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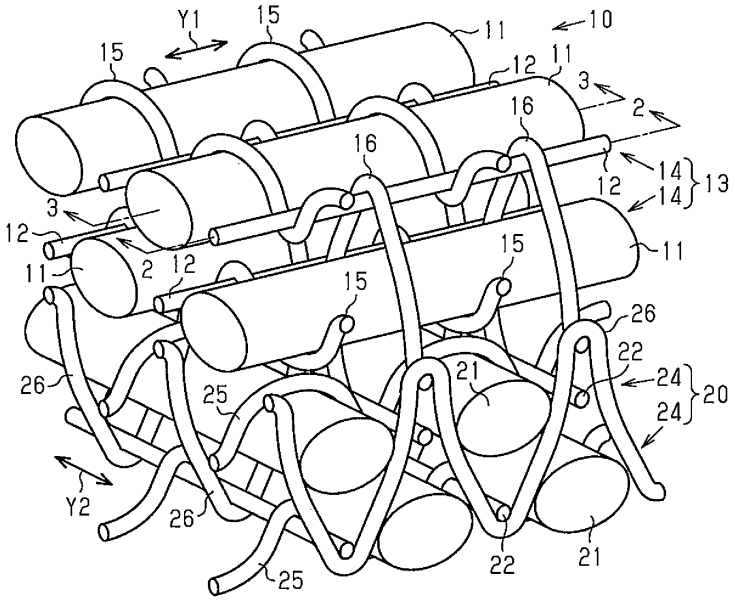
(54) **FIBER STRUCTURE**

(57) A fiber structure includes a first laminate and a second laminate, which are arranged such that the yarn main axes of first reinforcement fiber yarns and second reinforcement fiber yarns are caused to be orthogonal to each other and that the main yarn axes of first auxiliary yarns and second auxiliary yarns are caused to be orthogonal to each other. The engagement of first intermediate structure yarns of the first laminate and second intermediate structure yarns of the second laminate joins the first laminate and the second laminate together in the lamination direction.

Fig.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a fiber structure that is configured by multiple laminates.

BACKGROUND ART

[0002] Fiber-reinforced composites have been used as a light-weight, high-strength material. The fiber-reinforced composites include reinforcement fibers combined with a matrix such as resin and metal. This improves the dynamic property (mechanical property) of the fiber-reinforced composites compared with the matrix itself. The fiber-reinforced composites are therefore preferable as a structural component. In particular, resin is preferably used as the matrix since the weight of the structural component will be reduced.

[0003] A fiber structure is used as the base material of such a fiber-reinforced composite. The fiber structure includes a structure in which yarn main axes of reinforcement fiber yarns extend in two directions at 0 degrees and 90 degrees to increase the dynamic property in two directions when the fiber structure is used in the fiber-reinforced composite. Such a biaxial fiber structure is produced by stacking fiber layers in which reinforcement fiber yarns are oriented in one direction in such a manner that the yarn main axis of the reinforcement fiber yarns of one fiber layer is orthogonal to the yarn main axis of the reinforcement fiber yarns of another fiber layer.

[0004] Patent Document 1 discloses a fabric base material configured by fiber layers in which the reinforcement fiber yarns are oriented in one direction. The fabric base material is constituted by stacking two fiber layers. Each fiber layer includes reinforced fiber warps, which are arranged parallel to each other, and auxiliary yarns, each of which is arranged between the adjacent reinforced fiber warps and extends in the same direction as the reinforced fiber warps. The reinforced fiber warps of each fiber layer extend in the same direction as the reinforced fiber warps of the other fiber layer and are shifted in an arrangement direction in a state in which the reinforced fiber warps partially overlap the reinforced fiber warps of the other fiber layer. In each fiber layer, the reinforced fiber warps and the auxiliary yarns are joined with intralayer structural yarns. The fiber layers are joined with intermediate structural yarns to form a unidirectional fabric base material.

[0005] Producing a biaxial fiber structure by stacking the fabric base material disclosed in Patent Document 1 has been considered. In this case, first, multiple fabric base materials are stacked in such a manner that the yarn main axis of the reinforced fiber warps of one of the fabric base materials is orthogonal to the yarn main axis of the reinforced fiber warps of another fabric base material. The fabric base materials are then joined in the stacking direction with joining yarns prepared separately. As a result, the biaxial fiber structure is produced in which the directions of the yarn main axes of the reinforced fiber warps are at 0 degrees and 90 degrees.

[0006] However, to produce the above-described biaxial fiber structure, it is necessary to produce at least two fabric base materials and to join the two fabric base materials with separate yarns. It takes a lot of trouble joining the fabric base materials in the stacking direction and thus increases the manufacturing costs.

PRIOR ART DOCUMENT

Patent Document

[0007] Patent Document 1: Japanese Laid-Open Patent Publication No. 2013-133555

SUMMARY OF THE INVENTION

Problems that the Invention is to Solve

[0008] Accordingly, it is an objective of the present invention to provide a fiber structure that allows a biaxial fiber structure to be easily produced.

Means for Solving the Problems

[0009] To achieve the foregoing objective and in accordance with a first aspect of the present invention, a fiber structure including a plurality of laminates is provided. The laminates each include a plurality of stacked fiber layers. The fiber layers each include reinforcement fiber yarns, auxiliary yarns, and intralayer structural yarns. The reinforcement fiber yarns and the auxiliary yarns are arranged alternately. The intralayer structural yarns join the reinforcement fiber yarns and the auxiliary yarns together in an arrangement direction. In each laminate: yarn main axis directions of the reinforcement fiber yarns and the auxiliary yarns of each of the fiber layers are the same; the reinforcement fiber yarns are arranged in such a manner that the relative positions are shifted in a stacking direction of the fiber layers with the reinforcement fiber yarns overlapping each other; the auxiliary yarns are arranged in such a manner that the relative positions are shifted; and the fiber layers are joined with intermediate structural yarns engaged with the auxiliary yarns located on opposite ends in the stacking direction. The laminates are arranged such that: a yarn main axis of the reinforcement fiber yarns of each laminate is orthogonal to a yarn main axis of the reinforcement fiber yarns of another laminate; and a yarn main axis of the auxiliary yarns of each laminate is orthogonal to a yarn main axis of the auxiliary yarns of another laminate. The laminates are joined together in the stacking direction by an engagement between at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and at least one of a set of the intralayer

structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction.

[0010] To achieve the foregoing objective and in accordance with a second aspect of the present invention, a fiber-reinforced composite in which a fiber structure is impregnated with a matrix resin is provided. The fiber structure includes a plurality of laminates. The laminates each include a plurality of stacked fiber layers. The fiber layers each include reinforcement fiber yarns, auxiliary yarns, and intralayer structural yarns. The reinforcement fiber yarns and the auxiliary yarns are arranged alternately. The intralayer structural yarns join the reinforcement fiber yarns and the auxiliary yarns together in an arrangement direction. In each laminate: yarn main axis directions of the reinforcement fiber yarns and the auxiliary yarns of each of the fiber layers are the same; the reinforcement fiber yarns are arranged in such a manner that the relative positions are shifted in a stacking direction of the fiber layers with the reinforcement fiber yarns overlapping each other; the auxiliary yarns are arranged in such a manner that the relative positions are shifted; and the fiber layers are joined with intermediate structural yarns engaged with the auxiliary yarns located on opposite ends in the stacking direction. The laminates are arranged such that: a yarn main axis of the reinforcement fiber yarns of each laminate is orthogonal to a yarn main axis of the reinforcement fiber yarns of another laminate; and a yarn main axis of the auxiliary yarns of each laminate is orthogonal to a yarn main axis of the auxiliary yarns of another laminate. The laminates are joined together in the stacking direction by an engagement between at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a partial diagrammatic perspective view of a fiber structure according to a first embodiment of the present invention.

Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1.

Fig. 3 is a cross-sectional view taken along line 3-3 of Fig. 1.

Fig. 4 is a partial front view of the fiber structure according to the first embodiment.

Fig. 5 is a partial diagrammatic perspective view of a fiber structure according to a second embodiment of the present invention.

Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 5.

Fig. 7 is a cross-sectional view taken along line 7-7 of Fig. 5.

Fig. 8 is a partial front view of the fiber structure according to the second embodiment.

Fig. 9 is a partial diagrammatic perspective view of a fiber structure according to a third embodiment of the present invention.

Fig. 10 is a cross-sectional view taken along line 10-10 of Fig. 9.

Fig. 11 is a cross-sectional view taken along line 11-11 of Fig. 9.

Fig. 12 is a partial front view of the fiber structure according to the third embodiment.

MODES FOR CARRYING OUT THE INVENTION

First Embodiment

[0012] A fiber structure according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 4.

[0013] As shown in Figs. 1 to 3, a fiber structure 10 is formed by stacking a first laminate 13 and a second laminate 20 and joining the first and second laminates 13, 20 in the stacking direction.

[0014] The first laminate 13 is a laminate of two first fiber layers 14. The two first fiber layers 14 are joined in the stacking direction with first intermediate structural yarns 16.

[0015] Each first fiber layer 14 includes reinforcement fiber yarns, which are first reinforcement fiber yarns 11 in this embodiment, auxiliary yarns, which are first auxiliary yarns 12 in this embodiment, and first intralayer structural yarns 15, which join the first reinforcement fiber yarns 11 and the first auxiliary yarns 12 in an arrangement direction. In each first fiber layer 14, the first reinforcement fiber yarns 11 and the first auxiliary yarns 12 are arranged alternately. Additionally, in each first fiber layer 14, the first reinforcement fiber yarns 11 are arranged parallel to each other, the first auxiliary yarns 12 are arranged parallel to each other, and the first reinforcement fiber yarns 11 and the first auxiliary yarns 12 are arranged parallel to each other.

[0016] In the first fiber layers 14, each first intralayer structural yarn 15 is engaged with the upper surface or the lower surface of the first reinforcement fiber yarns 11 and is engaged with the lower surface or the upper surface of the first auxiliary yarns 12. Each first intralayer structural yarn 15 extends in the arrangement direction of the first reinforcement fiber yarns 11 and the first auxiliary yarns 12 while being alternately folded back with respect to the first reinforcement fiber yarns 11 and the first auxiliary yarns 12. The term "reinforcement fiber" of the first reinforcement fiber yarn 11 refers to a fiber bundle that reinforces the matrix of the fiber-reinforced composite when the fiber structure 10 is used as the reinforced base material of the fiber-reinforced composite. The first reinforcement fiber yarns 11 have the same thickness.

The first auxiliary yarns 12 are fiber bundles thinner than the first reinforcement fiber yarns 11.

[0017] As shown in Figs. 1 and 4, the two first fiber layers 14 of the first laminate 13 are stacked and joined together in the stacking direction with the first intermediate structural yarns 16.

[0018] As shown in Figs. 2 and 3, each first intermediate structural yarn 16 is arranged between the first intralayer structural yarns 15 that are adjacent to each other in the direction of the yarn main axis of the first reinforcement fiber yarns 11, and the first intermediate structural yarns 16 are arranged parallel to each other. As shown in Fig. 4, each first intermediate structural yarn 16 is engaged with the upper surface of one of the first auxiliary yarns 12 of the upper first fiber layer 14 located on one end in the stacking direction, is folded back, and then extends in the stacking direction. Subsequently, each first intermediate structural yarn 16 is engaged with the lower surface of one of the second intermediate structural yarns 26 below one of the first auxiliary yarns 12 of the lower first fiber layer 14 located on the other end in the stacking direction and is then folded back. Each first intermediate structural yarn 16 extends in the arrangement direction while repeating engagement with the first auxiliary yarns 12 and the second intermediate structural yarns 26. This joins the two first fiber layers 14 in the stacking direction.

[0019] In the first laminate 13, the first reinforcement fiber yarns 11 are arranged to partially overlap each other in the width direction of the first reinforcement fiber yarns 11 in the plan view. Additionally, in the first laminate 13, the first reinforcement fiber yarns 11 are arranged in a staggered manner by shifting the relative positions of the first reinforcement fiber yarns 11 in the stacking direction. Furthermore, in the first laminate 13, the first auxiliary yarns 12 are also arranged in a staggered manner by shifting the relative positions of the first auxiliary yarns 12 in the stacking direction.

[0020] As shown in Figs. 1 to 3, the second laminate 20 is a laminate of two second fiber layers 24 and is formed by joining the two second fiber layers 24 in the stacking direction with second intermediate structural yarns 26.

[0021] Each second fiber layer 24 includes reinforcement fiber yarns, which are second reinforcement fiber yarns 21 in this embodiment, auxiliary yarns, which are second auxiliary yarns 22 in this embodiment, and second intralayer structural yarns 25, which join the second reinforcement fiber yarns 21 and the second auxiliary yarns 22 in the arrangement direction. In each second fiber layer 24, the second reinforcement fiber yarns 21 and the second auxiliary yarns 22 are arranged alternately. Additionally, in each second fiber layer 24, the second reinforcement fiber yarns 21 are arranged parallel to each other, the second auxiliary yarns 22 are arranged parallel to each other, and the second reinforcement fiber yarns 21 and the second auxiliary yarns 22 are arranged parallel to each other.

[0022] In the second fiber layers 24, each second intralayer structural yarn 25 is engaged with the upper surface or the lower surface of the second reinforcement fiber yarns 21 and is engaged with the lower surface or the upper surface of the second auxiliary yarns 22. Each second intralayer structural yarn 25 extends in the arrangement direction of the second reinforcement fiber yarns 21 and the second auxiliary yarns 22 while being alternately folded back with respect to the second reinforcement fiber yarns 21 and the second auxiliary yarns 22. The second reinforcement fiber yarns 21 are the same yarns as the first reinforcement fiber yarns 11, and the second auxiliary yarns 22 are the same yarns as the first auxiliary yarns 12.

[0023] As shown in Figs. 3 and 4, the two second fiber layers 24 of the second laminate 20 are stacked and joined together in the stacking direction with the second intermediate structural yarns 26. Each second intermediate structural yarn 26 is arranged between the second intralayer structural yarns 25 that are adjacent to each other in the direction of the yarn main axis of the second reinforcement fiber yarns 21, and the second intermediate structural yarns 26 are arranged parallel to each other. Each second intermediate structural yarn 26 is engaged with the upper surface of one of the first intermediate structural yarns 16 above one of the second auxiliary yarns 22 of the upper second fiber layer 24 located on one end in the stacking direction, is folded back, and then extends in the stacking direction. Subsequently, each second intermediate structural yarn 26 is engaged with the lower surface of one of the second auxiliary yarns 22 of the lower second fiber layer 24 located on the other end in the stacking direction and is then folded back. Each second intermediate structural yarn 26 extends in the arrangement direction while repeating engagement with the first intermediate structural yarns 16 and the second auxiliary yarns 22. This joins the two second fiber layers 24 together in the stacking direction.

[0024] In the second laminate 20, the second reinforcement fiber yarns 21 are arranged to partially overlap each other in the width direction of the second reinforcement fiber yarns 21 in the plan view. Additionally, in the second laminate 20, the second reinforcement fiber yarns 21 are arranged in a staggered manner by shifting the relative positions of the second reinforcement fiber yarns 21 in the stacking direction. Furthermore, in the second laminate 20, the second auxiliary yarns 22 are also arranged in a staggered manner by shifting the relative positions of the second auxiliary yarns 22 in the stacking direction.

