



(51) International Patent Classification:

B29C 33/38 (2006.01) *B29C 70/54* (2006.01)
B29C 33/30 (2006.01)

(21) International Application Number:

PCT/CN2018/095546

(22) International Filing Date:

13 July 2018 (13.07.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: **GURIT TOOLING (TAICANG) CO., LTD.**
[CN/CN]; No. 181, Changsheng North Road, Taicang Eco-
nomic Development Zone, Suzhou, Jiangsu 215400 (CN).

(72) Inventor: **HOWARD, Fullonton Jones III**; 15-1-702#
Zone 1 Taihelidu, Taicang, Suzhou, Jiangsu 215400 (CN).

(74) Agent: **CCPIT PATENT AND TRADEMARK LAW
OFFICE**; 8th Floor, Vantone New World Plaza, 2 Fucheng-
menwai Street, Xicheng District, Beijing 100037 (CN).

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

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

(54) Title: Mold Tool and Method of Manufacture Thereof

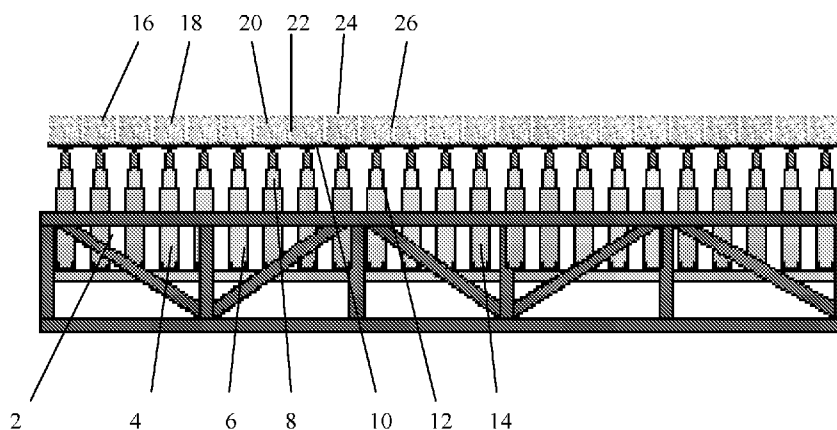


Figure 1

(57) **Abstract:** A method of manufacturing a mold tool (82), the method including the steps of: a) providing a contiguous array (16) of a plurality of bodies (18) composed of a cellular material; b) selectively moving individual bodies of the array to a respective desired position to define a three-dimensional profile (28) formed by the array of bodies, the three-dimensional profile having a three-dimensionally shaped surface (30); c) applying a support layer (40) to the three-dimensionally shaped surface to form a unitary mold precursor (42) comprising the array of bodies attached together by the support layer; d) machining a surface (58) of the unitary mold precursor opposite to the support layer, the surface being composed of the array of bodies, to form a first smoothed surface (60) of the three-dimensional profile; and e) forming a molding surface (84) on the first smoothed surface. Also disclosed is a mold tool made by the method which can avoid the requirement to use a conventional plug.

Published:

— *with international search report (Art. 21(3))*

Mold Tool and Method of Manufacture Thereof

Technical Field of the Invention

The present invention relates to a mold tool and to a method of manufacturing a mold tool. The present invention has particular application to the manufacture of large molds for manufacturing parts from composite materials, for example wind turbine blade molds, molds for marine craft and mold for aerospace parts.

Technical Background of the Invention

With the development of science and technology, wind power as a safe and green renewable energy has developed rapidly. In recent years, the production technology of wind turbine blades has been continuously developed and improved. Current wind turbine blades typically have a length of more than 50 metres and are molded out of fiber reinforced resin composite material. Accordingly, exceedingly large molds are required which have a mold surface corresponding to the dimensions of the wind blade to be molded.

It is known to produce typical wind turbine blade molds using a “plug”, which is a body on which the molding surface is constructed. The manufacture of a conventional plug for a large mold is expensive, and an individual single-use plug must be made for each mold tool that is manufactured.

There is a need to reduce the cost of producing a large mold tool, and avoiding the cost and associated inefficiency of the use of traditional single-use plugs for large mold tool manufacture.

Furthermore, there is a need for a method of manufacturing a mold tool which has a high degree of automation to reduce production costs, coupled with accuracy to produce a highly accurate A-surface finish to the mold tool.

Aim of the Invention

The present invention aims effectively to solve the problems with known mold tool manufacture, and aims in particular to provide a mold tool manufacturing method which can avoid the requirement to use a conventional plug.

Summary of the Invention

The present invention, in a first aspect, accordingly provides a method of manufacturing a mold tool, the method including the steps of:

- a) providing a contiguous array of a plurality of bodies composed of a cellular material;
- b) selectively moving individual bodies of the array to a respective desired position to define a three-dimensional profile formed by the array of bodies, the three-dimensional profile having a three-dimensionally shaped surface;
- c) applying a support layer to the three-dimensionally shaped surface to form a unitary mold precursor comprising the array of bodies attached together by the support layer;

- d) machining a surface of the unitary mold precursor opposite to the support layer, the surface being composed of the array of bodies, to form a first smoothed surface of the three-dimensional profile; and
- e) forming a molding surface on the first smoothed surface.

There is further provided, in accordance with a second aspect of the present invention, a mold tool for molding a fiber-reinforced resin matrix composite material, the mold tool comprising a molding layer structure defining a molding surface, a core layer having opposite first and second surfaces, the core layer comprising a contiguous array of a plurality of bodies of cellular material, each body extending between the first and second surfaces, each of the first and second surfaces being machined to define a respective continuous three-dimensional profile, wherein the molding layer structure is molded to the first surface of the core layer, and a support layer molded to the second surface of the core layer, wherein the support layer attaches together the plurality of bodies of cellular material.

Preferred features of both aspects of the present invention are defined in the dependent claims.

The preferred embodiments of the present invention can provide a reusable/changeable plug to make mold tool which can have the structure, properties and advantages of a traditional plug-constructed mold tool but avoids the need for a single-use traditional plug. The mold tool manufacturing method uses a shaping device, which is typically a rigid automated device composed of a dense, evenly distributed field of vertical cylinders capable of lifting cellular material bodies (e.g. polymeric foam or balsa blocks) into temporary position for use in making direct molds using a computer numerically controlled (CNC) machining process, or as reusable plug.

Furthermore, the preferred embodiments of the present invention can provide a temporary direct mold, without using a traditional high cost single use plug, which can be used for making low cost prototype mold tools, and corresponding prototype molded articles. Of course, alternatively the preferred embodiments of the present invention can provide a mold tool to be used in the full commercial mass production of direct, plug-free, mold tools.

