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(54) **COMPOSITE STRUCTURAL ELEMENT AND METHOD OF PRODUCING THE SAME**

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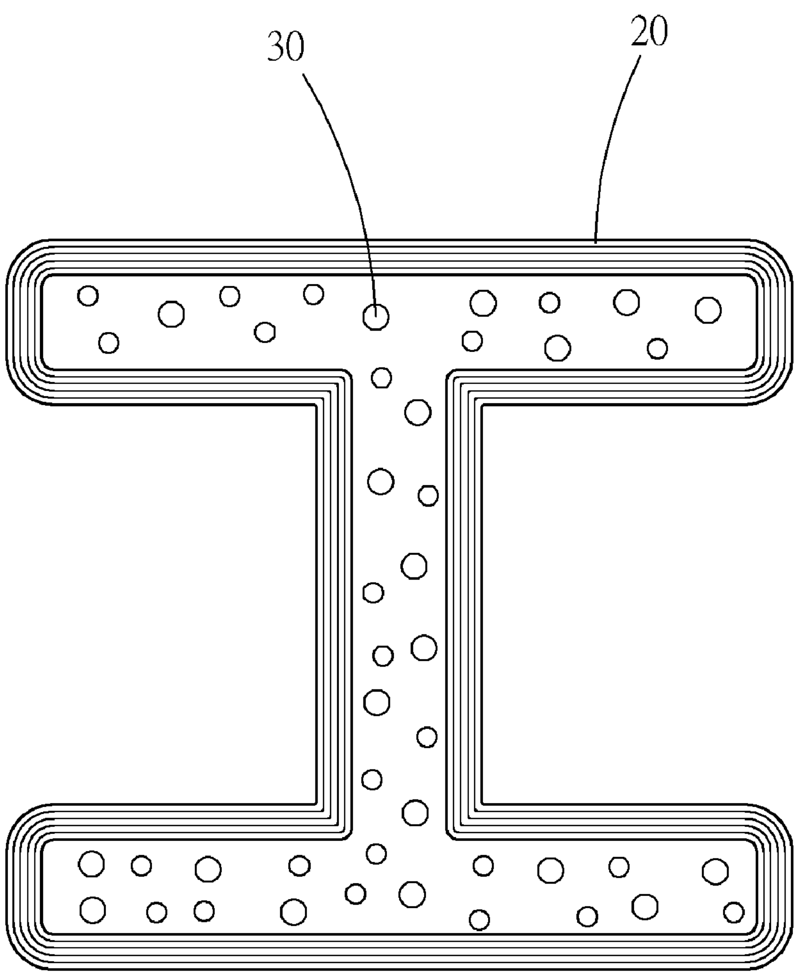
(57) **ABSTRACT**

The present invention provides a composite structural element and a method of producing the same, which includes taking a tape formed by alternatively laminating composite layers made of a non-isotropic composite material and interlayers made of an isotropic material as a major component of the structural element, molding into a structural element of a fixed shape for use in industry, and optionally, directly drilling holes on the laminate of the composite layers and the interlayers for connection.



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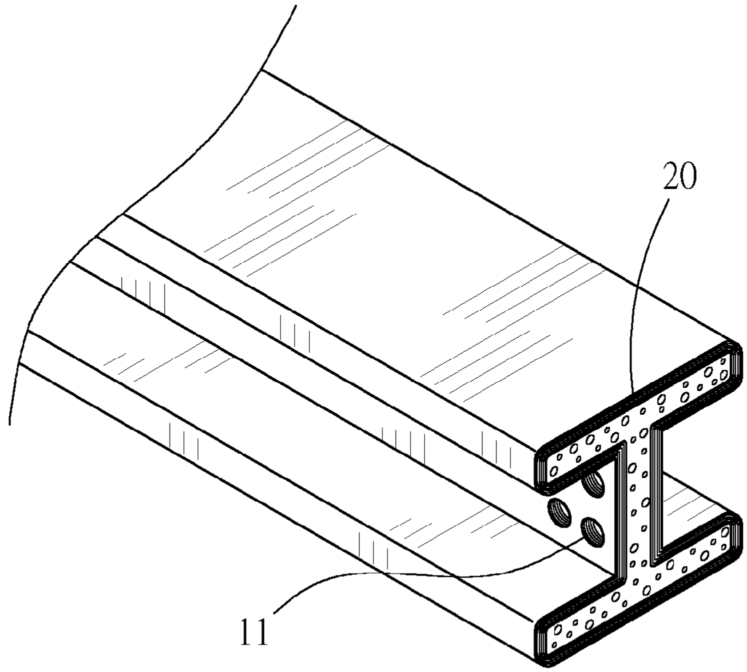

