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(54) **BADMINTON RACKET**

(57) A badminton racket 2 includes a shaft 4, a frame 6, a grip 8, and a string 10. A flexural rigidity value EI(2) of the shaft 4 at a second measurement point located at a distance of 75 mm from the grip 8 is greater than a flexural rigidity value EI(1) of the shaft 4 at a first measurement point located at a distance of 35 mm from the grip 8 and a flexural rigidity value EI(4) of the shaft 4 at a fourth measurement point located at a distance of 155 mm from the grip 8. A flexural rigidity value EI(3) of the shaft 4 at a third measurement point located at a distance of 115 mm from the grip 8 is greater than the flexural rigidity value EI(1) and the flexural rigidity value EI(4).

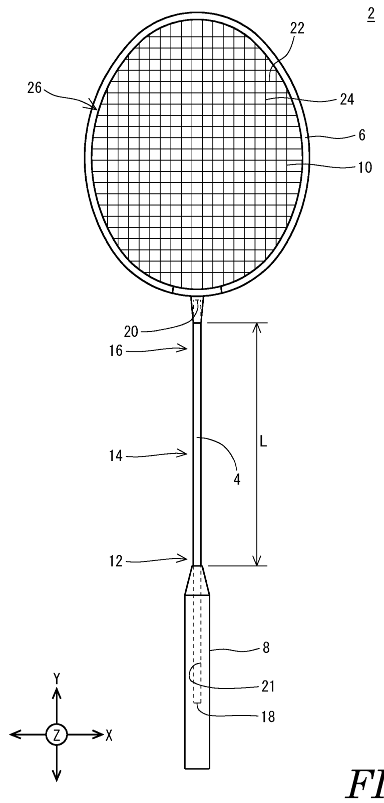

FIG. 1

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Description

Technical Field

[0001] The present invention relates to a badminton racket. In particular, the present invention relates to improvements to the shaft of the racket.

Background Art

[0002] A badminton racket includes a frame, a string, and a shaft. The player shots a shuttlecock with the racket. The shaft is deformed upon the shot.

[0003] Various attempts have been made to optimize the shaft deformation behavior. Chinese Patent Publication No. 107115641 discloses a racket including a shaft including a bending portion having a small diameter.

Citation List

Patent Literature

[0004] PTL 1: Chinese Patent Publication No. 107115641

Summary of Invention

Technical Problem

[0005] In a badminton game, the player performs various types of shots. The player performs shots such as smash, lob, cut, and clear.

[0006] The smash is a shot aimed at causing the opponent player to fail to receive the shuttlecock. For the smash, the player is required to have the skill to allow the shuttlecock to fly at an intended height. When the player is one who frequently uses the smash, the player wants to stabilize the trajectory of the shuttlecock in the smash.

[0007] In the smash, the shaft is significantly deflected in the in-plane direction and in the out-of-plane direction. The player wants to stabilize the trajectory of the shuttlecock also for shots which are other than the smash and in which the shaft is deflected in both the in-plane and out-of-plane directions.

[0008] An object of the present invention is to provide a badminton racket suitable for shots in which the shaft of the racket is significantly deflected in both the in-plane and out-of-plane directions.

[0009] A badminton racket according to the present invention includes:

a grip;
a shaft having a portion inserted into the grip, the inserted portion including a butt end of the shaft and a vicinity of the butt end; and
a frame attached to the shaft in a vicinity of a tip end of the shaft. A flexural rigidity value EI(2) of the shaft at a second measurement point located at a distance of 75 mm from the grip is greater than a flexural rigidity value EI(1) of the shaft at a first measurement point located at a distance of 35 mm from the grip and a flexural rigidity value EI(4) of the shaft at a fourth measurement point located at a distance of 155 mm from the grip. A flexural rigidity value EI(3) of the shaft at a third measurement point located at a distance of 115 mm from the grip is greater than the flexural rigidity value EI(1) and the flexural rigidity value EI(4).

[0010] Preferably, a ratio (EI(2)/EI(1)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(1) is not less than 1.10. Preferably, a ratio (EI(2)/EI(4)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(4) is not less than 1.10.

[0011] Preferably, a ratio (EI(3)/EI(1)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(1) is not less than 1.10. Preferably, a ratio (EI(3)/EI(4)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(4) is not less than 1.10.

[0012] Preferably, a difference (EI(2) - EI(1)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(1) is not less than 0.50 Nm^2. Preferably, a difference (EI(2) - EI(4)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(4) is not less than 0.50 Nm^2.

[0013] Preferably, a difference (EI(3) - EI(1)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(1) is not less than 0.50 Nm^2. Preferably, a difference (EI(3) - EI(4)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(4) is not less than 0.50 Nm^2.

[0014] The shaft may have a hollow structure. Preferably, an inner diameter of the shaft is substantially constant from the first measurement point to the fourth measurement point.

[0015] Preferably, an outer diameter of the shaft is substantially constant from the first measurement point to the fourth measurement point.

[0016] Preferably, a ratio (W2/W1) of a weight W2 of the shaft in a zone from the second measurement point to the third measurement point to a weight W1 of the shaft in a zone from the first measurement point to the second measurement point is not less than 0.95 and not greater than 1.05. Preferably, a ratio (W2/W3) of the weight W2 of the shaft in the zone from the second measurement point to the third measurement point to a weight W3 of the shaft in a zone from the third measurement point to the fourth measurement point is not less than 0.95 and not greater than 1.05.

[0017] Preferably, the shaft includes a fiber-reinforced layer. The fiber-reinforced layer is located in a zone including the second and third measurement points and not including the first and fourth measurement points in an axial direction of the shaft. The fiber-reinforced layer includes a plurality of reinforcing fibers oriented substantially in the axial direction.