[0025] As shown in Fig. 1, the direction of the yarn main axis of the first reinforcement fiber yarns 11 in the first laminate 13 is defined as a first yarn main axis direction Y1. The orientation angle of the first reinforcement fiber yarns 11 is defined as 0 degrees. The direction of the yarn main axis of the second reinforcement fiber yarns 21 in the second laminate 20 is defined as a second yarn main axis direction Y2. The yarn main axis of the first reinforcement fiber yarns 11 in the first laminate 13 in-

tersects the yarn main axis of the second reinforcement fiber yarns 21 in the second laminate 20 at 90 degrees, that is, the yarn main axis of the first reinforcement fiber yarns 11 in the first laminate 13 is orthogonal to the yarn main axis of the second reinforcement fiber yarns 21 in the second laminate 20. The fiber structure 10 has a biaxial fiber structure of 0 degrees and 90 degrees. In the fiber structure 10, the first laminate 13, in which the yarn main axis of the first reinforcement fiber yarns 11 extends in one direction (the first yarn main axis direction Y1), and the second laminate 20, in which the yarn main axis of the second reinforcement fiber yarns 21 extends in the other direction (the second yarn main axis direction Y2), are joined together in the stacking direction. The first laminate 13 and the second laminate 20 are joined together in the stacking direction by the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20.

[0026] As shown in Figs. 3 and 4, each first intermediate structural yarn 16 of the first laminate 13 extends to a position between the first reinforcement fiber yarns 11 of the lower first fiber layer 14 and the second laminate 20 and is folded back. Each second intermediate structural yarn 26 of the second laminate 20 extends to a position between the second reinforcement fiber yarns 21 of the upper second fiber layer 24 and the first laminate 13 and is folded back. Each first intermediate structural yarn 16 of the first laminate 13 is orthogonal to and engaged with the second intermediate structural yarns 26 of the second laminate 20 at positions between the laminates 13, 20.

[0027] The above-described fiber structure 10 is shaped and preformed. Subsequently, the fiber structure 10 is impregnated with a liquid thermosetting resin (matrix) by, for example, a resin transfer molding (RTM) method and the liquid thermosetting resin is cured to form the fiber-reinforced composite.

[0028] Operation of the fiber structure 10 will now be described.

[0029] The first laminate 13 and the second laminate 20 of the fiber structure 10 are joined together in the stacking direction using the first intermediate structural yarns 16 of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20.

[0030] The above-described embodiment achieves the following advantages.

(1) When the fiber structure 10 is produced using a loom, the manner in which the first intermediate structural yarns 16 and the second intermediate structural yarns 26 are fed is controlled to engage the first intermediate structural yarns 16 with the second intermediate structural yarns 26. The engagement joins the first laminate 13 and the second laminate 20 together in the stacking direction. This allows for easy production using the loom, of the biaxial fiber structure 10, in which the yarn main axis of the first reinforcement fiber yarns 11 in the first laminate 13 (the first yarn main axis direction Y1) is orthogonal to the yarn main axis of the second reinforcement fiber yarns 21 in the second laminate 20 (the second yarn main axis direction Y2). Consequently, the biaxial fiber structure 10 is easily produced compared with, for example, a method in which the first laminate 13 and the second laminate 20 are separately produced, and the first laminate 13 and the second laminate 20 are joined in the stacking direction using separate yarns in the subsequent process.

(2) In the fiber structure 10, the first reinforcement fiber yarns 11 and the second reinforcement fiber yarns 21 extend straight and do not curve or bend. This prevents a decrease in the dynamic property in the first yarn main axis direction Y1 and the second yarn main axis direction Y2 of the fiber-reinforced composite that includes the fiber structure 10 as the reinforced base material.

(3) The first intermediate structural yarns 16 of the first laminate 13 join the two first fiber layers 14 of the first laminate 13 together in the stacking direction. The second intermediate structural yarns 26 of the second laminate 20 join the two second fiber layers 24 of the second laminate 20 in the stacking direction. Thus, the intermediate structural yarns 16, 26 perform the above-mentioned two joining processes without increasing the yarns to be used.

(4) The fiber layers 14 of the first laminate 13 can be joined together by the engagement between the auxiliary yarns 12 of the fiber layers 14 and the intermediate structural yarns 16. The the fiber layers 24 of the second laminate 20 can be joined together by the engagement between the auxiliary yarns 22 of the fiber layers 24 and the intermediate structural yarns 26. The first laminate 13 and the second laminate 20 can be joined together in the stacking direction by the engagement between the first intermediate structural yarns 16 and the second intermediate structural yarns 26. That is, the laminates and the fiber layers of the fiber structure 10 can be joined together in the stacking direction by the engagement between the yarns other than the first reinforcement fiber yarns 11 and the second reinforcement fiber yarns 21. This prevents the first reinforcement fiber yarns 11 and the second reinforcement fiber yarns 21 from bending or curving due to the joining of the laminates and the fiber layers of the fiber structure 10 in the stacking direction. Thus, the dynamic property in the yarn main axis directions Y1, Y2 of the fiber-reinforced composite that uses the fiber structure 10 is not decreased.

Second Embodiment

[0031] A fiber structure 10 according to a second embodiment will now be described with reference to Figs. 5 to 8. The detailed description of the configuration of the

second embodiment that is the same as the first embodiment will be omitted.

[0032] As shown in Fig. 5, in the fiber structure 10 according to the second embodiment, the first laminate 13 and the second laminate 20 are joined together in the stacking direction by the engagement between the first intralayer structural yarns 15 of the first laminate 13 and the second intralayer structural yarns 25 of the second laminate 20.

[0033] As shown in Figs. 6 and 7, the first intralayer structural yarns 15 of one of the first fiber layers 14 of the first laminate 13 that is located close to the second laminate 20 is defined as first engaging intralayer structural yarns 15a. The second intralayer structural yarns 25 of one of the second fiber layers 24 of the second laminate 20 that is located close to the first laminate 13 is defined as second engaging intralayer structural yarns 25a.

[0034] In the vicinity of the boundary between the first laminate 13 and the second laminate 20, each second engaging intralayer structural yarn 25a engages with the first engaging intralayer structural yarns 15a from above and engages with the second auxiliary yarns 22 that are adjacent in the arrangement direction from below. The first engaging intralayer structural yarns 15a are located above the second reinforcement fiber yarns 21 of the second fiber layer 24. With this configuration, the second engaging intralayer structural yarns 25a join the second reinforcement fiber yarns 21 of the second fiber layer 24 in the arrangement direction together with the first engaging intralayer structural yarns 15a.

[0035] As shown in Fig. 8, in the first laminate 13, the two first fiber layers 14 are joined together in the stacking direction with the first intermediate structural yarns 16. In the second laminate 20, the two second fiber layers 24 are joined together in the stacking direction with the second intermediate structural yarns 26. The first laminate 13 and the second laminate 20 are joined together in the stacking direction by the engagement between the first engaging intralayer structural yarns 15a and the second engaging intralayer structural yarns 25a.

[0036] In addition to the advantages (1) and (2) of the first embodiment, the second embodiment achieves the following advantage.

(5) In the vicinity of the boundary between the first laminate 13 and the second laminate 20, the first fiber layer 14 and the second fiber layer 24 that are adjacent in the stacking direction are joined together with each other using the engaging intralayer structural yarns 15a, 25a. Thus, the first laminate 13 and the second laminate 20 are joined together at a position close to each other in the stacking direction. Thus, the first and second laminates 13, 20 are securely joined.

Third Embodiment

[0037] A fiber structure 10 according to a third embodiment will now be described with reference to Figs. 9 to 12. The detailed description of the configuration of the third embodiment that is the same as the first embodiment will be omitted.