The preferred embodiments of the present invention can provide a mold tool which can be used to manufacture fiber-reinforced resin composite materials, or any other materials that can be molded by a mold tool comprising a mold surface composed of composite material. The mold tool may be used for molding final articles or products, such as wind turbine blades, marine parts or aerospace parts, or for preforming fabrics and cores for use in composite material, e.g. wind turbine blade, manufacture. The mold tool can be used for molding materials other than composite materials, such as concrete forms for large structures such as bridges or other industrial large scale products.

Brief Description of the Drawings

Embodiments of the present invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is an schematic side view of a shaping device mounting a plurality of bodies of cellular material for use in a method of manufacturing a mold tool according to an embodiment of the present invention;

Figure 2 is a schematic side view of the shaping device as illustrated in Figure 1 after movement of actuator devices therein to form a three-dimensional profile of the bodies of cellular material;

Figure 3 is a schematic side view of machining step to the three-dimensional profile of Figure 2;

Figure 4 is a schematic side view of the machined three-dimensional profile of Figure 3;

Figure 5 is a schematic side view of the machined three-dimensional profile of Figure 4 after lamination of a composite material layer;

Figure 6 is a schematic side view of the attachment of a frame to the composite material layer illustrated in Figure 5;

Figure 7 is a schematic side view of the raising of the frame illustrated in Figure 6;

Figure 8 is a schematic side view of the rotating of the frame illustrated in Figure 7;

Figure 9 is a schematic side view of the machining of the three-dimensional profile of the unitary mold precursor on the rotated frame illustrated in Figure 8;

Figure 10 is a schematic side view of the machined three-dimensional profile of Figure 9 after lamination of a composite material layer;

Figure 11 is a schematic side view of the application of a heating wire assembly on the composite material layer of Figure 10;

Figure 12 is a schematic side view of the three-dimensional profile of Figure 11 after lamination of a further composite material layer;

Figure 13 is a schematic side view of the machining of the three-dimensional profile of the further composite material layer illustrated in Figure 12;

Figure 14 is a schematic side view of the spraying of a top coat layer over the machined further composite material layer illustrated in Figure 13;

Figure 15 is a schematic perspective view of a mold tool after sanding the top coat layer illustrated in Figure 14; and

Figure 16 is an enlarged cross-section through a portion of the mould tool illustrated in Figure 15.

Detailed Description of the Preferred Embodiments

Referring to Figure 1, there is shown a shaping device 2 for use in a method of manufacturing a mold tool, typically a mold tool for molding a fiber-reinforced resin matrix composite material, in accordance with a first embodiment of the present invention. The mold tool most typically is shaped and dimensioned to mold a wind turbine blade or a portion thereof, although alternatively the mold tool may be shaped and dimensioned to mold a marine component, such as a boat hull, or an aerospace component, such as a fuselage panel or portion.

In accordance with the method of the illustrated embodiment of the present invention, the shaping device 2 is provided. The shaping device 2 comprises an array 4 of mutually aligned actuatable devices 6. Typically, the array 4 is a linear array in one dimension. Alternatively, the array 4 extends in two orthogonal directions to form a two-dimensional array. Each actuatable device 6 comprises a movable element 8 individually movable over an operating range between opposite end positions. Each movable element 8 has a free end 10. Typically, the shaping device 2 extends in a horizontal direction or plane and the movable element 8 is individually movable over the operating range between a raised position and a lowered position. In the preferred embodiment, the movable element 8 is an extendable piston element 12 mounted in a fixed cylinder assembly 14, and typically the actuatable device 6 is a hydraulic piston and cylinder assembly. The piston element 12 is individually movable over the operating range between an extended raised position and a lowered retracted position.

As shown in Figure 1, a contiguous array 16 of a plurality of bodies 18, each

composed of a cellular material, is provided by mounting each of the bodies 18 to a respective free end 10 of a movable element 8. In the illustrated embodiment, each body 18 is mounted to a respective free end 10, so that each free end 10 has one body 18 thereon; however, in an alternative embodiment a plurality of adjacent bodies 18 is mounted to a respective free end 10. The array 16 of bodies 18 is mounted on, and temporarily affixed to, the shaping device 2; for example, the plurality of bodies 18 are temporarily affixed to the free ends 10 using vacuum suction between the bodies 18 and the free ends 10. The free end 10 may be shaped as a planar plate member, optionally with raised peripheral edges, the plate extending orthogonal to the axis of motion of the movable element 8, for securely supporting the body 18 of cellular material.

The cellular material typically comprises a polymeric foam or balsa wood. As will be described hereinafter, the cellular material forms a central core layer of the resultant mold tool.

Each body 18 is preferably an elongate element 20 having a regular cross-section orthogonal to an elongate direction of the elongate element 20 (the elongate direction being orthogonal to the plane of the drawing of Figure 1). The regular cross-section is preferably a rectangular or square cross-section. Each elongate element 20 has opposite elongate side surfaces 22, which are typically planar, and an upper surface 24, which is preferably planar. Preferably, each elongate element 20 has (i) a length, which is in an elongate direction of the elongate element 20, which is from 0.1 to 1 meters; (ii) a width, which is orthogonal to an elongate direction of the elongate element 20 and defines a width of the upper surface 24, which is from 0.1 to 1 meters; and (iii) a height, which is orthogonal to both the width, and an

elongate direction, of the elongate element 20, which is from 0.1 to 1 meters.

Preferably, the opposed elongate side surfaces 24 of respective adjacent elongate elements 20 are mutually spaced by a gap 26. Typically, the gap has a width of from 0.1 to 3 mm.

Referring to Figure 2, the method includes the subsequent step of selectively moving individual bodies 18 of the array 16 to a respective desired position to define a three-dimensional profile 28 formed by the array 16 of bodies 18. The three-dimensional profile 28 has a three-dimensionally shaped surface 30. The three-dimensionally shaped surface 30 is opposite to the array 16 of actuatable devices 6. The movement is achieved by selectively actuating the actuatable devices 6 to cause each movable element 8 to be individually moved to a desired position within the respective operating range to define the three-dimensionally shaped surface 30 formed by the array 16 of bodies 18. When the bodies 18 have a planar upper surface, the three-dimensionally shaped surface 30 is a stepped surface, as shown in Figure 2.

In a preferred embodiment, the actuatable devices 6 of the shaping device 2 are connected to a control system 32 which includes an input module 34 adapted to receive an input command to define a desired three-dimensionally shaped surface and an output module 36 which is adapted, in response to the input command, to cause the actuatable devices 6 to be operated so that each movable element 8 is individually moved to a desired position within the respective operating range to define the desired three-dimensionally shaped surface 30.