Advantageous Effects of Invention

[0018] A player using the badminton racket according to the present invention can easily perform shots in which the shaft is significantly deflected in both the in-plane and out-of-plane directions. The racket can contribute to winning badminton games.

Brief Description of Drawings

[0019]

FIG. 1 is a front view showing a badminton racket according to one embodiment of the present invention.
FIG. 2 is a right side view showing the racket of FIG. 1.
FIG. 3 is an enlarged cross-sectional view showing a part of the shaft of the racket of FIG. 1.
FIG. 4 is an enlarged cross-sectional view taken along the line IV-IV of FIG. 3.
FIG. 5 is a developed view showing prepregs for the shaft of the racket of FIG. 1.
FIG. 6 is a schematic diagram showing a method of measuring a flexural rigidity value EI of the shaft of the racket of FIG. 1.
FIG. 7 is a graph showing a flexural rigidity distribution of the shaft of the racket of FIG. 1.
FIG. 8 is a graph showing a flexural rigidity distribution of a shaft of a racket according to Comparative Example.
FIG. 9 is a graph showing a flexural rigidity distribution of a shaft of a racket according to Example 2 of the present invention.
FIG. 10 is a graph showing a flexural rigidity distribution of a shaft of a racket according to Example 3 of the present invention.

Description of Embodiments

[0020] The following will describe in detail the present invention based on preferred embodiments with appropriate reference to the drawings.

[0021] FIGS. 1 and 2 show a badminton racket 2. The racket 2 includes a shaft 4, a frame 6, a grip 8, and a string 10. In FIGS. 1 and 2, the arrow X represents the width direction, the arrow Y represents the axial direction, and the arrow Z represents the thickness direction.

[0022] The shaft 4 includes a butt portion 12, a middle portion 14, and a tip portion 16. The shaft 4 further includes a butt end 18 and a tip end 20. The shaft 4 is hollow. The shaft 4 is formed from a fiber-reinforced resin. The fiber-reinforced resin includes a resin matrix and a large number of reinforcing fibers. The shaft 4 includes a plurality of fiber-reinforced layers (which will be described in detail later).

[0023] Examples of the base resin of the shaft 4 include: thermosetting resins such as epoxy resin, bismaleimide resin, polyimide, and phenol resin; and thermoplastic resins such as polyether ether ketone, polyethersulfone, polyetherimide, polyphenylene sulfide, polyamide, and polypropylene. Epoxy resin is particularly suitable as the resin of the shaft 4.

[0024] Examples of the reinforcing fibers of the shaft 4 include carbon fibers, metal fibers, glass fibers, and aramid fibers. Carbon fibers are particularly suitable as the fibers of the shaft 4. Different kinds of fibers may be used in combination.

[0025] The frame 6 is ring-shaped and hollow. The frame 6 is formed from a fiber-reinforced resin. Any of the resins as mentioned for the base resin of the shaft 4 can be used as the base resin of the fiber-reinforced resin. Any of the fibers as mentioned for the reinforcing fibers of the shaft 4 can be used as the reinforcing fibers of the fiber-reinforced resin. The frame 6 is firmly joined to the tip end 20 of the shaft 4.

[0026] The grip 8 includes a hole 21 extending in the axial direction (Y direction). The butt end 18 and its vicinity of the shaft 4 are inserted into the hole 21. The inner peripheral surface of the hole 21 and the outer peripheral surface of the shaft 4 are bonded with an adhesive.

[0027] The string 10 is strung on the frame 6. The string 10 is placed along the width direction X and the axial direction Y. The portions of the string 10 that extend along the width direction X are referred to as transverse threads 22. The portions of the string 10 that extend along the axial direction Y are referred to as longitudinal threads 24. The plurality of transverse threads 22 and the plurality of longitudinal threads 24 form a face 26. The face 26 extends generally along the X-Y plane.

[0028] In FIG. 1, the reference sign L represents the length of the exposed portion of the shaft 4. The length L is usually not less than 150 mm and not greater than 210 mm.

[0029] FIG. 3 is an enlarged cross-sectional view showing a part of the shaft 4 of the racket 2 of FIG. 1. FIG. 4 is an enlarged cross-sectional view taken along the line IV-IV of FIG. 3. As previously stated, the shaft 4 is hollow. As shown in FIG. 4, the cross-section of the shaft 4 is circular. In other words, the shaft 4 is in the shape of a cylindrical tube.

[0030] In FIGS. 3 and 4, the arrow Di represents the inner diameter of the shaft 4. The inner diameter Di is typically not less than 3 mm and not greater than 10 mm. In FIGS. 3 and 4, the arrow Do represents the outer diameter of the shaft 4. The outer diameter Do is typically not less than 5 mm and not greater than 15 mm.

[0031] As previously stated, the shaft 4 is formed from a fiber-reinforced resin. The shaft 4 can be produced by a sheet winding method. In the sheet winding method, a plurality of prepregs are wound on a mandrel. Each prepreg includes a plurality of fibers and a matrix resin. The matrix resin is uncured.