Fig. 1

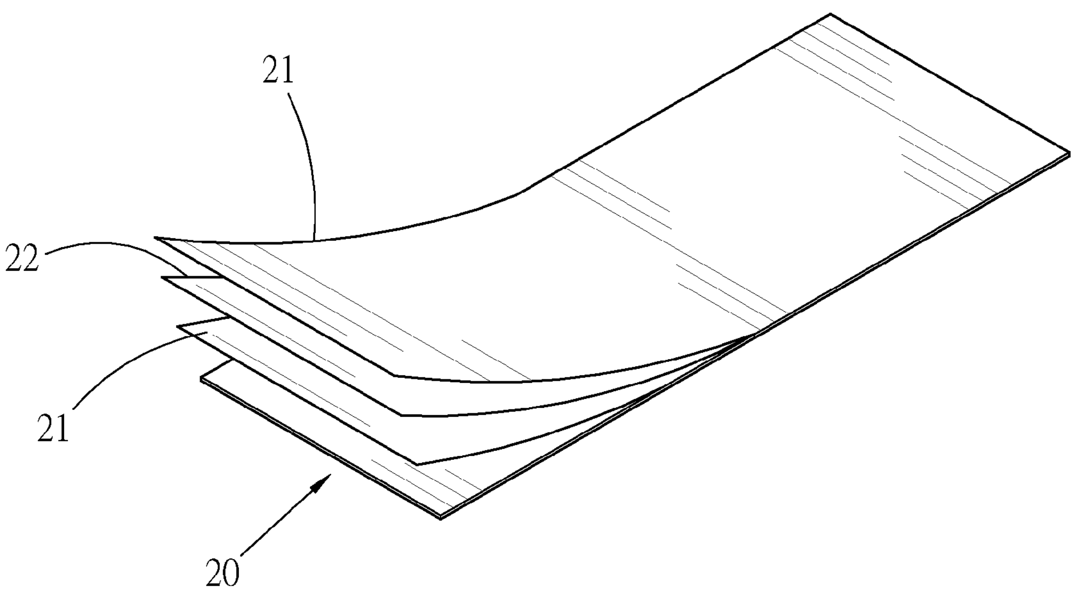

Fig. 2

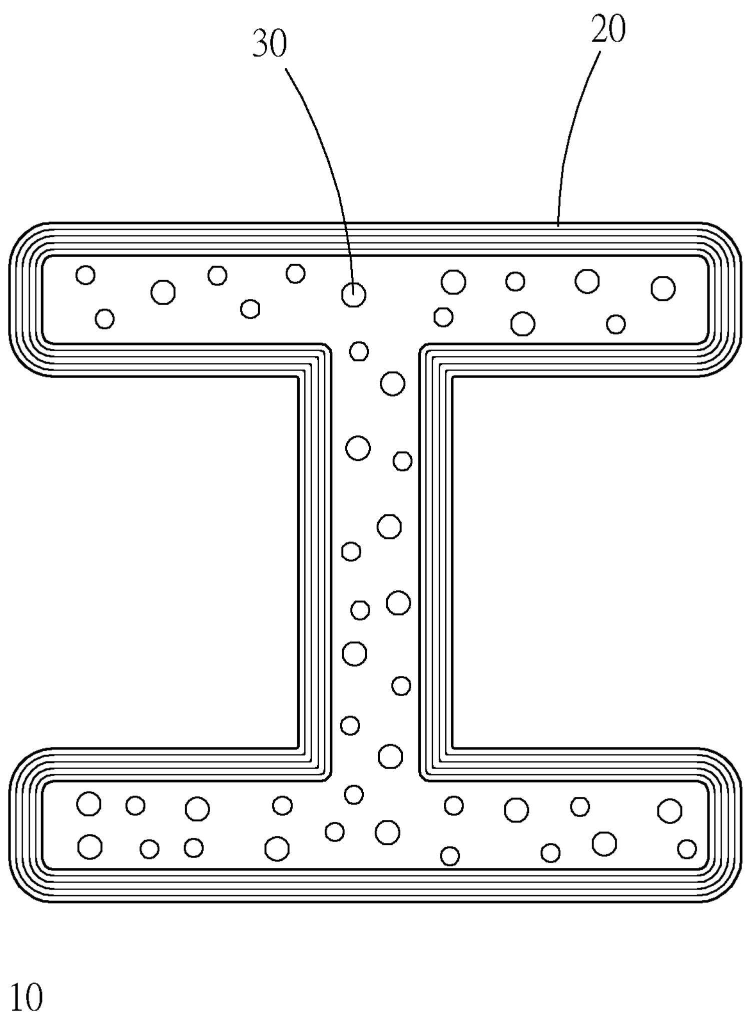

Fig. 3

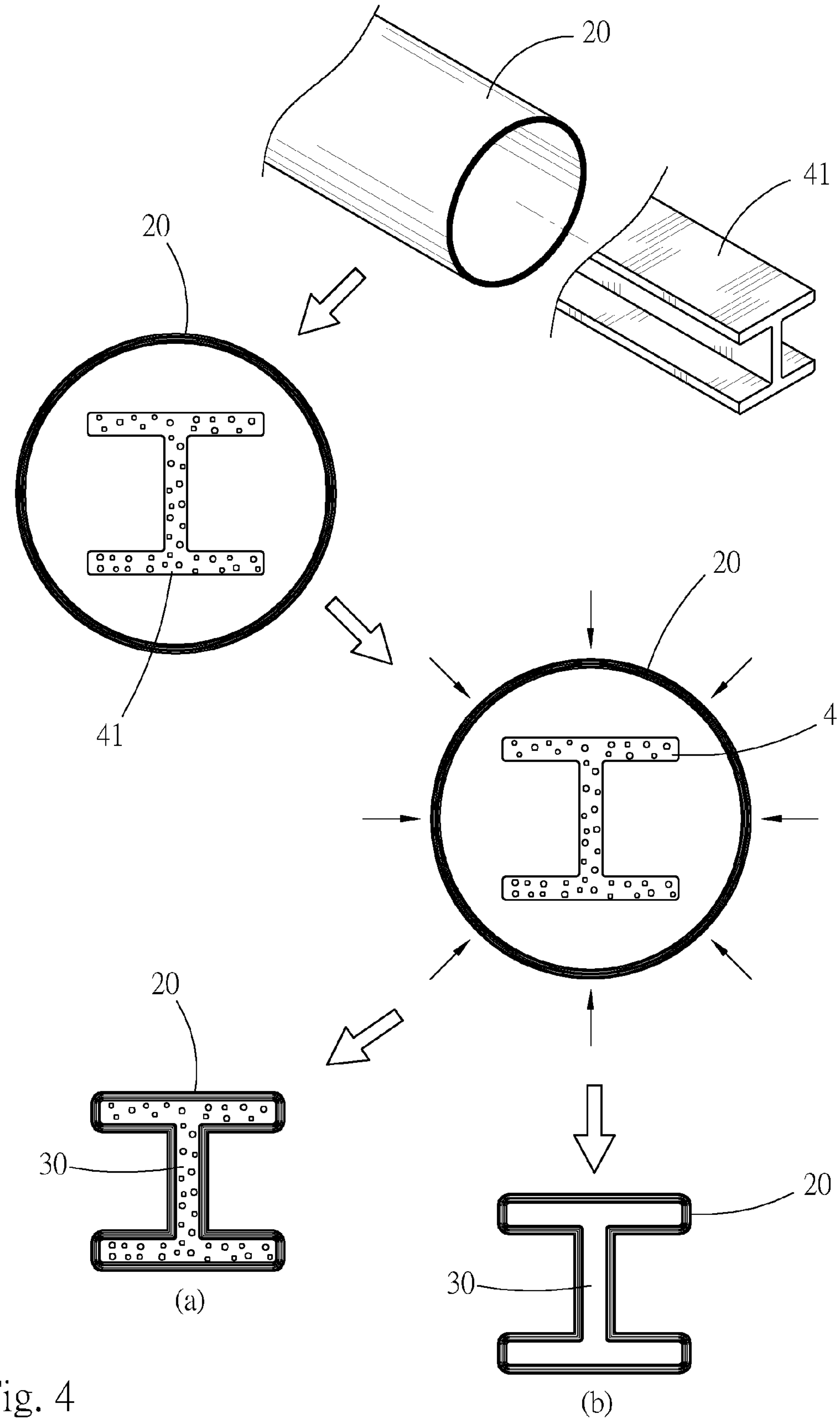

Fig. 4

COMPOSITE STRUCTURAL ELEMENT AND METHOD OF PRODUCING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a structural element, and more particularly, to a composite structural element and a method of producing the same.

2. Description of the Related Art

[0002] A method of producing a composite structural element disclosed in U.S. Pat. No. 7,357,726 is a conventional pultrusion method that is commonly used for continuously producing a special-shaped product, which enables the cross section of the molded structural element to have an I-shape, a C-shape, an L-shape, or an annular shape, and so on through a molding space provided by a specific mould, for use in construction, automotive, and other industries.

[0003] Microscopically, in the composite structural element, a desired arrangement direction of reinforcing materials such as fiber must be maintained by means of a base material such as resin, and a closed protection film is formed at the periphery of the fiber to provide a lateral support, so as to avoid stress concentration caused by the damage of the fiber due to the mutual friction, thereby affecting the strength and structure of the structural element itself. Moreover, in order to facilitate the combination of the composite material with other components, it is still necessary to adopt the technical means of drilling holes on the structural element for the combination by combining components. However, once holes are drilled on the structural element, breakpoints are generated in the continuity of the fiber to become the parts having concentrated stress, resulting in the damage that affects the structural strength such as delamination or cracks, which is contrary to the purpose of providing reinforcement by the reinforcing materials.