[0038] As shown in Figs. 9 and 12, in the fiber structure 10 according to the third embodiment, the first laminate 13 and the second laminate 20 are joined together in the stacking direction by the engagement between the first intralayer structural yarns 15 and the second intralayer structural yarns 25 and the engagement between the first intermediate structural yarns 16 and the second intermediate structural yarns 26.

[0039] As shown in Figs. 10 and 11, the first intralayer structural yarns 15 of one of the first fiber layers 14 of the first laminate 13 that is located close to the second laminate 20 is defined as the first engaging intralayer structural yarns 15a. The second intralayer structural yarns 25 of one of the second fiber layers 24 of the second laminate 20 that is located close to the first laminate 13 is defined as the second engaging intralayer structural yarns 25a.

[0040] As shown in Figs. 9 and 12, in the vicinity of the boundary between the first laminate 13 and the second laminate 20, each second engaging intralayer structural yarn 25a engages with the first engaging intralayer structural yarns 15a from above and engages with the second auxiliary yarns 22 that are adjacent in the arrangement direction from below. The first engaging intralayer structural yarns 15a are located above the second reinforcement fiber yarns 21 of the second fiber layer 24. With this configuration, the second engaging intralayer structural yarns 25a join the second reinforcement fiber yarns 21 of the second fiber layer 24 in the arrangement direction together with the first engaging intralayer structural yarns 15a.

[0041] Each first intermediate structural yarn 16 of the first laminate 13 extends to a position between the first reinforcement fiber yarns 11 of the lower first fiber layer 14 and the second laminate 20 and is folded back. Each second intermediate structural yarn 26 of the second laminate 20 extends to a position between the second reinforcement fiber yarns 21 of the upper second fiber layer 24 and the first laminate 13 and is folded back. Each first intermediate structural yarn 16 of the first laminate 13 is orthogonal to and engaged with the second intermediate structural yarns 26 of the second laminate 20 at positions between the laminates 13, 20.

[0042] In addition to the advantages (1) and (2) of the first embodiment, the third embodiment achieves the following advantage.

(6) The first laminate 13 and the second laminate 20 are joined together in the stacking direction by the engagement between the intralayer structural yarns 15a, 25a and the engagement between the interme-

diate structural yarns 16, 26. This enhances the joining between the first laminate 13 and the second laminate 20 in the stacking direction.

[0043] The above described embodiments may be modified as follows.

[0044] In the first embodiment, the engaging position of the second intralayer structural yarns 25 with respect to the second auxiliary yarns 22 and the second reinforcement fiber yarns 21 in the second laminate 20 may be opposite to the position in the first embodiment. Specifically, the second intralayer structural yarns 25 may be engaged with the upper surface of the second auxiliary yarns 22 and engaged with the lower surface of the second reinforcement fiber yarns 21. That is, the second intralayer structural yarns 25 may be located at positions not facing the first intralayer structural yarns 15 in the stacking direction. The second intralayer structural yarns 25 of one of the second fiber layers 24 of the second laminate 20 that is located close to the first laminate 13 are referred to as the second engaging intralayer structural yarns 25a.

[0045] The first laminate 13 and the second laminate 20 may be joined together in the stacking direction by the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second engaging intralayer structural yarns 25a of the second laminate 20. Furthermore, the first laminate 13 and the second laminate 20 may be joined together in the stacking direction by the engagement between the first engaging intralayer structural yarns 15a of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20.

[0046] The first laminate 13 and the second laminate 20 may be joined together by the engagement between the first engaging intralayer structural yarns 15a of the first laminate 13 and the second engaging intralayer structural yarns 25a of the second laminate 20 and the engagement between the first engaging intralayer structural yarns 15a of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20.

[0047] Furthermore, the first laminate 13 and the second laminate 20 may be joined together by the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20 and the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second engaging intralayer structural yarns 25a of the second laminate 20.

[0048] Moreover, the first laminate 13 and the second laminate 20 may be joined together by the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20 and the engagement between the first engaging intralayer structural yarns 15a of the first laminate 13 and the second intermediate structural yarns 26 of the second laminate 20.

[0049] Additionally, the first laminate 13 and the second laminate 20 may be joined together by the engagement between the first intermediate structural yarns 16 of the first laminate 13 and the second engaging intralayer structural yarns 25a of the second laminate 20 and the engagement between the first engaging intralayer structural yarns 15a of the first laminate 13 and the second engaging intralayer structural yarns 25a of the second laminate 20.

[0050] The number of the fiber layers constituting the first and second laminates 13, 20 may be three or more.

[0051] The fiber structure 10 may be constituted by stacking three or more laminates.

[0052] The cross-sectional shape and the thickness of the first reinforcement fiber yarns 11 and the second reinforcement fiber yarns 21 may be changed as required.

[0053] When the fiber structure 10 is used as the reinforced base material of the fiber-reinforced composite, the kind of the matrix resin and the method for producing the fiber-reinforced composite are not limited to any particular resin or method.

[0054] The fiber bundles constituting the first reinforcement fiber yarns 11 and the second reinforcement fiber yarns 21 may be high-strength organic fiber such as aramid fiber, poly-p-phenylenebenzobisoxazole fiber, and ultra-high-molecular-weight polyethylene fiber or inorganic fiber such as glass fiber and ceramic fiber in accordance with the physical properties required for the fiber-reinforced composite.

Claims

1. A fiber structure comprising a plurality of laminates, wherein

the laminates each include a plurality of stacked fiber layers,

the fiber layers each include reinforcement fiber yarns, auxiliary yarns, and intralayer structural yarns, the reinforcement fiber yarns and the auxiliary yarns being arranged alternately, and the intralayer structural yarns joining the reinforcement fiber yarns and the auxiliary yarns together in an arrangement direction,

in each laminate,

yarn main axis directions of the reinforcement fiber yarns and the auxiliary yarns of each of the fiber layers are the same,

the reinforcement fiber yarns are arranged in such a manner that the relative positions are shifted in a stacking direction of the fiber layers with the reinforcement fiber yarns overlapping each other,

the auxiliary yarns are arranged in such a manner that the relative positions are shifted, and

the fiber layers are joined with intermediate structural yarns engaged with the auxiliary yarns

located on opposite ends in the stacking direction,

the laminates are arranged such that

a yarn main axis of the reinforcement fiber yarns of each laminate is orthogonal to a yarn main axis of the reinforcement fiber yarns of another laminate, and
a yarn main axis of the auxiliary yarns of each laminate is orthogonal to a yarn main axis of the auxiliary yarns of another laminate, and

the laminates are joined together in the stacking direction by an engagement between at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction.

2. The fiber structure according to claim 1, wherein the laminates are joined together by the engagement between the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction.

3. The fiber structure according to claim 1, wherein the laminates are joined together by the engagement between the intralayer structural yarns of the laminate in which the yarn main axis extends in one direction and the intralayer structural yarns of the laminate in which the yarn main axis extends in another direction.

4. The fiber structure according to claim 1, wherein the laminates are joined together by
the engagement between the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction, and
the engagement between the intralayer structural yarns of the laminate in which the yarn main axis extends in one direction and the intralayer structural yarns of the laminate in which the yarn main axis extends in another direction.

5. The fiber structure according to any one of claims 1 to 4, wherein each of the intermediate structural yarns is arranged between the intralayer structural yarns located adjacent to each other in the yarn main axis direction of the reinforcement fiber yarns and the auxiliary yarns.