Referring to Figure 3, the method includes the subsequent step of machining the stepped surface 30 of the three-dimensional profile 28 to form a

smoothened surface 38 of the three-dimensional profile 28. The machining step uses computerized numerical controlled three-dimensional movement of a machining head 39 which is moved over the surface 30 of the three-dimensional profile 28. Preferably, during the machining step the surface 30 of the three-dimensional profile 28 is upwardly oriented; however, that surface 30 may be oriented in any other direction, provided that the bodies 18 remain securely affixed to the free ends 10 during the machining step. The machined,

smoothened surface 38 of the three-dimensional profile 28 shapes a B-surface, i.e. non-molding surface, of the resultant mold tool, as described hereinafter. Figure 4 shows the smoothened surface 38 after completion of the machining step.

Referring to Figure 5, the method includes the subsequent step of applying a support layer 40 to the three-dimensionally shaped surface 38 to form a unitary mold precursor 42 comprising the array 16 of bodies 18 attached together by the support layer 40. The support layer 40 is applied by applying a first fiber-reinforced resin matrix composite material 44 to the three-dimensionally shaped surface 38. The first fiber-reinforced resin matrix composite material typically comprises a fiberglass-reinforced thermosetting resin, for example an epoxy resin, having a thickness of from 2 to 10 mm. The support layer 40 is typically hand-laminated over the three-dimensionally shaped surface 38. The support layer 40 defines an outermost support surface 46 of the unitary mold precursor 42.

Referring to Figure 6, the method includes the subsequent step of attaching a support frame 48 to the support surface 46 of the unitary mold precursor 42. The support frame 48 comprises a framework 50 of structural members 51,

for example steel bars welded or otherwise affixed together, which has mounted thereto a body 52 having a three-dimensionally shaped outer surface 54 which substantially corresponds to the shape and dimensions of the resultant molding surface of the mold tool to be manufactured. The body 52 is typically known to those skilled in the art of mold manufacture as a “plug” and is used to assist the shaping of the molding surface to the desired three-dimensionally shaped profile. As will be apparent from the disclosure herein, in accordance with the preferred embodiments of the present invention the body 52 constitutes a re-usable “plug”, which can be used to manufacture a succession of mold tools.

The three-dimensionally shaped outer surface 54 of the body 52 has an array of a plurality of attachment devices 56, for example suction cups 56, for temporarily fixing the unitary mold precursor 42 to the support frame 48. Preferably, the support frame 48 is attached to the support layer 40 of the unitary mold precursor 42 using vacuum suction between the support frame 48 and the support layer 40.

Referring to Figure 7, the method includes the subsequent step of moving the support frame 48 and the unitary mold precursor 42, which is attached thereto, so that the surface 58 of the unitary mold precursor 42 opposite to the support layer 40 is exposed. This step is achieved by initially releasing any temporary fixing between the array 16 of bodies 18 and the shaping device 2, for example by releasing the vacuum suction applied between the free ends 10 and the bodies 18. Thereafter, the support frame 48, carrying the unitary mold precursor 42, is raised away from the shaping device 2.

Referring to Figures 8 and 9, the method preferably includes the subsequent

step of rotating the support frame 48, carrying the unitary mold precursor 42, about a horizontal axis and about an angle of 180 degrees so that the surface 58 of the unitary mold precursor 42 opposite to the support layer 40 is upwardly oriented and exposed. Thereafter, the surface 58, the surface being composed of the array 16 of bodies 18, is machined to form a smoothed surface 60 of the three-dimensional profile. The machined, smoothed surface 60 of the three-dimensional profile 28 shapes an A-surface, i.e. a molding surface, of the resultant mold tool, as described hereinafter. The machining step uses computerized numerical controlled three-dimensional movement of a machining head 62, which may be the same machining head 39 described with respect to Figure 3, which is moved over the exposed surface 58 of the unitary mold precursor 42. Again, during the machining step the exposed surface 58 of the unitary mold precursor 42 is preferably upwardly oriented, but may alternatively be oriented in any other direction.

Referring to Figures 10 to 15, the method includes the subsequent step of forming a molding surface on the smoothed surface 60. This step preferably includes a number of sub-steps.

Figure 10 shows that a second fiber-reinforced resin matrix composite material 64 is applied to the smoothed surface 60. Typically, the second fiber-reinforced resin matrix composite material 64 comprises a fiberglass-reinforced thermosetting resin, for example epoxy resin, forming a layer 66 having a thickness of from 2 to 10 mm, for example 4 mm.

Next, as shown in Figure 11, a heating wire assembly 68 is applied over the second fiber-reinforced resin matrix composite material 64. Such a heating wire assembly 68 for incorporation into mold tools is well known to those

skilled in the art of mold manufacture, particularly molds for manufacturing wind turbine blades, for example as disclosed in WO-A-2014/113970 in the name of Suzhou Red Maple Wind Blade Mold Co Ltd.

Thereafter, as shown in Figure 12, the second fiber-reinforced resin matrix composite material 64, and the heating wire assembly 68 when present, is covered by a third fiber-reinforced matrix resin composite material. Initially, a layer of fibers 70 is applied to the second fiber-reinforced resin matrix composite material, and subsequently a polymeric resin, in liquid form, is infused into the layer of fibers 70 to form a layer 72 of a third fiber-reinforced matrix resin composite material. The fibers may be composed of synthetic fibers (such as glass, carbon, polyamide, etc) or natural fibers (such as flax, hemp, cotton, etc), and preferably the fibers are natural fibers composed of flax.

Subsequently, as shown in Figure 13, an exposed surface 74 of the third fiber-reinforced matrix resin composite material 72 is machined to form a smoothened surface 76 of the third fiber-reinforced matrix resin composite material layer 74. The machining step uses computerized numerical controlled three-dimensional movement of a machining head 78, which may be the same machining head 39 described with respect to Figure 3, which is moved over the exposed surface 74 of the third fiber-reinforced matrix resin composite material 72. Again, during the machining step the exposed surface 74 is preferably upwardly oriented, but may alternatively be oriented in any other direction.

Subsequently, as shown in Figure 14, a resin-containing top coat layer 80 is sprayed over the smoothened surface 76 of the third fiber-reinforced matrix

resin composite material layer 74.

Finally, as shown in Figure 15, the top coat layer 80 is sanded to form a mold tool 82 a molding surface 84 having an A-surface finish of the desired surface quality and fineness.

In alternative embodiments, the third fiber-reinforced matrix resin composite material layer 74 may be omitted and, optionally, the second fiber-reinforced matrix resin composite material 64 may be machined or otherwise prepared or finished to form an A-surface molding surface. The use of the heating wire assembly 68 may be entirely omitted, for example for smaller mold tools or for mold tools not intended to be used for molding thermosetting resins, such as epoxy resin. In alternative embodiments, the top coat layer 80 and sanding may be omitted.

Consequently, the resultant mold tool 82, which is suitable for molding a fiber-reinforced resin matrix composite material, has a specific multilaminar construction.

Figure 16 is an enlarged cross-section through a portion of the mould tool 82. The drawing is highly schematic, and for the purpose of clarity of illustration some dimensions are exaggerated and the mould tool is illustrated as being planar rather than three-dimensionally curved.