[0004] Therefore, in order to avoid the deficiency derived from the drilling on the composite material, the prior art discloses that on the premise that the integrity of fiber in the composite material is maintained, the structural element is combined with other components by adhering. Although such technologies can avoid the damage on the fiber so as to ensure the strength of the composite structural element, due to the limited adhesion of the combination sites, the application of the composite structural element is limited. For example, a vehicle transmission shaft made of carbon fiber can only be combined with metal joints on both ends by means of gluing, and the deterioration degree of the adhesive and the fatigue tolerance of the metal interfaces are unpredictable and thus have become potential dangerous factors for the driving security.

[0005] Thus, although the composite material has been widely used in various technical fields, the combination thereof with other components is still limited in technology. For drilling holes, good combination strength can be provided by means of the combining components such as bolts, but the concentration of stress will result in the damage on the composite structural element itself; and for the adhesive gluing means, the integrity of the composite structural element can be maintained, thereby avoiding the occurrence of stress concentration, but due to the deterioration of the adhesive that cannot be avoided, the combination strength is less than that of the bolts. Both means are imperfect.

SUMMARY OF THE INVENTION

[0006] In view of the above, the major objective of the present invention is to provide a composite structural element and a method of producing the same, which can avoid the damage on the structural element due to the stress concentration caused by the damage of the structural element at local structures such as drilled holes during the combination between the structural element and the external components.

[0007] Therefore, in order to achieve the above objective, the present invention provides a composite structural element, obtained by taking a tape formed by alternatively laminating composite layers made of a non-isotropic composite material and interlayers made of an isotropic material as a major component of the structural element, molding into a structural element of a fixed shape for use in industry, and optionally, directly drilling holes on the laminate of the composite layers and the interlayers.

[0008] Each of the composite layers has unidirectionally aligned fiber reinforcing materials and a polymeric base material wrapping each of the fiber reinforcing materials, and each of the interlayers is made of an isotropic material, and is located between any two adjacent ones of the composite layers.

[0009] To achieve a specific shape for the structural element, the composite structural element further includes an inner portion having a specific shape, and each of the composite layers and each of the interlayers wrap the external side of the inner portion, so as to forma profile having the same contour as that of the inner portion.

[0010] The shape of the inner portion may be an I-shape, an L-shape, a C-shape, or other geometric shapes, and the inner portion may be a non-physical space in addition to a physical article.