6. A fiber-reinforced composite in which a fiber structure is impregnated with a matrix resin, wherein
the fiber structure includes a plurality of laminates,
the laminates each include a plurality of stacked fiber layers,
the fiber layers each include reinforcement fiber yarns, auxiliary yarns, and intralayer structural yarns, the reinforcement fiber yarns and the auxiliary yarns being arranged alternately, and the intralayer structural yarns joining the reinforcement fiber yarns and the auxiliary yarns together in an arrangement direction,
in each laminate,

yarn main axis directions of the reinforcement fiber yarns and the auxiliary yarns of each of the fiber layers are the same,
the reinforcement fiber yarns are arranged in such a manner that the relative positions are shifted in a stacking direction of the fiber layers with the reinforcement fiber yarns overlapping each other,
the auxiliary yarns are arranged in such a manner that the relative positions are shifted, and
the fiber layers are joined with intermediate structural yarns engaged with the auxiliary yarns located on opposite ends in the stacking direction,

the laminates are arranged such that

a yarn main axis of the reinforcement fiber yarns of each laminate is orthogonal to a yarn main axis of the reinforcement fiber yarns of another laminate, and
a yarn main axis of the auxiliary yarns of each laminate is orthogonal to a yarn main axis of the auxiliary yarns of another laminate, and

the laminates are joined together in the stacking direction by an engagement between at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in one direction and at least one of a set of the intralayer structural yarns and a set of the intermediate structural yarns of the laminate in which the yarn main axis extends in another direction.

Fig.1

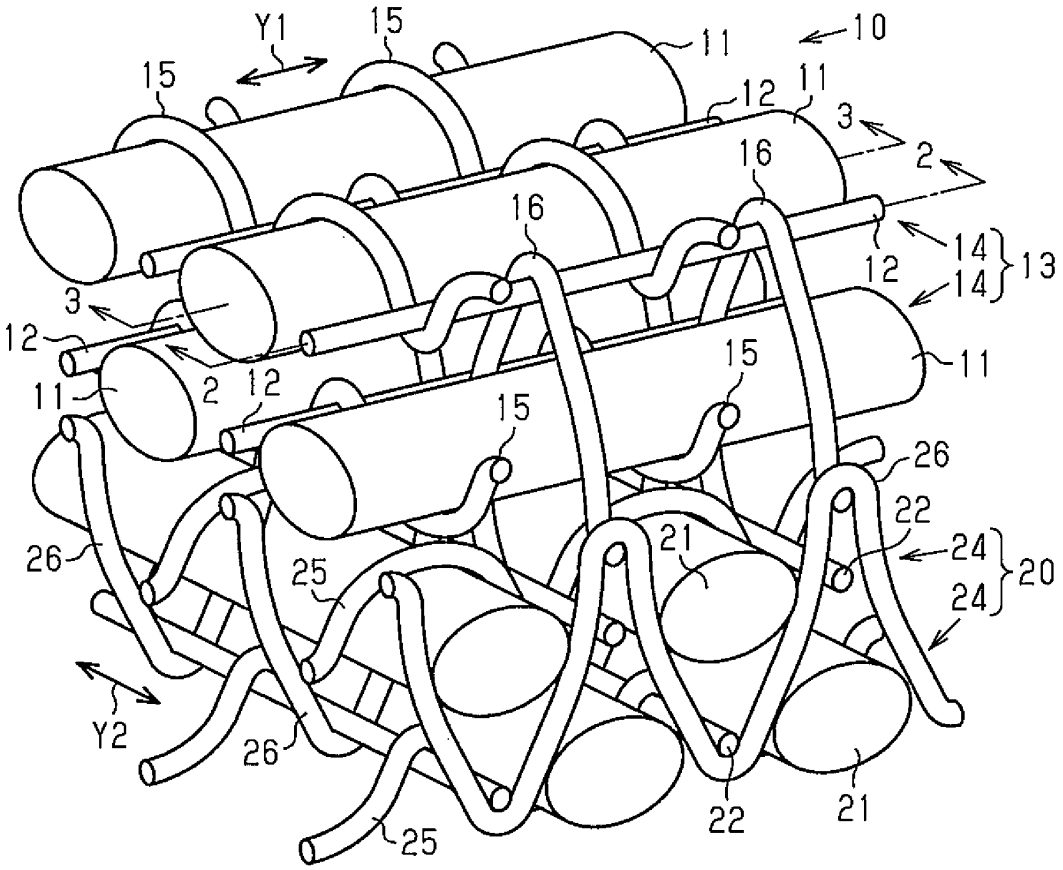
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Fig.2

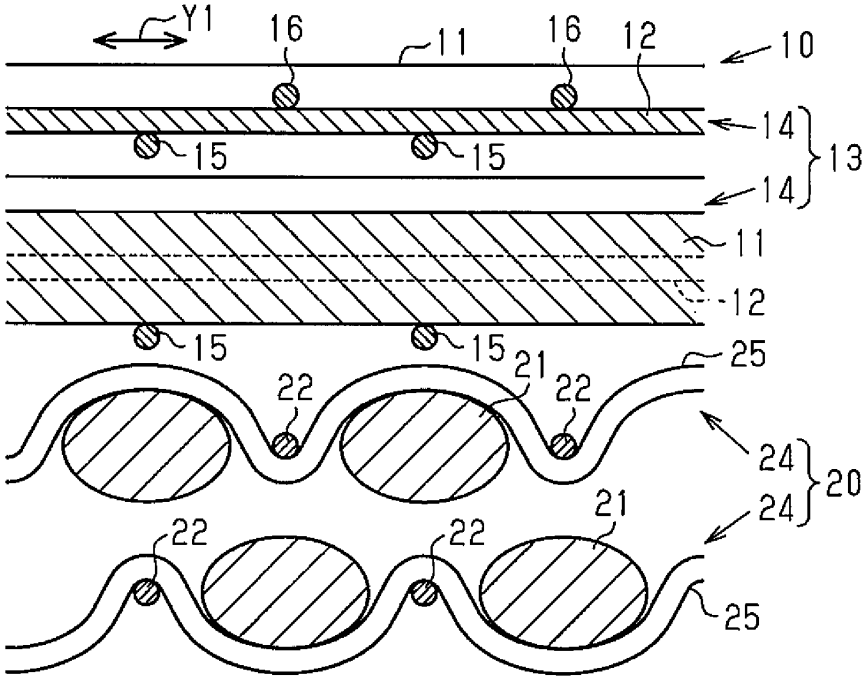
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Fig.3

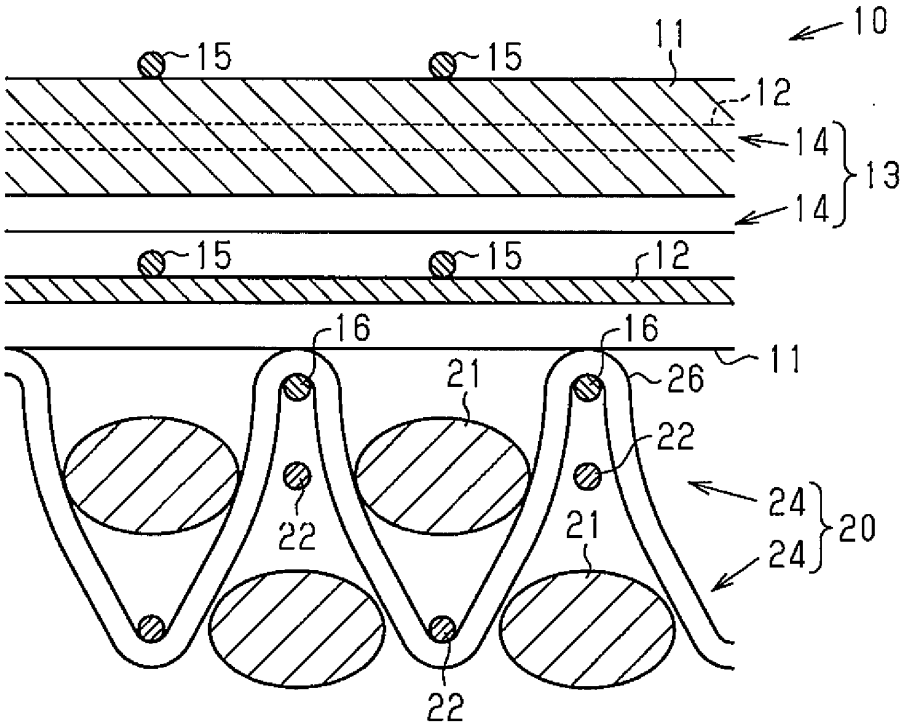
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Fig.4