The mold tool 82 comprises a molding layer structure 86 defining the molding surface 84. A core layer 88 has opposite first and second surfaces 90, 92. The core layer 88 comprises the contiguous array 16 of the plurality of bodies 18 of cellular material. Each body 18 extends between the first and

second surfaces 90, 92. Each of the first and second surfaces 90, 92 is machined to define a respective continuous three-dimensional profile 94, 96.

The molding layer structure 86 is molded to the first surface 90 of the core layer 88. The support layer 40 is molded to the second surface 92 of the core layer 88, and attaches together the plurality of bodies 18 of cellular material.

Typically, the mold tool 82 is shaped and dimensioned to mold a wind turbine blade or a portion thereof. Such a wind turbine blade mold tool 82 typically has a length of at least 30 metres, and more typically a length of at least 50 metres. Alternatively, the mold tool 82 may be shaped and dimensioned to mold a marine component, such as a boat hull, or an aerospace component, such as a fuselage panel or portion.

Typically, the mold tool 82 comprises a section of an entire mold tool. In particular, when the desired entire mold tool has one or more dimensions, in particular a length, which exceeds the length of the computer numerically controlled (CNC) machine, or if the design of the entire mold requires specific splits in the entire mold tool, for example for shipping purposes, the mold tool made by the method comprises a section of an entire larger mold tool, and a series of sections can be individually manufactured to produce the entire mold tool in sections to be subsequently assembled together. The sections may be assembled together by conventional laminating steps, for example by infusion of a fiberglass laminate across the joint between adjacent sections.

The sections may be assembled together during the laminating step illustrated in Figure 10. In particular, a plurality of mold precursor elements, each having

a respectively shaped machined, smoothened surface 60 of the three-dimensional profile 28, are assembled together to form an entire mold tool precursor, and then during the step illustrated in Figure 10 the second fiber-reinforced resin matrix composite material 64 is applied to the entire assembled smoothened surface 60. The subsequent steps of Figures 11 to 14 are carried out on the entire assembly.

The step illustrated in Figure 13 may be CNC process carried out on the entire assembled mold tool. The CNC machine may be correspondingly adapted as required to operate over long distances, for example up to 80m which is a typical current distance of a high-load wind turbine blade. Typically, the CNC machine may be movably mounted for longitudinal motion along a gantry, designed to any given length required, which can perform the machining operation on the required surface as shown in Figures 3, 9 and 11 and as described above. The gantry and CNC machine may also subsequently be used to perform fiber layout for the production of the resultant wind turbine blade, or used in other wind blade production process steps requiring an automated assistance along the length of the wind blade during the wind blade production process.

Effects and Advantages of the Invention

The preferred embodiments of the present invention can provide a reusable/changeable plug to make a low cost, accurately dimensioned and high quality A-surface mold tool which can be used as a temporary direct mold, without using a traditional high cost single use plug, to make low cost prototype mold tools or mold tools to be used in the full commercial mass production of direct, plug-free, mold tools. The mold tool manufacturing method uses a shaping device, which is typically a rigid automated device

composed of a dense, evenly distributed field of vertical cylinders capable of lifting cellular material bodies (e.g. polymeric foam or balsa blocks) into temporary position for use in making direct CNC molds, or as reusable plug. The mold tool can be used to manufacture fiber-reinforced resin composite materials, or any other materials that can be molded by a mold tool comprising a mold surface composed of composite material. The mold tool may be used for molding final articles or products, such as wind turbine blades, marine parts or aerospace parts, or for preforming fabrics and cores for use in composite material, e.g. wind turbine blade, manufacture. The mold tool can be used for molding materials other than composite materials, such as concrete forms for large structures such as bridges or other industrial large scale products.

Claims

1.A method of manufacturing a mold tool, the method including the steps of:

a)providing a contiguous array of a plurality of bodies composed of a cellular material;

b) selectively moving individual bodies of the array to a respective desired position to define a three-dimensional profile formed by the array of bodies, the three-dimensional profile having a three-dimensionally shaped surface;

c)applying a support layer to the three-dimensionally shaped surface to form a unitary mold precursor comprising the array of bodies attached together by the support layer;

d) machining a surface of the unitary mold precursor opposite to the support layer, the surface being composed of the array of bodies, to form a first smoothed surface of the three-dimensional profile; and

e)forming a molding surface on the first smoothed surface.

2.A method according to claim 1, wherein in steps a) to c) the array of bodies is mounted on, and temporarily affixed to, a shaping device.

3.A method according to claim 2, wherein the method further comprises the steps of:

i. providing the shaping device, wherein the shaping device comprises an array of mutually aligned actuatable devices, each actuatable device comprising a movable element individually movable over an operating range between opposite end positions, each movable element having a free end;

ii. mounting the plurality of bodies to the free ends to define the contiguous array of bodies;

iii. selectively actuating the actuatable devices to cause each movable element to be individually moved to a desired position within the respective operating range to define the three-dimensionally shaped surface formed by the array of bodies, the three-dimensionally shaped surface being opposite to the array of actuatable devices.

4.A method according to claim 3, wherein the plurality of bodies are temporarily affixed to the free ends using vacuum suction between the bodies and the free ends.

5.A method according to claim 3 or claim 4, wherein in step b) the three-dimensionally shaped surface is a stepped surface; and further comprising the step, between steps b) and c), of:

iv. machining the stepped surface of the three-dimensional profile to form a second smoothened surface of the three-dimensional profile.

6. A method according to claim 5, wherein the machining step iv uses computerized numerical controlled three-dimensional movement of a machining head which is moved over the surface of the three-dimensional profile.

7. A method according to claim 5 or claim 6, wherein during the machining step iv the surface of the three-dimensional profile is upwardly oriented.

8. A method according to any one of claims 3 to 7, wherein the movable element is individually movable over the operating range between a raised position and a lowered position.

9. A method according to any one of claims 3 to 8, wherein the movable element is an extendable piston element mounted in a fixed cylinder assembly, the piston element being individually movable over the operating range between an extended raised position and a lowered retracted position.

10. A method according to any one of claims 3 to 9, wherein the actuatable devices of the shaping device are connected to a control system which includes an input module adapted to receive an input command to define a desired three-dimensionally shaped surface and an output module which is adapted, in response to the input command, to cause the actuatable devices to be operated so that each movable element is individually moved to a desired position within the respective operating range to define the desired three-dimensionally shaped surface.

11. A method according to any one of claims 1 to 10, wherein each body is an elongate element having a regular cross-section orthogonal to an elongate direction of the elongate element.

12. A method according to claim 11, wherein the regular cross-section is a rectangular or square cross-section.

13. A method according to claim 11 or claim 12, wherein each elongate element has opposite elongate side surfaces which are planar and an

upper surface forming a part of the three-dimensionally shaped surface formed in step b).