[0032] FIG. 5 is a developed view showing a prepreg arrangement for the shaft 4 of the racket 2 of FIG. 1. The prepreg arrangement includes 13 prepregs (sheets). Specifically, the prepreg arrangement includes a first sheet S1, a second sheet S2, a third sheet S3, a fourth sheet S4, a fifth sheet S5, a sixth sheet S6, a seventh sheet S7, an eighth sheet S8, a ninth sheet S9, a tenth sheet S10, an eleventh sheet 11, a twelfth sheet 12, and a thirteenth sheet 13. A plurality of fiber-reinforced layers are formed from the prepregs by a method described later. Specifically, a first fiber-reinforced layer is formed from the first sheet S1, a second fiber-reinforced layer is formed from the second sheet S2, a third fiber-reinforced layer is formed from the third sheet S3, a fourth fiber-reinforced layer is formed from the fourth sheet S4, a fifth fiber-reinforced layer is formed from the fifth sheet S5, a sixth fiber-reinforced layer is formed from the sixth sheet S6, a seventh fiber-reinforced layer is formed from the seventh sheet S7, an eighth fiber-reinforced layer is formed from the eighth sheet S8, a ninth fiber-reinforced layer is formed from the ninth sheet S9, a tenth fiber-reinforced layer is formed from the tenth sheet S10, an eleventh fiber-reinforced layer is formed from the eleventh sheet S11, a twelfth fiber-reinforced layer is formed from the twelfth sheet S12, and a thirteenth fiber-reinforced layer is formed from the thirteenth sheet S13.

[0033] The left-right direction in FIG. 5 is the axial direction of the shaft 4. In FIG. 5, the locations of the butt end 18 and tip end 20 are indicated by arrows. In FIG. 5, the locations of four measurement points P1, P2, P3, and P4 described later are also indicated by arrows. In FIG. 5, the reduction scale in the left-right direction (axial direction) is not equal to the reduction scale in the up-down direction.

[0034] The first sheet S1 extends over the entirety of the shaft 4. The first sheet S1 is generally rectangular. The first sheet S1 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than 30° and not greater than 60° with the axial direction. In the present embodiment, the angle is 45°. The first sheet S1 is 70 mm wide and 340 mm long.

[0035] The second sheet S2 extends over the entirety of the shaft 4. The second sheet S2 is generally rectangular. The second sheet S2 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than -60° and not greater than -30° with the axial direction. In the present embodiment, the angle is -45°. The second sheet S2 is 70 mm wide and 340 mm long.

[0036] The direction of the inclination of the carbon fibers in the second sheet S2 is opposite to the direction of the inclination of the carbon fibers in the first sheet S1. Thus, the direction of the inclination of the carbon fibers in the second fiber-reinforced layer is opposite to the direction of the inclination of the carbon fibers in the first fiber-reinforced layer. In the shaft 4, a bias structure is achieved by the first and second fiber-reinforced layers. The first and second fiber-reinforced layers contribute to the flexural rigidity and torsional rigidity of the shaft 4. The first and second fiber-reinforced layers particularly contribute to the torsional rigidity of the shaft 4.

[0037] The third sheet S3 is localized towards the tip end 20 of the shaft 4. The third sheet S3 is generally trapezoidal. The third sheet S3 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than 30° and not greater than 60° with the axial direction. In the present embodiment, the angle is 45°. The third sheet S3 is 35 mm wide, 105 mm long on the upper base, and 115 mm long on the lower base.

[0038] The fourth sheet S4 is localized towards the tip end 20 of the shaft 4. In the axial direction, the location of the fourth sheet S4 is the same as the location of the third sheet S3. The fourth sheet S4 is generally trapezoidal. The fourth sheet S4 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than -60° and not greater than -30° with the axial direction. In the present embodiment, the angle is -45°. The fourth sheet S4 is 35 mm wide, 105 mm long on the upper base, and 115 mm long on the lower base.

[0039] The direction of the inclination of the carbon fibers in the fourth sheet S4 is opposite to the direction of the inclination of the carbon fibers in the third sheet S3. Thus, the direction of the inclination of the carbon fibers in the fourth fiber-reinforced layer is opposite to the direction of the inclination of the carbon fibers in the third fiber-reinforced layer. In the shaft 4, a bias structure is achieved by the third and fourth fiber-reinforced layers. The third and fourth fiber-reinforced layers contribute to the flexural rigidity and torsional rigidity of the middle portion 14 and tip portion 16. The third and fourth fiber-reinforced layers particularly contribute to the torsional rigidity of the middle portion 14 and tip portion 16.

[0040] The fifth sheet S5 is localized towards the butt end 18 of the shaft 4. The fifth sheet S5 is generally trapezoidal. The fifth sheet S5 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than 30° and not greater than 60° with the axial direction. In the present embodiment, the angle is 45°. The fifth sheet S5 is 35 mm wide, 155 mm long on the upper base, and 165 mm long on the lower base.

[0041] The sixth sheet S6 is localized towards the butt end 18 of the shaft 4. In the axial direction, the location of the sixth sheet S6 is the same as the location of the fifth sheet S5. The sixth sheet S6 is generally trapezoidal. The sixth sheet S6 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than -60° and not greater than -30° with the axial direction. In the present embodiment, the angle is -45°. The sixth sheet S6 is 35 mm wide, 155 mm long on the upper base, and 165 mm long on the lower base.

[0042] The direction of the inclination of the carbon fibers in the sixth sheet S6 is opposite to the direction of the inclination of the carbon fibers in the fifth sheet S5. Thus, the direction of the inclination of the carbon fibers in the sixth fiber-reinforced layer is opposite to the direction of the inclination of the carbon fibers in the fifth fiber-reinforced layer. In the shaft 4, a bias structure is achieved by the fifth and sixth fiber-reinforced layers. The fifth and sixth fiber-reinforced layers contribute to the flexural rigidity and torsional rigidity of the butt portion 12 and middle portion 14. The fifth and sixth fiber-reinforced layers particularly contribute to the torsional rigidity of the butt portion 12 and middle portion 14.