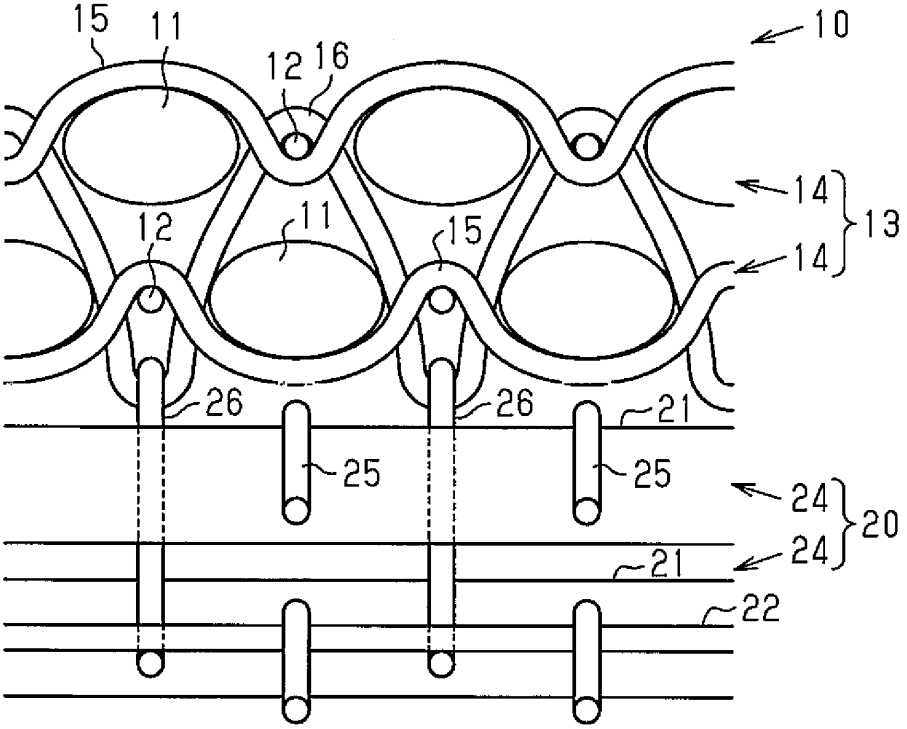
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Fig.5

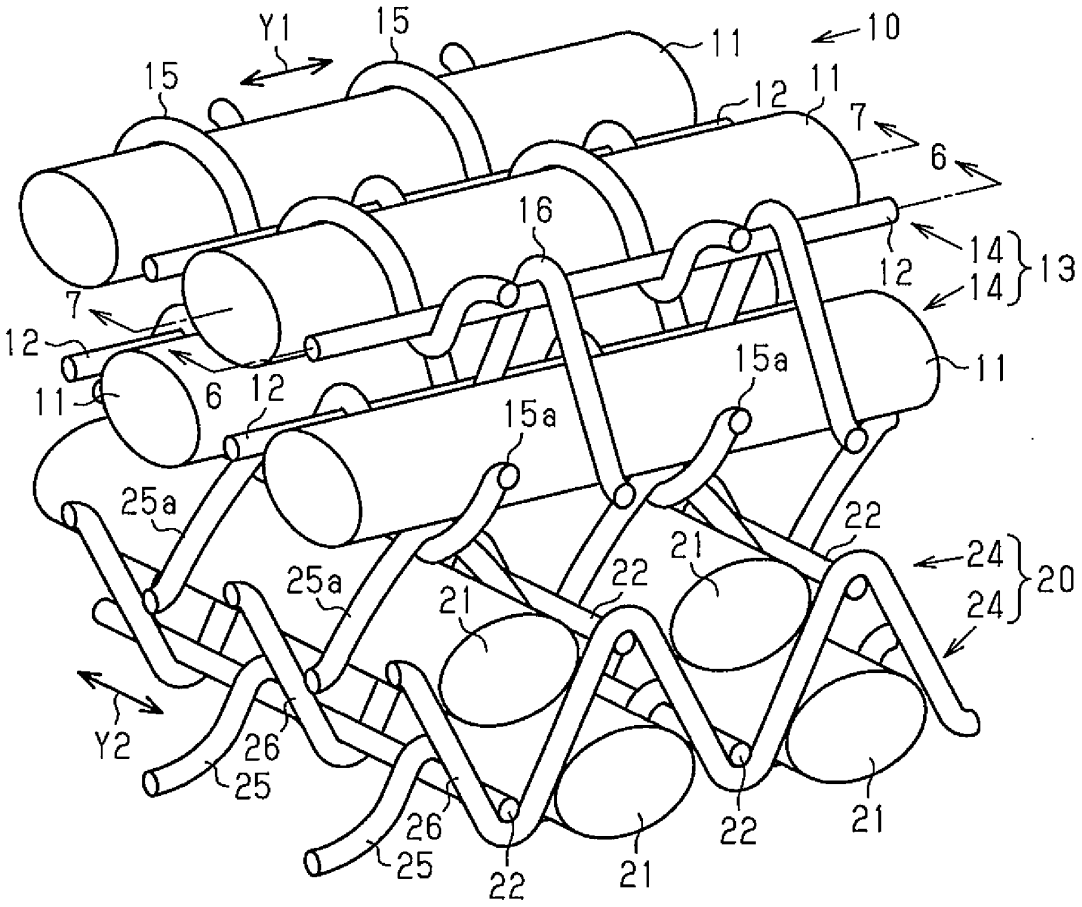
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Fig.6

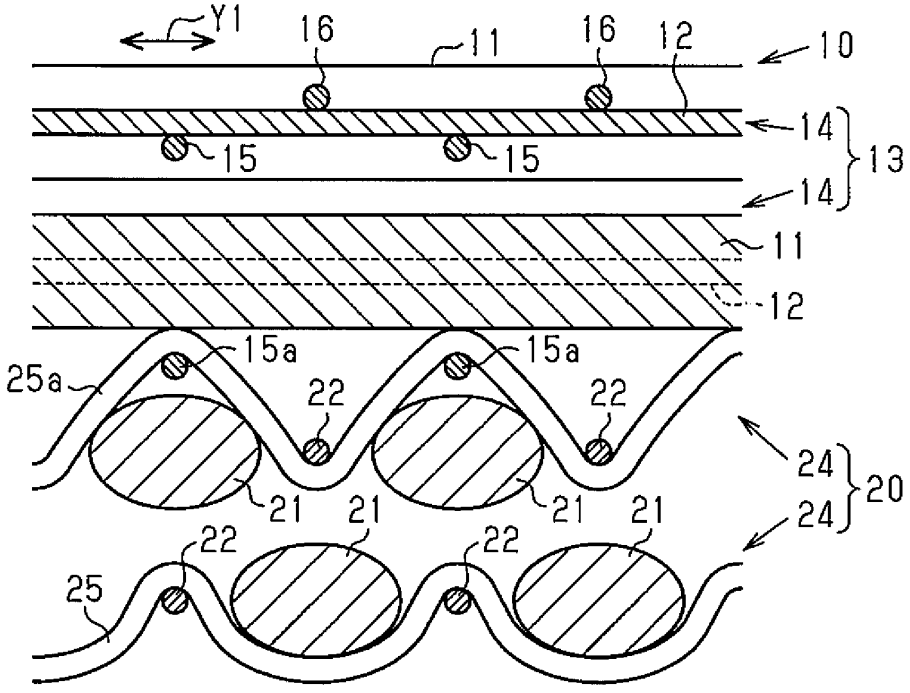
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Fig.7