14. A method according to claim 13, wherein opposed elongate side surfaces of respective adjacent elongate elements are mutually spaced by a gap.

15. A method according to claim 14, wherein the gap has a width of from 0.1 to 3 mm.

16. A method according to any one of claims 11 to 15, wherein each elongate element has a length, which is in an elongate direction of the elongate element, which is from 0.1 to 1 meters.

17. A method according to any one of claims 11 to 16, wherein each elongate element has a width, which is orthogonal to an elongate direction of the elongate element and defines a width of the upper surface extending in a direction along the three-dimensionally shaped surface, which is from 0.1 to 1 meters.

18. A method according to any one of claims 11 to 17, wherein each elongate element has a height, which is orthogonal to both the width, and an elongate direction, of the elongate element, which is from 0.1 to 1 meters.

19. A method according to any one of claims 1 to 18, wherein the cellular material comprises a polymeric foam or balsa wood.

20. A method according to any one of claims 1 to 19, further comprising the step, between steps c) and d), of:

v. attaching a support frame to the support layer of the unitary mold precursor;

vi. moving the support frame and the unitary mold precursor so that the surface of the unitary mold precursor opposite to the support layer is exposed.

21. A method according to claim 20, wherein in step v) the support frame is attached to the support layer of the unitary mold precursor using vacuum suction between the support frame and the support layer.

22. A method according to claim 20 or claim 21, wherein in steps a) to c) the array of bodies is mounted on, and temporarily affixed to, a shaping device and between steps v) and vi) the temporary fixing between the array of bodies and the shaping device is released.

23. A method according to any one of claims 1 to 22, wherein the machining step d) uses computerized numerical controlled three-dimensional movement of a machining head which is moved over the exposed surface of the unitary mold precursor opposite to the support layer.

24. A method according to claim 23, wherein during the machining step d) the exposed surface of the unitary mold precursor is upwardly oriented.

25. A method according to any one of claims 1 to 24, wherein in step c) the support layer is applied by applying a first fiber-reinforced resin matrix composite material to the three-dimensionally shaped surface.

26. A method according to claim 25, wherein in step c) the first fiber-reinforced resin matrix composite material comprises a fiberglass-reinforced thermosetting resin having a thickness of from 2 to 10 mm.

27. A method according to any one of claims 1 to 26, wherein step e) includes the step of:

vii. applying a second fiber-reinforced resin matrix composite material to the first smoothed surface.

28. A method according to claim 27, wherein in step e) the second fiber-reinforced resin matrix composite material comprises a fiberglass-reinforced thermosetting resin having a thickness of from 2 to 10 mm.

29. A method according to claim 27 or claim 28, wherein step e) further includes the steps, after step vii), of:

viii. applying a layer of fibers to the fiber-reinforced resin matrix composite material;

ix. infusing a polymeric resin into the layer of fibers to form a third fiber-reinforced matrix resin composite material; and

x. machining an exposed surface, opposite to the fiber-reinforced resin matrix composite material, of the third fiber-reinforced matrix resin

composite material layer to form a third smoothened surface of the third fiber-reinforced matrix resin composite material layer.

30. A method according to claim 29, wherein the machining step x) uses computerized numerical controlled three-dimensional movement of a machining head which is moved over the exposed surface of the third fiber-reinforced matrix resin composite material.

31. A method according to claim 29 or claim 30, wherein during the machining step x) the exposed surface of the third fiber-reinforced matrix resin composite material is upwardly oriented.

32. A method according to any one of claims 29 to 31, wherein step e) further includes the steps, after step x), of:

- xi. spraying a top coat layer over the third smoothened surface of the third fiber-reinforced matrix resin composite material layer; and
- xii. sanding the top coat layer.

33. A method according to claim 32, wherein the top coat layer comprises a resin.

34. A method according to any one of claims 29 to 33, wherein between steps vii) and viii) a heating wire assembly is applied over the second fiber-reinforced resin matrix composite material and thereafter in steps viii) to x) the heating wire assembly is covered by the third fiber-reinforced matrix resin composite material.

35. A method according to any one of claims 29 to 34, wherein in step viii) the fibers are composed of synthetic or natural fibers.

36. A method according to claim 35, wherein in step viii) the fibers are natural fibers composed of flax.

37. A method according to any one of claims 1 to 36, wherein the mold tool is shaped and dimensioned to mold a wind turbine blade or a portion thereof.

38. A mold tool for molding a fiber-reinforced resin matrix composite material, the mold tool comprising a molding layer structure defining a molding surface, a core layer having opposite first and second surfaces, the core layer comprising a contiguous array of a plurality of bodies of cellular material, each body extending between the first and second surfaces, each of the first and second surfaces being machined to define a respective continuous three-dimensional profile, wherein the molding layer structure is molded to the first surface of the core layer, and a support layer molded to the second surface of the core layer, wherein the support layer attaches together the plurality of bodies of cellular material.

39. A mold tool according to claim 38, wherein each body is an elongate element having opposite elongate side surfaces.

40. A mold tool according to claim 39, wherein opposed elongate side surfaces of respective adjacent elongate elements are planar and mutually spaced by a gap.

41. A mold tool according to claim 40, wherein the gap has a width of from 0.1 to 3 mm.

42. A mold tool according to any one of claims 39 to 41, wherein each elongate element has a length, which is in an elongate direction of the elongate element, which is from 0.1 to 1 meters.

43. A mold tool according to any one of claims 39 to 42, wherein each elongate element has a width, which is orthogonal to an elongate direction of the elongate element and is orthogonal to a direction extending between the first and second surfaces, which is from 0.1 to 1 meters.

44. A mold tool according to any one of claims 39 to 43, wherein each elongate element has a thickness, which is in a direction extending between the first and second surfaces, which is from 0.1 to 1 meters.

45. A mold tool according to any one of claims 38 to 44, wherein the cellular material comprises a polymeric foam or balsa wood.

46. A mold tool according to any one of claims 38 to 45, wherein the support layer comprises a first fiber-reinforced resin matrix composite material.

47. A mold tool according to claim 46, wherein the first fiber-reinforced resin matrix composite material comprises a fiberglass-reinforced thermosetting resin having a thickness of from 2 to 10 mm.

48. A mold tool according to any one of claims 38 to 47, wherein the molding layer structure comprises a second fiber-reinforced matrix resin composite material which is molded to the first surface of the core layer, a heating wire assembly over the second fiber-reinforced resin matrix composite material and a third fiber-reinforced matrix resin composite material covering the heating wire assembly, the third fiber-reinforced matrix resin composite material having an outer surface machined to define a continuous three-dimensional profile.

49. A mold tool according to claim 48, wherein the molding layer structure further comprises a top coat layer over the outer surface of the third fiber-reinforced matrix resin composite material layer.