[0043] The seventh sheet S7 is localized in the middle portion 14 of the shaft 4. The seventh sheet S7 is generally in the shape of a parallelogram. The seventh sheet S7 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is the same as the axial direction. In other words, the direction in which each carbon fiber extends forms an angle of substantially 0° with the axial direction. The seventh sheet S7 is 70 mm wide and 70 mm long.

[0044] As stated above, the carbon fibers contained in the seventh sheet S7 are oriented substantially in the axial direction. Thus, the carbon fibers are oriented substantially in the axial direction also in the seventh fiber-reinforced layer. The structure in which the carbon fibers are oriented substantially in the axial direction is herein referred to as a "straight structure". The seventh fiber-reinforced layer has a straight structure. Upon deflection of the shaft 4, the carbon fibers are subjected to a strong tension. The tension acts to prevent further deflection of the shaft 4. In other words, the carbon fibers contribute to the flexural rigidity of the shaft 4. As shown in FIG. 5, the seventh sheet S7 is located in a zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. Thus, the seventh fiber-reinforced layer is also located in the zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. The seventh fiber-reinforced layer particularly contributes to the flexural rigidity of the middle portion 14.

[0045] The eighth sheet S8 is localized towards the tip end 20 of the shaft 4. The eighth sheet S8 is generally trapezoidal. The eighth sheet S8 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than 30° and not greater than 60° with the axial direction. In the present embodiment, the angle is 45°. The eighth sheet S8 is 35 mm wide, 85 mm long on the upper base, and 95 mm long on the lower base.

[0046] The ninth sheet S9 is localized towards the tip end 20 of the shaft 4. In the axial direction, the location of the ninth sheet S9 is the same as the location of the eighth sheet S8. The ninth sheet S9 is generally trapezoidal. The ninth sheet S9 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than -60° and not greater than -30° with the axial direction. In the present embodiment, the angle is -45°. The ninth sheet S9 is 35 mm wide, 85 mm long on the upper base, and 95 mm long on the lower base.

[0047] The direction of the inclination of the carbon fibers in the ninth sheet S9 is opposite to the direction of the inclination of the carbon fibers in the eighth sheet S8. Thus, the direction of the inclination of the carbon fibers in the ninth fiber-reinforced layer is opposite to the direction of the inclination of the carbon fibers in the eighth fiber-reinforced layer. In the shaft 4, a bias structure is achieved by the eighth and ninth fiber-reinforced layers. The eighth and ninth fiber-reinforced layers contribute to the flexural rigidity and torsional rigidity of the tip portion 16. The eighth and ninth fiber-reinforced layers particularly contribute to the torsional rigidity of the tip portion 16.

[0048] The tenth sheet S10 is localized towards the butt end 18 of the shaft 4. The tenth sheet S10 is generally trapezoidal. The tenth sheet S10 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than 30° and not greater than 60° with the axial direction. In the present embodiment, the angle is 45°. The tenth sheet S10 is 35 mm wide, 135 mm long on the upper base, and 145 mm long on the lower base.

[0049] The eleventh sheet S11 is localized towards the butt end 18 of the shaft 4. In the axial direction, the location of the eleventh sheet S11 is the same as the location of the tenth sheet S10. The eleventh sheet S11 is generally trapezoidal. The eleventh sheet S11 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is inclined with respect to the axial direction. The direction in which each carbon fiber extends forms an angle of not less than -60° and not greater than -30° with the axial direction. In the present embodiment, the angle is -45°. The eleventh sheet S11 is 35 mm wide, 135 mm long on the upper base, and 145 mm long on the lower base.

[0050] The direction of the inclination of the carbon fibers in the eleventh sheet S11 is opposite to the direction of the inclination of the carbon fibers in the tenth sheet S10. Thus, the direction of the inclination of the carbon fibers in the eleventh fiber-reinforced layer is opposite to the direction of the inclination of the carbon fibers in the tenth fiber-reinforced layer. In the shaft 4, a bias structure is achieved by the tenth and eleventh fiber-reinforced layers. The tenth and eleventh fiber-reinforced layers contribute to the flexural rigidity and torsional rigidity of the butt portion 12. The tenth and eleventh fiber-reinforced layers particularly contribute to the torsional rigidity of the butt portion 12.

[0051] The twelfth sheet S12 is localized in the middle portion 14 of the shaft 4. The twelfth sheet S12 is generally in the shape of a parallelogram. The twelfth sheet S12 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is the same as the axial direction. In other words, the direction in which each carbon fiber extends forms an angle of substantially 0° with the axial direction. The twelfth sheet S12 is 70 mm wide and 110 mm long.

[0052] As stated above, the carbon fibers contained in the twelfth sheet S12 are oriented substantially in the axial direction. Thus, the carbon fibers are oriented substantially in the axial direction also in the twelfth fiber-reinforced layer. The twelfth fiber-reinforced layer has a straight structure. Upon deflection of the shaft 4, the carbon fibers are subjected to a strong tension. The tension acts to prevent further deflection of the shaft 4. In other words, the carbon fibers contribute to the flexural rigidity of the shaft 4. As shown in FIG. 5, the twelfth sheet S12 is located in a zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. Thus, the twelfth fiber-reinforced layer is also located in the zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. The twelfth fiber-reinforced layer particularly contributes to the flexural rigidity of the middle portion 14.

[0053] The thirteenth sheet S13 extends over the entirety of the shaft 4. The thirteenth sheet S13 is generally rectangular. The thirteenth sheet S13 includes a plurality of carbon fibers arranged in parallel. The direction in which each of the carbon fibers extends is the same as the axial direction. In other words, the direction in which each carbon fiber extends forms an angle of substantially 0° with the axial direction. The thirteenth sheet S13 is 40 mm wide and 340 mm long.