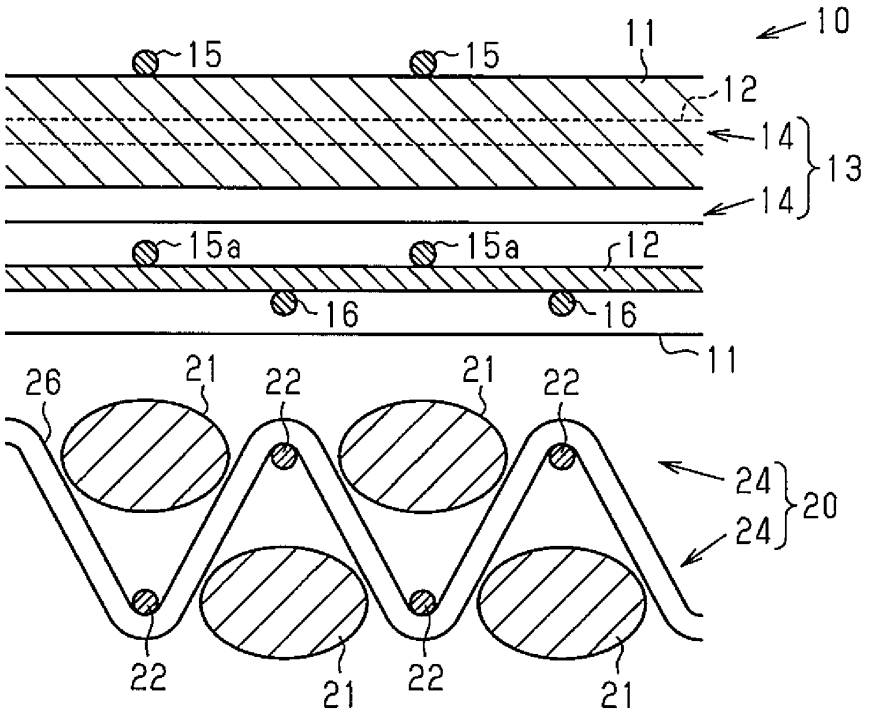
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Fig.8

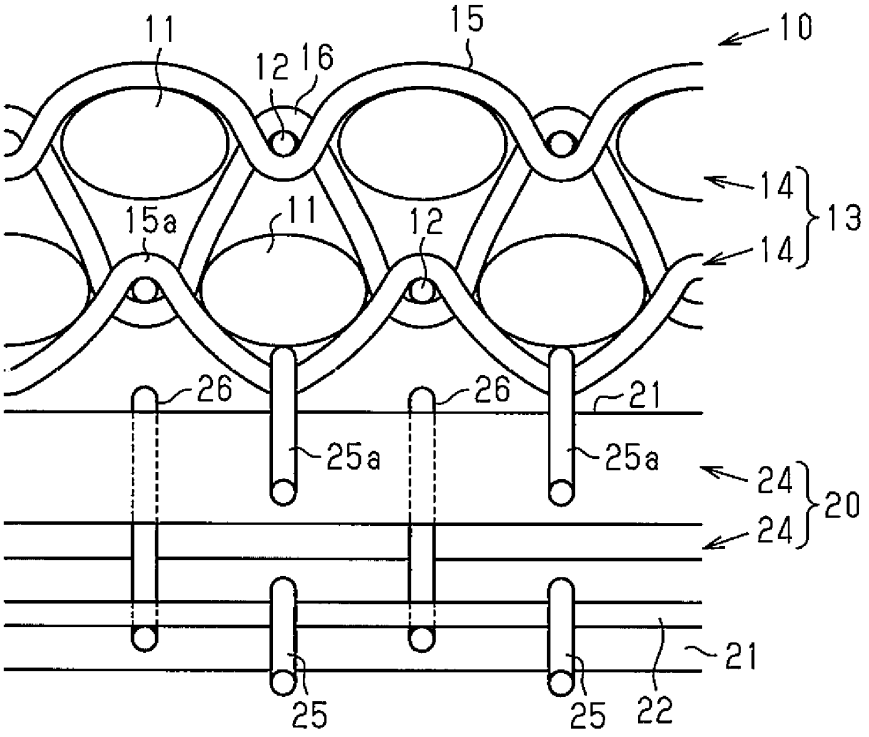
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Fig.9

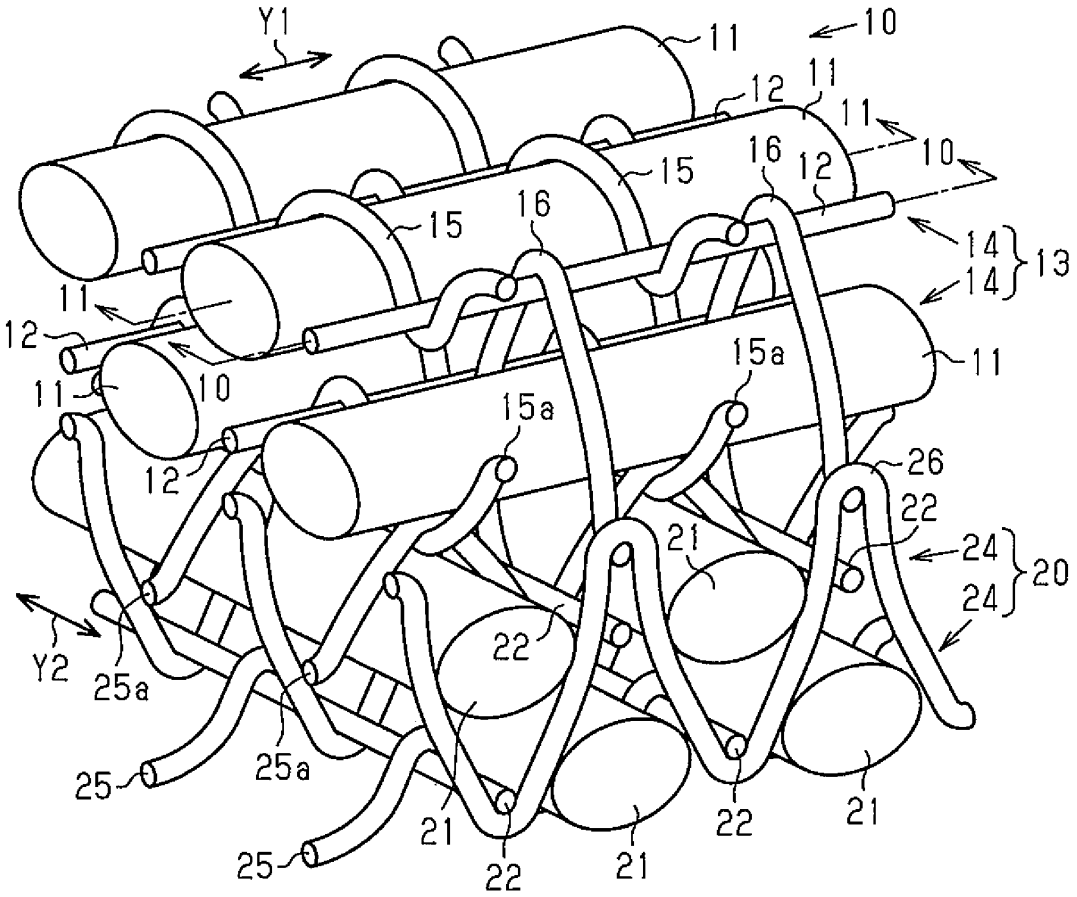
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Fig.10