[0011] In order to properly distribute the stress transmission by means of the interlayers and avoid the damage on the fiber reinforcing materials of the composite layers, the interlayers are evenly distributed among the composite layers such that they are sequentially alternatively laminated with each other. Also, in order to further strengthen the mechanical strength of the structural element, the individual thickness of the composite layers is made between 10 μm and 40 μm, and the individual thickness of the interlayers is made between 6 μm and 35 μm.

[0012] When the interlayers are made of aluminum or alloy materials thereof, surface treatment such as anodizing treatment should be performed on the interlayers, so as to avoid galvanic corrosion.

[0013] In addition, the method of producing a composite structural element provided by the present invention includes forming a laminate by laminating the composite layers with the interlayers as described above, winding the laminate into a tubular outer portion, then taking a core having a specific shape to pass through the inner space of the outer portion as a mould, and exerting an external force such as an air pressure, such that the outer portion is contracted and attached to the periphery of the core, and then curing.

[0014] During the curing of the outer portion, the core may be formed integrally with the outer portion, such that the core serves as the inner portion of the structural element. In this case, for the purpose of lightweight, foamed plastics or other lightweight materials can be used to produce the core.

[0015] In contrast, after the curing of the outer portion, the core may also be drawn off, such that the space where the core is originally located becomes a non-physical space, so as to form the inner portion with a non-physical space.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a perspective view of a structural element according to a preferred embodiment of the present invention.

[0017] FIG. **2** is a schematic view of a laminate of composite layers and interlayers alternatively laminated with each other according to a preferred embodiment of the present invention.

[0018] FIG. **3** is a cross-sectional view of a preferred embodiment of the present invention.

[0019] FIG. **4** is a schematic view of a producing process according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] First of all, as shown in FIG. **1** to FIG. **3**, a composite structural element (**10**) provided in a preferred embodiment the present invention has an I-shape, which can be used as a substitute of an I-shaped steel beam in building materials or a component of a vehicle, and of course, it may also has other different shapes or structures for use in other different industries. In other words, the so-called structural element in the present invention is not limited to the so-called structural element in the building technology, and in terms of the structure, the composite structural element (**10**) mainly comprises an outer portion (**20**) and an inner portion (**30**).

[0021] The outer portion (**20**) is a laminate formed by laminating a plurality of single layers respectively made of a composite material and an isotropic material with each other, and includes a plurality of composite layers (**21**) and a plurality of interlayers (**22**), wherein the composite layers (**21**) are respectively structured as a fiber tape and not a fiber cloth, and each have unidirectionally aligned fiber reinforcing materials and a polymeric base material wrapping on each of the fiber reinforcing materials. The thickness of the single layer is preferably between 10 μm and 40 μm, and may be a material such as a glass fiber, a graphite fiber, a Keviar fiber, a carbon nanotube, or a substitute or surrogate thereof;

[0022] each of the interlayers (**22**) is made of an isotropic material including metals such as aluminum or other non-metals, and the thickness of a single layer thereof is preferably between 6 μm and 35 μm; and

[0023] each of the composite layers (**21**) and each of the interlayers (**22**) are sequentially alternatively laminated with each other, such that the interlayers (**22**) can be uniformly distributed in the whole laminate, whereby the interlayers (**22**) can uniformly distribute the received force inside the laminate, thereby avoiding the damage derived from the local concentration of stress.

[0024] The inner portion (**30**) serves to give a specific shape as a whole of the structural element (**10**) and achieve the effect of increasing the volume of the structural element and reducing the usage amount of the outer portion (**20**, and thus may be a lightweight material such as foam or foamed plastics, such that the outer portion (**20**) is wrapped onto the inner portion (**30**).