[0054] As stated above, the carbon fibers contained in the thirteenth sheet S13 are oriented substantially in the axial direction. Thus, the carbon fibers are oriented substantially in the axial direction also in the thirteenth fiber-reinforced layer. The thirteenth fiber-reinforced layer has a straight structure. Upon deflection of the shaft 4, the carbon fibers are subjected to a strong tension. The tension acts to prevent further deflection of the shaft 4. In other words, the carbon fibers contribute to the flexural rigidity of the shaft 4.

[0055] In the shaft 4, the first, second, and thirteenth fiber-reinforced layers extend from the butt end 18 to the tip end 20. These fiber-reinforced layers can contribute to the durability of the shaft 4.

[0056] In production of the shaft 4, the sheets shown in FIG. 5 are sequentially wound on a mandrel. A stack of the first and second sheets S1 and S2 may be wound on the mandrel. A stack of the third and fourth sheets S3 and S4 may be wound on the mandrel. A stack of the fifth and sixth sheets S5 and S6 may be wound on the mandrel. A stack of the eighth and ninth sheets S8 and S9 may be wound on the mandrel. A stack of the tenth and eleventh sheets S10 and S11 may be wound on the mandrel. In addition to these sheets, another sheet may be wound on the mandrel. An example of the other sheet is a sheet containing glass fibers.

[0057] A wrapping tape is further wound on the above sheets. The mandrel, prepregs (sheets S1 to S13), and wrapping tape are heated by means such as an oven. The heating fluidizes the matrix resin. Further heating induces a curing reaction of the resin, as a result of which a shaped product is obtained. The shaped product is subjected to various processes such as end face machining, polishing, and painting, and thus the shaft 4 is completed.

[0058] FIG. 6 is a schematic diagram showing a method of measuring a flexural rigidity value EI of the shaft 4 of the racket 2 of FIG. 1. FIG. 6 shows the measurement at a measurement point P located at a distance L1 from the grip 8.

In this measurement, the shaft 4 is supported from below at first and second support points 28 and 30. The distance from the measurement point P to the first support point 28 is 30 mm. The distance from the measurement point P to the second support point 30 is 30 mm. The measurement is performed using a universal testing machine (manufactured by INTESCO Co., Ltd. under the product name "2020"). The testing machine includes an indenter 32. The indenter 32 is in the shape of a hemisphere. The radius of curvature of the hemisphere is 20 mm. The indenter 32 gradually descends at a speed of 2 mm/min. The indenter 32 comes into contact with the measurement point P and presses the shaft 4. The pressing causes gradual deflection of the shaft 4. The amount of deflection B (m) of the shaft 4 is measured at the moment when the load applied to the shaft 4 by the indenter 32 reaches 100 N. The amount of deflection B is substituted into the following equation to calculate the flexural rigidity value EI (Nm^2).

$$EI = F \cdot L2^3/(48 \cdot B)$$

[0059] In this equation, F is the load (N), L2 is the distance (m) between the two support points, and B is the amount of deflection (m). In the present embodiment, the load F is 100 N, and the distance L2 is 0.06 m. The flexural rigidity value EI of the shaft 4 may be measured in the absence of the grip 8 and frame 6.

[0060] In the present embodiment, the flexural rigidity values EI are measured at the first, second, third, and fourth measurement points P1, P2, P3, and P4. The distance L1 from the grip 8 to each measurement point is as follows.

First measurement point P1: 35 mm
Second measurement point P2: 75 mm
Third measurement point P3: 115 mm
Fourth measurement point P4: 155 mm

[0061] In the shaft 4 having the prepreg arrangement shown in FIG. 5, the flexural rigidity value EI(1) at the first measurement point P1 is 3.82 Nm^2, the flexural rigidity value EI(2) at the second measurement point P2 is 5.51 Nm^2, the flexural rigidity value EI(3) at the third measurement point P3 is 5.74 Nm^2, and the flexural rigidity value EI(4) at the fourth measurement point P4 is 3.58 Nm^2. The flexural rigidity distribution of the shaft 4 is shown in the graph of FIG. 7.

[0062] In the shaft 4, the flexural rigidity value EI(2) at the second measurement point P2 is greater than the flexural rigidity value EI(1) at the first measurement point P1 and the flexural rigidity value EI(4) at the fourth measurement point P4. Furthermore, in the shaft 4, the flexural rigidity value EI(3) at the third measurement point P3 is greater than the flexural rigidity value EI(1) at the first measurement point P1 and the flexural rigidity value EI(4) at the fourth measurement point P4. In the shaft 4, the following four inequality relations are established.

EI(2) > EI(1)
EI(2) > EI(4)
EI(3) > EI(1)
EI(3) > EI(4)

[0063] As shown in FIG. 7, the shaft 4 has a rigidity distribution with an upward-convex profile.

[0064] As previously stated, the seventh fiber-reinforced layer is located in a zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. The twelfth fiber-reinforced layer is located in a zone including the second and third measurement points P2 and P3 and not including the first and fourth measurement points P1 and P4 in the axial direction. There is no fiber-reinforced layer having a straight structure and located in a zone including the first measurement point P1 and not including the second measurement point P2. There is no fiber-reinforced layer having a straight structure and located in a zone not including the third measurement point P3 but including the fourth measurement point P4. This layer structure can attain a flexural rigidity distribution with an upward-convex profile.

[0065] Another layer structure can also attain a flexural rigidity distribution with an upward-convex profile. Local presence of a fiber-reinforced layer having a straight structure in the middle portion 14 can result in a flexural rigidity distribution with an upward-convex profile.

