claims 20 to 23, comprising at least one component selected from the group comprising floor attachments, cockpit windshields, cabin windows and passenger door surrounding structures.
### INTERNATIONAL SEARCH REPORT

**International application No**

PCT/IB2010/001724

**A. CLASSIFICATION OF SUBJECT MATTER**

<table>
<thead>
<tr>
<th>Classifications</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV. B29C65/00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B29C70/30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B29C70/44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B64C1/06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B64F5/00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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)
  - B29C
  - B64C
  - B64F
  - B32B
  - B65H

**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 practical, search terms used)**

- EPO-Internal
- WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FR 2 710 871 Al (FRANCE ETAT ARMEEMENT [FR]) 14 April 1995 (1995-04-14) page 1, lines 4-10 page 2, line 30 - page 4, line 13; claims 1-10; figures 1-4</td>
<td>1-24</td>
</tr>
<tr>
<td>A</td>
<td>US 6 347 839 Bi (LEW PAUL [US] ET AL) 19 February 2002 (2002-02-19) column 2, lines 17-62 column 5, line 48 - col umn 6, line 40; figures 4-6</td>
<td>1-24</td>
</tr>
</tbody>
</table>

* Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

- Date of the actual completion of the international search: 15 November 2010
- Date of mailing of the international search report: 22/11/2010

**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

Deubler, Ulrich

See patent family annex.

Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR 2710871 A1</td>
<td>14-04-1995</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>US 6347839 B1</td>
<td>19-02-2002</td>
<td>AT 461057 T</td>
<td>15-04-2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 3083701 A</td>
<td>08-04-2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES 2340463 T3</td>
<td>04-06-2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2004509800 T</td>
<td>02-04-2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 0226510 A1</td>
<td>04-04-2002</td>
</tr>
</tbody>
</table>