[0025] Through the constitution of the components above, the composite structural element (**10**) can provide a good mechanical strength by means of the outer portion (**20**), and also, a plurality of fixing holes (**11**) may be directly drilled on the outer portion (**20**) and the inner portion (**30**) to respectively pass through each of the composite layers (**21**) and each of the interlayers (**22**). Hereby, when the combining components such as bolts are fixed in the fixing holes (**11**) to combine the composite structural element (**10**) with another composite structural element or an external component, although the fiber continuity of the fiber reinforcing materials is damaged by the fixing holes (**11**), so that the force fails to be further transmitted and focuses at breakpoint sites, by means of the interlayers (**22**), the force that is not transmitted by the fiber may be further transmitted to the fiber with the isotropy of the material of the interlayers (**22**), so as to avoid stress concentration, thereby achieving the purpose of enhancing the mechanical strength of the combination sites of the composite structural element (**10**) and making the composite structural element (**10**) have a wider application range. In addition, because the interlayers (**22**) are uniformly distributed in the laminate and have a very small thickness, the uniform distribution of force can be ensured and the delamination can be avoided, so as to maintain the structural stability of the composite structural element (**10**).

[0026] Further, referring to FIG. **4**, in order to manufacture the composite structural element (**10**), the following steps may be carried out:

[0027] a. taking a laminate formed by laminating each of the composite layers (**21**) with each of the interlayers (**22**) and winding to form a tubular outer portion (**20**);

[0028] b. taking an elongated core (**41**) to coaxially pass through the inner space of the outer portion (**20**);

[0029] c. exerting an external forces such as an air pressure to the external side of the outer portion (**20**), such that the outer portion is contracted and attached to the periphery of the core (**41**); and

[0030] d. wrapping the outer portion (**20**) onto the core (**41**) and curing.

[0031] When the step d is carried out, if the outer portion (**20**) is integrally formed with the core (**41**), so that the core (**41**) cannot be separated from the outer portion after molding, the core (**41**) becomes the inner portion (**30**) of the composite structural element (**10**) as shown in (a) of FIG. **4**. For this reason, a lightweight material such as foams or other foamed plastics is preferably used as the material of the core, so as to achieve the purpose and effect of lightweight.

[0032] In contrast, if after the step d is carried out, it is necessary to separate the core (**41**) from the cured outer portion (**20**), when the step d is carried out, a possibility of separating the outer portion (**20**) from the core (**41**) should be provided, for example, a release agent is applied on the surface of the core (**41**) in advance, such that after the step d is carried out, the core (**41**) is drawn away, and as shown in (b) of FIG. **4**, the space after the core (**41**) is drawn away forms the inner portion (**30**) of the composite structural element (**10**).

[0033] Regardless of a physical core or a non-physical space which constitutes the inner portion (**30**) of the composite structural element (**10**), the efficacy of avoiding the stress concentration achieved by the outer portion (**20**) is not affected, and also, in order to obtain a specific shape of the composite structural element (**10**), in addition to the I-shape, the sectional shape of the core may be a C-shape, an L-shape, or other geometric shapes, such that the shape of the composite structural element (**10**) can satisfy different requirements.

DESCRIPTION OF REFERENCE NUMERALS

[0034] (**10**) composite structural element (**11**) fixing hole (**20**) outer portion

[0035] (**21**) composite layer (**22**) interlayer (**30**) inner portion

[0036] (**41**) core

1. A composite structural element, comprising:

an outer portion, comprising a plurality of composite layers and a plurality of interlayers laminated with each other, wherein each of the composite layers has unidirectionally aligned fiber reinforcing materials and a polymeric base material wrapping each of the fiber reinforcing materials, and each of the interlayers is made of an isotropic material being aluminum and is located between any two adjacent ones of the composite layers; and

a plurality of fixing holes respectively passing through each of the composite layers and each of the interlayers;

wherein the thickness of each of the composite layers is between 10 μm and 40 μm, and the thickness of each of the interlayers is between 6 μm and 35 μm.

2. The composite structural element according to claim **1**, further comprising an inner portion having a section with an I-shape, an L-shape, a C-shape, or other geometric shapes, located within the outer portion.

3. The composite structural element according to claim **2**, wherein the inner portion is a tangible article or a space.

4. The composite structural element according to claim **1**, wherein each of the composite layers and each of the interlayers are sequentially alternatively laminated with each other.

5-6. (canceled)

7. The composite structural element according to claim **2**, wherein each of the composite layers and each of the interlayers are sequentially alternatively laminated with each other.

8-9. (canceled)

10. The composite structural element according to claim **3**, wherein each of the composite layers and each of the interlayers are sequentially alternatively laminated with each other.

11-12. (canceled)

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