[0066] According to the findings obtained by the present inventors, the shaft 4 having a flexural rigidity distribution with an upward-convex profile is suitable for the smash. The player who performs the smash using the racket 2 can easily achieve an intended trajectory of the shuttlecock. With the use of the racket 2, the variation in the height of the trajectory of the shuttlecock in the smash is small.

[0067] The reason why the racket 2 according to the present invention is suitable for the smash is that the flexural rigidity distribution shown in FIG. 7 matches the deformation behavior of the shaft 4 in the smash. In the smash, the shaft 4 is significantly deflected in the in-plane direction (direction along the X-Y plane) and in the out-of-plane direction

(Z direction). The racket 2 according to the present invention is suitable also for shots which are other than the smash and in which the shaft 4 is significantly deflected in both the in-plane and out-of-plane directions.

[0068] The flexural rigidity distribution can be adjusted by changing the location of the prepregs, the number of the prepregs, the width of the prepregs, the length of the prepregs, the angle of the fibers, the weight per unit area of the fibers, and the elastic modulus of the fibers.

[0069] From the viewpoint of the stability of the trajectory, the ratio (EI(2)/EI(1)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(1) is preferably not less than 1.10, more preferably not less than 1.22, and particularly preferably not less than 1.30. From the viewpoint of ease of production of the shaft 4, the ratio is preferably not greater than 2.50.

[0070] From the viewpoint of the stability of the trajectory, the ratio (EI(2)/EI(4)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(4) is preferably not less than 1.10, more preferably not less than 1.33, and particularly preferably not less than 1.45. From the viewpoint of ease of production of the shaft 4, the ratio is preferably not greater than 3.00.

[0071] From the viewpoint of the stability of the trajectory, the ratio (EI(3)/EI(1)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(1) is preferably not less than 1.10, more preferably not less than 1.24, and particularly preferably not less than 1.45. From the viewpoint of ease of production of the shaft 4, the ratio is preferably not greater than 3.00.

[0072] From the viewpoint of the stability of the trajectory, the ratio (EI(3)/EI(4)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(4) is preferably not less than 1.10, more preferably not less than 1.35, and particularly preferably not less than 1.50. From the viewpoint of ease of production of the shaft 4, the ratio is preferably not greater than 3.00.

[0073] The ratio (EI(1)/EI(4)) is preferably not less than 0.5 and not greater than 2.0. The ratio (EI(2)/EI(3)) is preferably not less than 0.5 and not greater than 2.0.

[0074] From the viewpoint of the stability of the trajectory, the difference (EI(2) - EI(1)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(1) is preferably not less than 0.50 Nm^2, more preferably not less than 0.91 Nm^2, and particularly preferably not less than 1.30 Nm^2. From the viewpoint of ease of production of the shaft 4, the difference is preferably not greater than 3.5 Nm^2.

[0075] From the viewpoint of the stability of the trajectory, the difference (EI(2) - EI(4)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(4) is preferably not less than 0.50 Nm^2, more preferably not less than 1.24 Nm^2, and particularly preferably not less than 1.50 Nm^2. From the viewpoint of ease of production of the shaft 4, the difference is preferably not greater than 3.5 Nm^2.

[0076] From the viewpoint of the stability of the trajectory, the difference (EI(3) - EI(1)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(1) is preferably not less than 0.50 Nm^2, more preferably not less than 0.99 Nm^2, and particularly preferably not less than 1.50 Nm^2. From the viewpoint of ease of production of the shaft 4, the difference is preferably not greater than 3.5 Nm^2.

[0077] From the viewpoint of the stability of the trajectory, the difference (EI(3) - EI(4)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(4) is preferably not less than 0.50 Nm^2, more preferably not less than 1.32 Nm^2, and particularly preferably not less than 1.70 Nm^2. From the viewpoint of ease of production of the shaft 4, the difference is preferably not greater than 3.5 Nm^2.

[0078] Preferred ranges of the flexural rigidity values EI are as follows.

EI(1): Not less than 2.0 Nm^2 and not greater than 6.0 Nm^2
EI(2): Not less than 3.5 Nm^2 and not greater than 7.5 Nm^2
EI(3): Not less than 3.5 Nm^2 and not greater than 7.5 Nm^2
EI(4): Not less than 2.0 Nm^2 and not greater than 6.0 Nm^2

[0079] FIG. 3 shows the first, second, third, and fourth measurement points P1, P2, P3, and P4. As is clear from FIG. 3, the inner diameter Di of the shaft 4 is substantially constant from the first measurement point P1 to the fourth measurement point P4. The shaft 4 can be produced using a mandrel having a simple shape. In the production of the shaft 4, the winding of the prepregs is easy. The shaft 4 may have a slight variation in the inner diameter Di due to, for example, production error. The ratio (Di1/Di2) of the maximum inner diameter Di1 to the minimum inner diameter Di2 in the zone from the first measurement point P1 to the fourth measurement point P4 is preferably not greater than 1.10, more preferably not greater than 1.05, and particularly preferably not greater than 1.03. The ratio (Di1/Di2) is ideally 1.00.

[0080] As is clear from FIG. 3, the outer diameter Do of the shaft 4 is substantially constant from the first measurement point P1 to the fourth measurement point P4. The shaft 4 can be produced using a mandrel having a simple shape. In the production of the shaft 4, the winding of the prepregs is easy. The shaft 4 may have a slight variation in the outer diameter Do due to, for example, production error. The ratio (Do1/Do2) of the maximum outer diameter Do1 to the minimum outer diameter Do2 in the zone from the first measurement point P1 to the fourth measurement point P4 is preferably not greater than 1.10, more preferably not greater than 1.05, and particularly preferably not greater than 1.03. The ratio (Do1/Di2) is ideally 1.00.