50. A mold tool according to claim 49, wherein the top coat layer comprises a resin.

51. A mold tool according to claim 48 or claim 49, wherein the third fiber-reinforced matrix resin composite material comprises synthetic or natural fibers.

52. A mold tool according to claim 51, wherein the fibers are natural fibers composed of flax.

53. A mold tool according to any one of claims 38 to 52, wherein the mold tool is shaped and dimensioned to mold a wind turbine blade or a portion thereof.

Figure 1

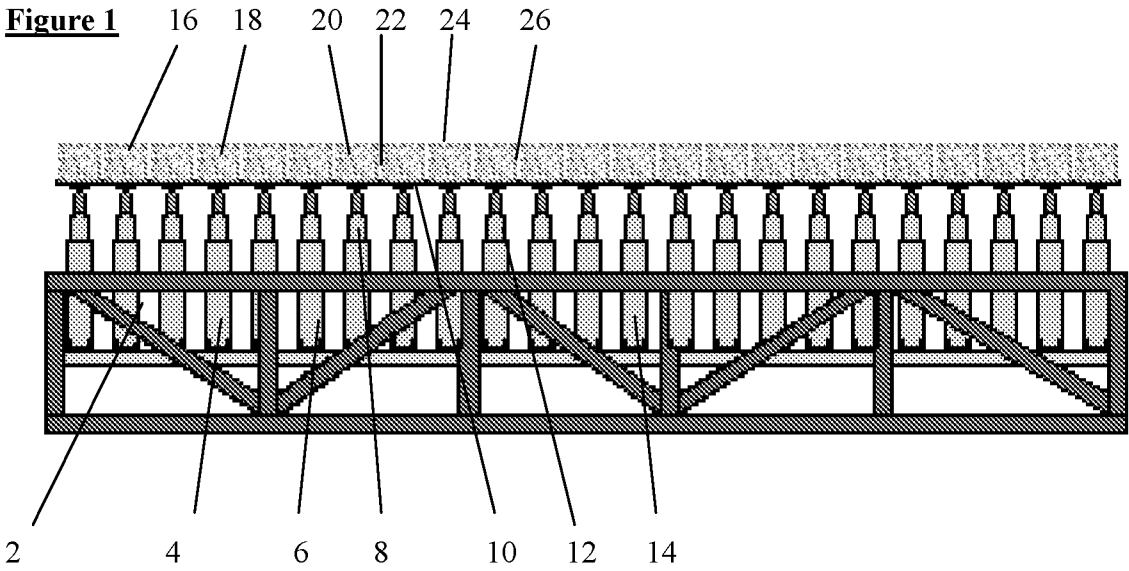


Figure 2

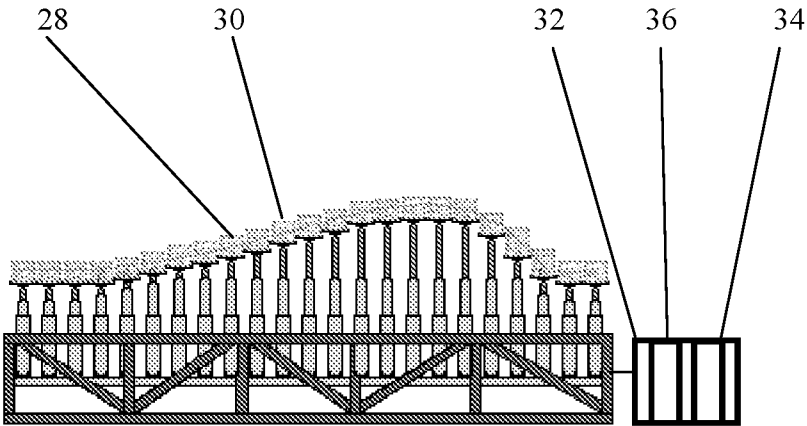


Figure 3

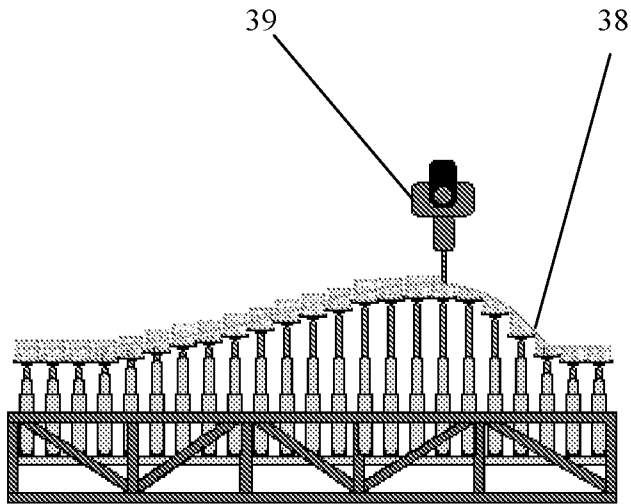


Figure 4

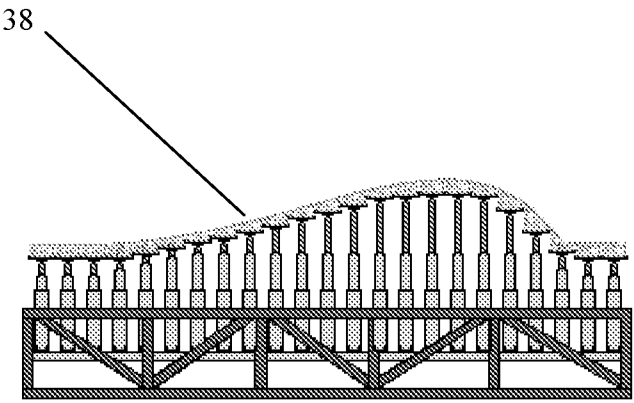


Figure 5

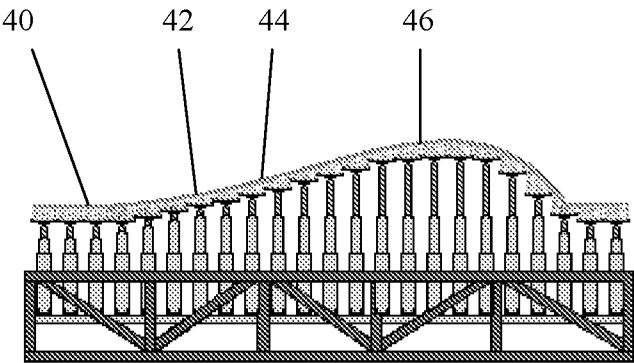


Figure 6

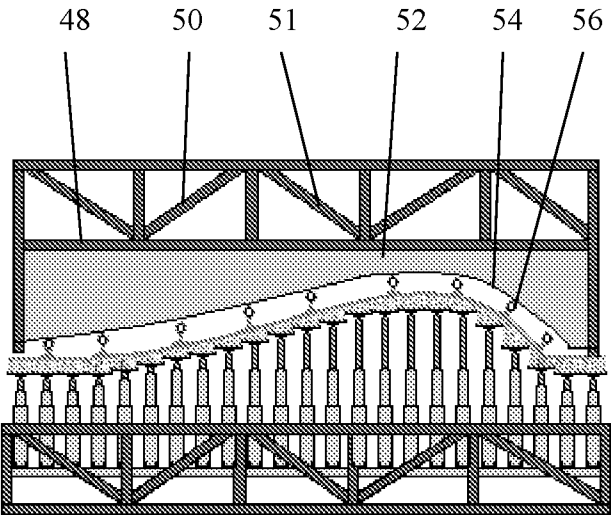


Figure 7

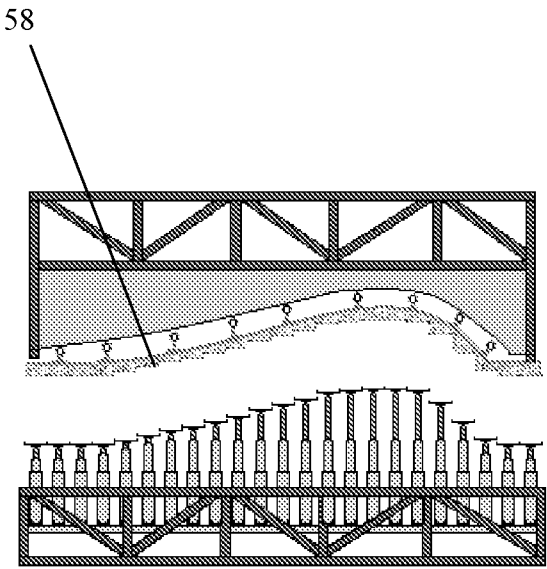


Figure 8

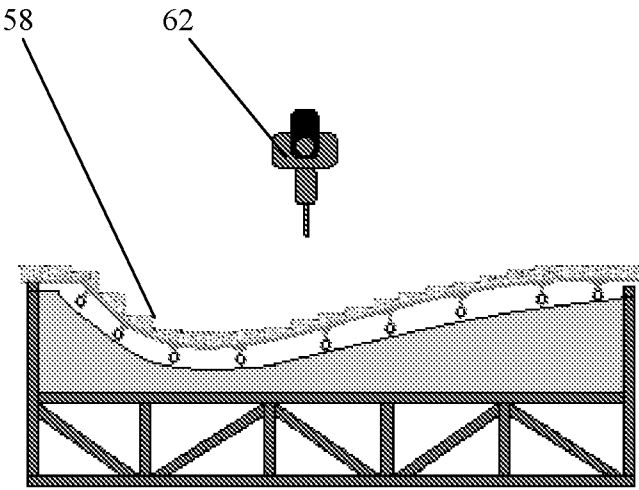


Figure 9

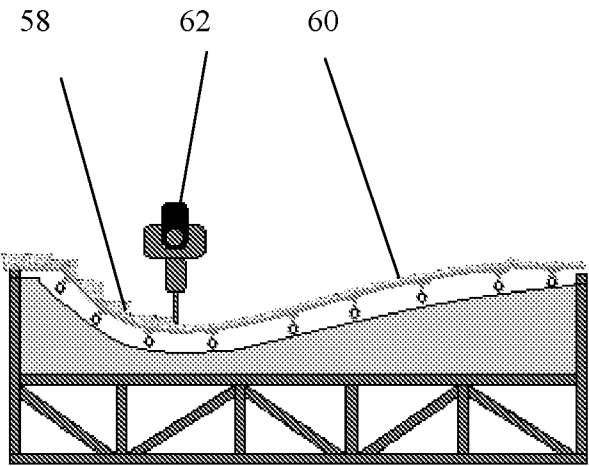


Figure 10

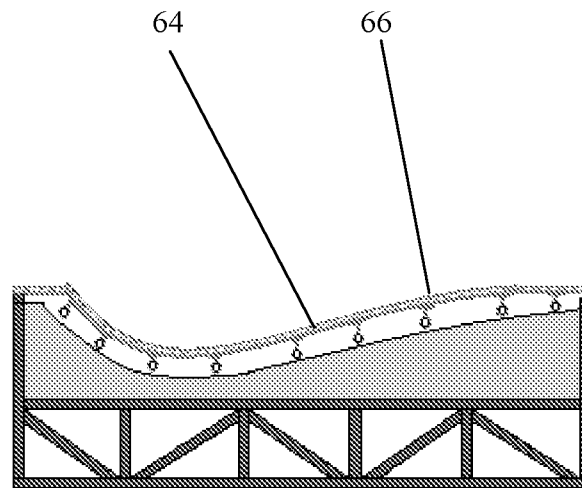


Figure 11

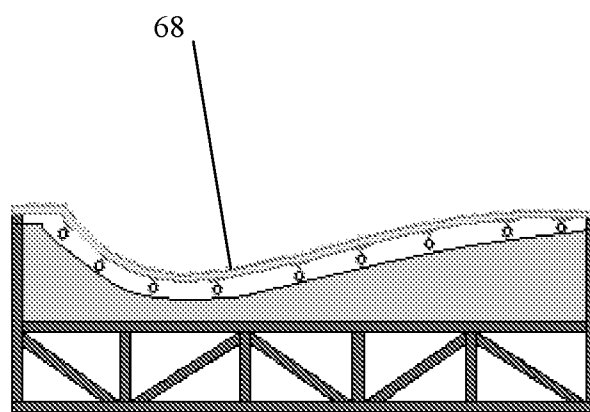


Figure 12

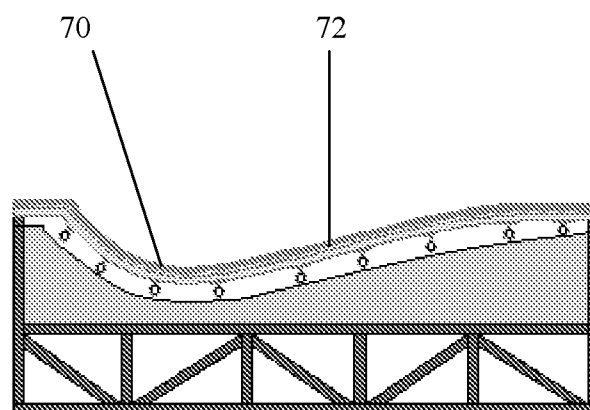


Figure 13

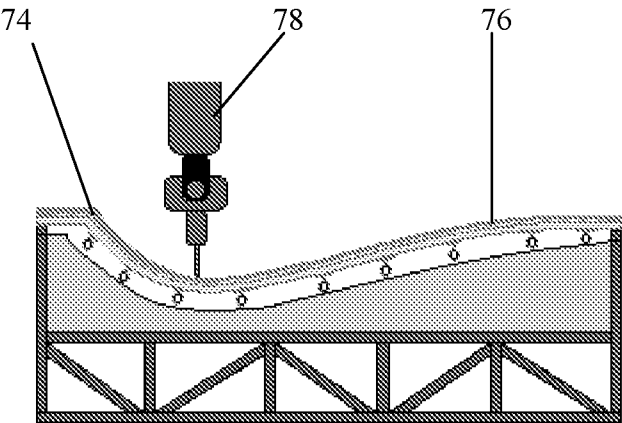


Figure 14

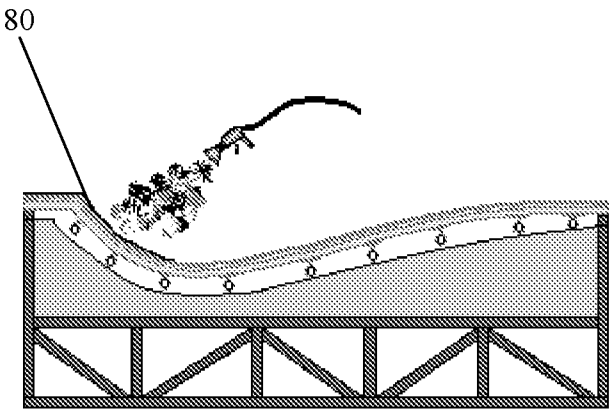


Figure 15

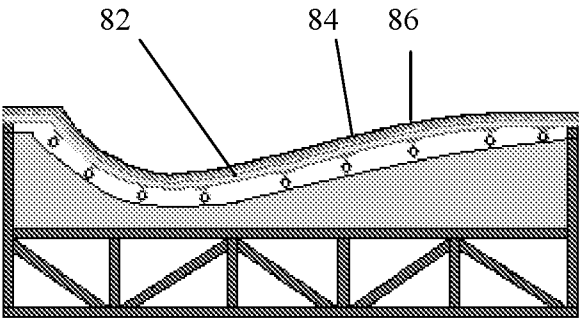
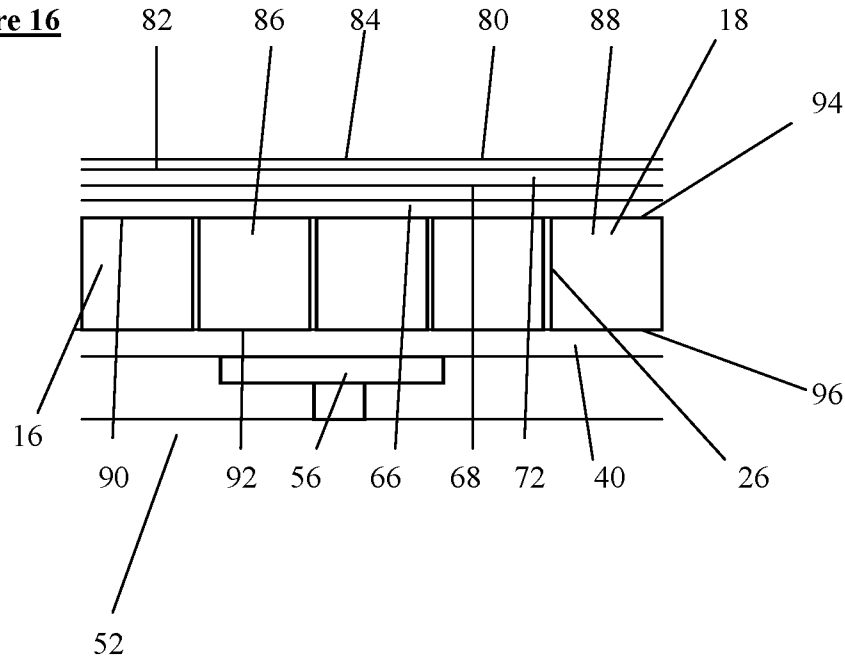


Figure 16



INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/095546

A. CLASSIFICATION OF SUBJECT MATTER

B29C 33/38(2006.01)i; B29C 33/30(2006.01)i; B29C 70/54(2006.01)i

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

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)

EPODOC,WPI,CNPAT,CNKI: GURIT, mold+,array, cellular, mov+,three dimension+, support, layer, wind+, blade

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102335982 A (GENERAL ELECTRIC CO.) 01 February 2012 (2012-02-01) description paragraphs 49-83, figures 1-2	38-53
A	CN 101396852 A (GENERAL ELECTRIC CO.) 01 April 2009 (2009-04-01) the whole document	1-53
A	CN 203765856 U (GURIT TOOLING TAICANG CO., LTD.) 13 August 2014 (2014-08-13) the whole document	1-53
A	CN 102019656 A (SUZHOU RED MAPLE WIND BLADE MOULD CO., LTD.) 20 April 2011 (2011-04-20) the whole document	1-53
A	CN 102501337 A (BEIJING COMPOSITE MATERIAL CO., LTD.) 20 June 2012 (2012-06-20) the whole document	1-53
A	US 2008302500 A1 (THE BOEING COMPANY) 11 December 2008 (2008-12-11) the whole document	1-53



Further documents are listed in the continuation of Box C.



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

“E” earlier application or patent 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

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“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

05 March 2019