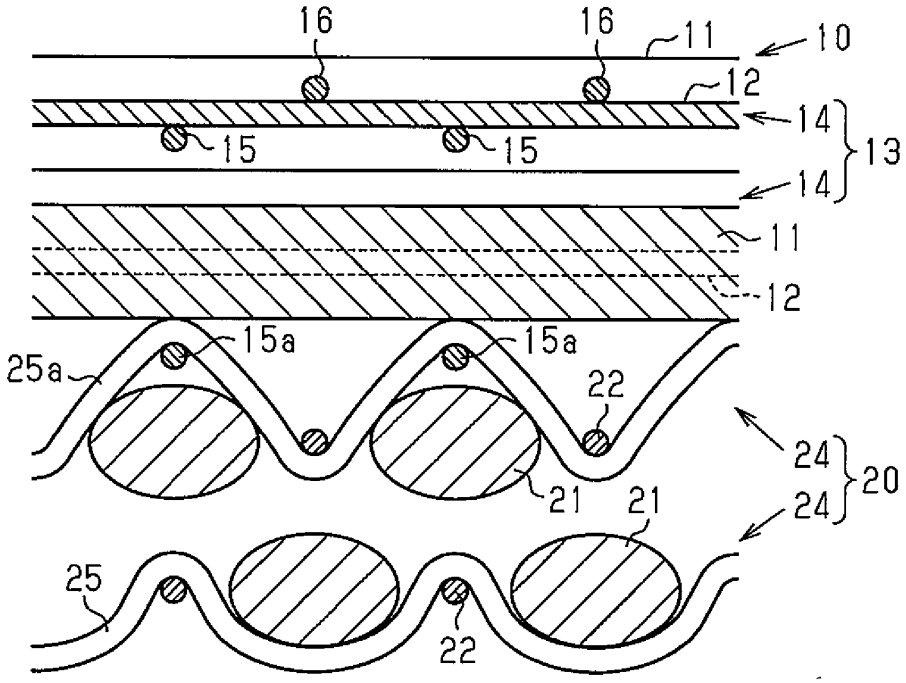
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Fig.11

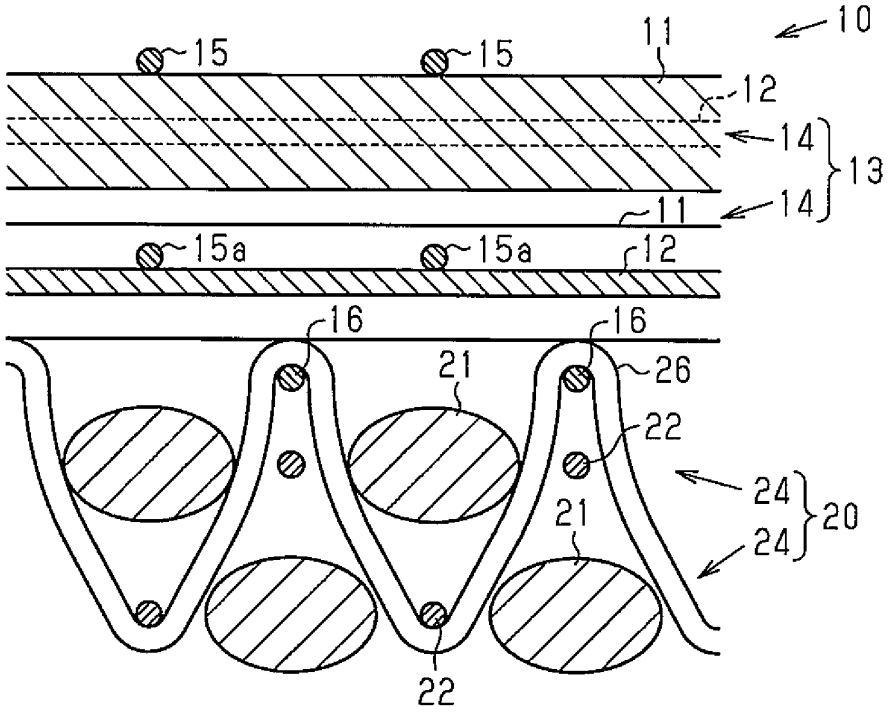
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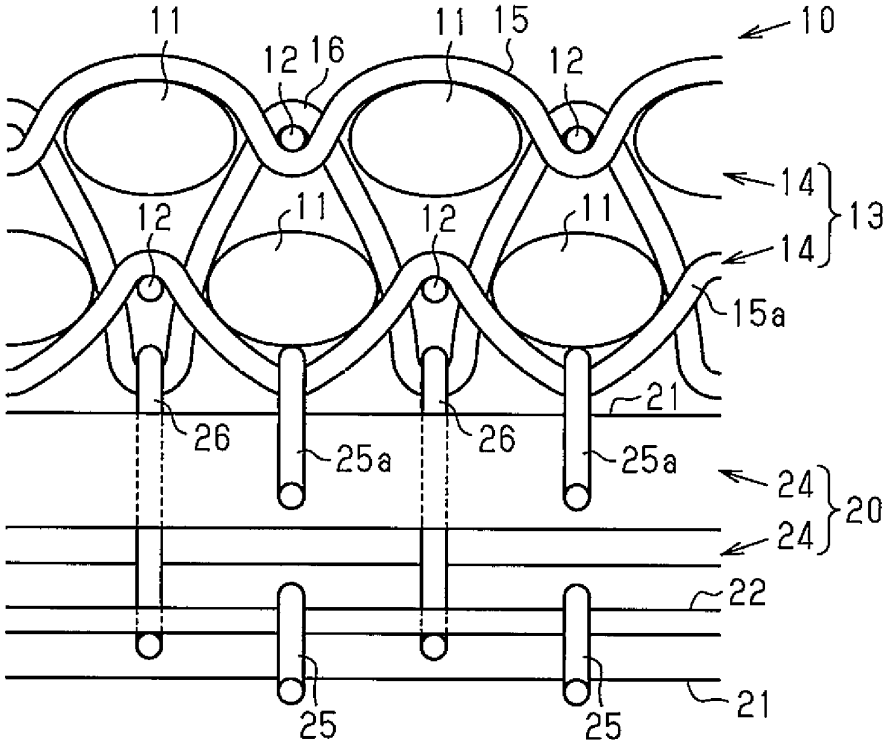
Fig.12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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/081859

A. CLASSIFICATION OF SUBJECT MATTER
D03D1/00(2006.01)i, *D03D15/00*(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)
D03D1/00-27/18, B29B11/16, B29B15/08-15/14, C08J5/04-5/10, C08J5/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017
Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-133555 A (Toyota Industries Corp.), 08 July 2013 (08.07.2013), & WO 2013/035518 A1	1-6
A	JP 2009-249754 A (Mitsubishi Rayon Co., Ltd.), 29 October 2009 (29.10.2009), (Family: none)	1-6
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 127548/1989(Laid-open No. 066739/1991) (Unitika UM Glass Co., Ltd.), 28 June 1991 (28.06.1991), (Family: none)	1-6

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Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2017 (16.01.17)	24 January 2017 (24.01.17)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/081859

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 052282/1991(Laid-open No. 135986/1992) (Kanebo, Ltd.), 17 December 1992 (17.12.1992), (Family: none)	1-6
A	US 2015/0224737 A1 (KABUSHIKI KAISHA TOYOTA JIDOSHOKKI), 13 August 2015 (13.08.2015), & WO 2014/030631 A1 & EP 2889325 A1	1-6

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Patent documents cited in the description

- JP 2013133555 A **[0007]**