[0081] The ratio (W2/W1) of the weight W2 of the shaft 4 in the zone from the second measurement point P2 to the second measurement point P3 to the weight W1 of the shaft 4 in the zone from the first measurement point P1 to the second measurement point P2 is preferably not less than 0.95 and not greater than 1.05. Furthermore, the ratio (W2/W3) of the weight W2 to the weight W3 of the shaft 4 in the zone from the third measurement point P3 to the fourth measurement point P4 is preferably not less than 0.95 and not greater than 1.05. Such a shaft 4 is free from a significant local increase in weight. The player can swing the racket 2 including the shaft 4 without feeling discomfort. From this viewpoint, the ratios (W2/W1) and (W2/W3) are more preferably not less than 0.97 and not greater than 1.03 and particularly preferably not less than 0.98 and not greater than 1.02.

[0082] In the shaft 4, the flexural rigidity distribution is not adjusted by thickness adjustment. In the shaft 4, the flexural rigidity distribution is not adjusted by opening formation. The shaft 4 is less likely to suffer stress concentration. The shaft 4 has excellent durability.

Examples

[0083] Hereinafter, the effect of the present invention will be demonstrated by examples. The present invention should not be restrictively interpreted based on the description of the examples.

[Example 1]

[0084] A badminton racket as shown in FIGS. 1 to 6 was produced. The flexural rigidity values EI of the racket are shown in Table 1 below and in FIG. 7.

[Examples 2 and 3 and Comparative Example]

[0085] Badminton rackets of Examples 2 and 3 and Comparative Example were obtained in the same manner as the badminton racket of Example 1, except for changing the prepreg arrangement. The flexural rigidity values EI of the rackets are shown in Table 1 below and in FIGS. 8 to 10.

[Practical Test]

[0086] A shuttlecock was launched by a launching machine. A player was caused to perform smash on the shuttlecock, and a video image of the trajectory of the shuttlecock was captured. The image was analyzed to measure the height at which the shuttlecock passed above the net. The measurement was conducted six times, and an average height Hav, a maximum height Hmax, and a minimum height Hmin were determined. The results are shown in Table 1 below.

[Table 1]

[0087]

Table 1 Evaluation Results

	Comparative Example	Example 2	Example 1	Example 3
Flexural rigidity distribution	FIG. 8	FIG. 9	FIG. 7	FIG. 10
EI(1) (Nm^2)	4.36	4.11	3.82	3.60
EI(2) (Nm^2)	4.45	5.02	5.51	5.87
EI(3) (Nm^2)	4.36	5.10	5.74	6.35
EI(4) (Nm^2)	4.08	3.78	3.58	3.39
EI(2)/EI(1)	1.02	1.22	1.44	1.63
EI(3)/EI(1)	1.00	1.24	1.50	1.76
EI(2)/EI(4)	1.09	1.33	1.54	1.73
EI(3)/EI(4)	1.07	1.35	1.60	1.87
EI(2) - EI(1) (Nm^2)	0.09	0.91	1.69	2.27

(continued)

	Comparative Example	Example 2	Example 1	Example 3
EI(3) - EI(1) (Nm^2)	0.00	0.99	1.92	2.75
EI(2) - EI(4) (Nm^2)	0.37	1.24	1.93	2.48
EI(3) - EI(4) (Nm^2)	0.28	1.32	2.16	2.96
Hmax (m)	1.76	1.60	1.52	1.45
Hmin (m)	1.41	1.41	1.39	1.38
Hmax - Hmin (m)	0.35	0.19	0.13	0.07

[0088] As is clear from Table 1, the trajectory of the shuttlecock in the smash is stable when any of the badminton rackets of Examples is used. The evaluation results demonstrate the superiority of the present invention.

Industrial Applicability

[0089] The badminton racket according to the present invention is suitable for players who play in a style involving frequent use of smash. The racket is suitable also for players who play in other styles.

Reference Signs List

[0090]

2 badminton racket

4 shaft

6 frame

8 grip

10 string

12 butt portion

14 middle portion

16 tip portion

18 butt end

20 tip end

26 face

S1 first sheet

S2 second sheet

S3 third sheet

S4 fourth sheet

S5 fifth sheet

S6 sixth sheet

S7 seventh sheet

S8 eighth sheet

Claims

1. A badminton racket comprising:

a grip;
a shaft having a portion inserted into the grip, the inserted portion including a butt end of the shaft and a vicinity of the butt end; and
a frame attached to the shaft in a vicinity of a tip end of the shaft, wherein
a flexural rigidity value EI(2) of the shaft at a second measurement point located at a distance of 75 mm from the grip is greater than a flexural rigidity value EI(1) of the shaft at a first measurement point located at a distance of 35 mm from the grip and a flexural rigidity value EI(4) of the shaft at a fourth measurement point located at a distance of 155 mm from the grip, and
a flexural rigidity value EI(3) of the shaft at a third measurement point located at a distance of 115 mm from the grip is greater than the flexural rigidity value EI(1) and the flexural rigidity value EI(4).

2. The racket according to claim 1, wherein a ratio (EI(2)/EI(1)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(1) is not less than 1.10.

3. The racket according to claim 1 or 2, wherein a ratio (EI(2)/EI(4)) of the flexural rigidity value EI(2) to the flexural rigidity value EI(4) is not less than 1.10.

4. The racket according to any one of claims 1 to 3, wherein a ratio (EI(3)/EI(1)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(1) is not less than 1.10.

5. The racket according to any one of claims 1 to 4, wherein a ratio (EI(3)/EI(4)) of the flexural rigidity value EI(3) to the flexural rigidity value EI(4) is not less than 1.10.