Date of mailing of the international search report

21 March 2019

Name and mailing address of the ISA/CN

National Intellectual Property Administration, PRC
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088
China

Facsimile No. (86-10)62019451

Authorized officer

JIANG,Yumei

Telephone No. 86-10-53960973

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/095546

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	102335982	A	01 February 2012	US	9346193	B2	24 May 2016
				DK	2407292	T3	16 December 2013
				EP	2407292	B1	13 November 2013
				CN	102335982	B	20 May 2015
				US	2012013038	A1	19 January 2012
				CA	2745908	A1	14 January 2012
				US	10112322	B2	30 October 2018
				US	2016303770	A1	20 October 2016
				EP	2407292	A1	18 January 2012
				CA	2745908	C	03 July 2018
CN	101396852	A	01 April 2009	DE	102008044530	A1	09 April 2009
				US	2009084932	A1	02 April 2009
				DK	200801308	A	28 March 2009
CN	203765856	U	13 August 2014	None			
CN	102019656	A	20 April 2011	DE	212010000141	U1	07 May 2012
				KR	20110002774	U	17 March 2011
				WO	2011029275	A1	17 March 2011
				KR	200479696	Y1	25 February 2016
				US	9061447	B2	23 June 2015
				US	2012205052	A1	16 August 2012
				CN	102019656	B	25 March 2015
				BR	PI1003368	A2	30 October 2012
CN	102501337	A	20 June 2012	CN	102501337	B	28 May 2014
US	2008302500	A1	11 December 2008	WO	2008154137	A1	18 December 2008