6. The racket according to any one of claims 1 to 5, wherein a difference (EI(2) - EI(1)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(1) is not less than 0.50 Nm^2.

7. The racket according to any one of claims 1 to 6, wherein a difference (EI(2) - EI(4)) between the flexural rigidity value EI(2) and the flexural rigidity value EI(4) is not less than 0.50 Nm^2.

8. The racket according to any one of claims 1 to 7, wherein a difference (EI(3) - EI(1)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(1) is not less than 0.50 Nm^2.

9. The racket according to any one of claims 1 to 8, wherein a difference (EI(3) - EI(4)) between the flexural rigidity value EI(3) and the flexural rigidity value EI(4) is not less than 0.50 Nm^2.

10. The racket according to any one of claims 1 to 9, wherein

the shaft has a hollow structure, and
an inner diameter of the shaft is substantially constant from the first measurement point to the fourth measurement point.

11. The racket according to any one of claims 1 to 10, wherein an outer diameter of the shaft is substantially constant from the first measurement point to the fourth measurement point.

12. The racket according to any one of claims 1 to 11, wherein

a ratio (W2/W1) of a weight W2 of the shaft in a zone from the second measurement point to the third measurement point to a weight W1 of the shaft in a zone from the first measurement point to the second measurement point is not less than 0.95 and not greater than 1.05, and a ratio (W2/W3) of the weight W2 of the shaft in the zone from the second measurement point to the third measurement point to a weight W3 of the shaft in a zone from the third measurement point to the fourth measurement point is not less than 0.95 and not greater than 1.05.

13. The racket according to any one of claims 1 to 12, wherein

the shaft includes a fiber-reinforced layer located in a zone including the second and third measurement points and not including the first and fourth measurement points in an axial direction of the shaft, and
the fiber-reinforced layer includes a plurality of reinforcing fibers oriented substantially in the axial direction.

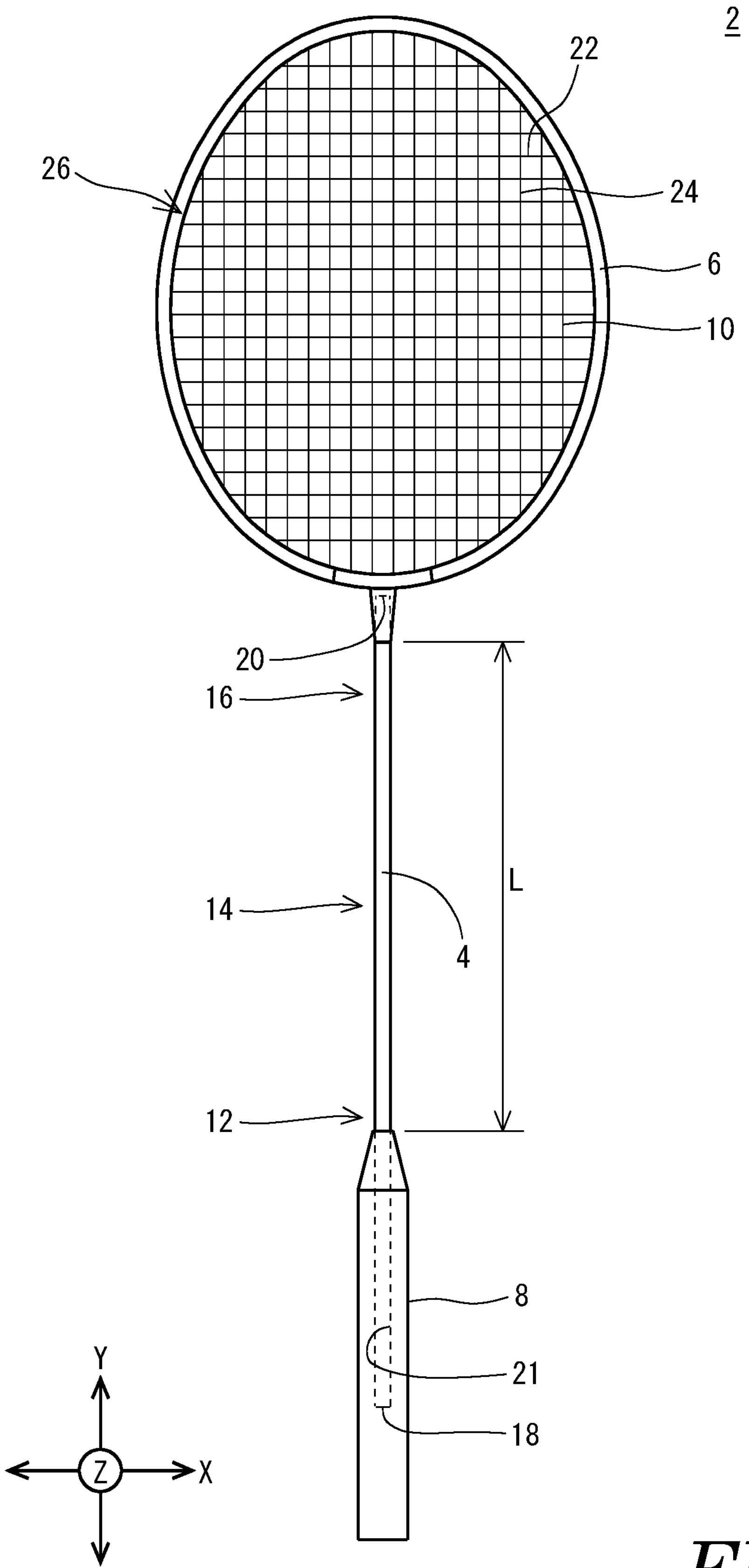

FIG. 1

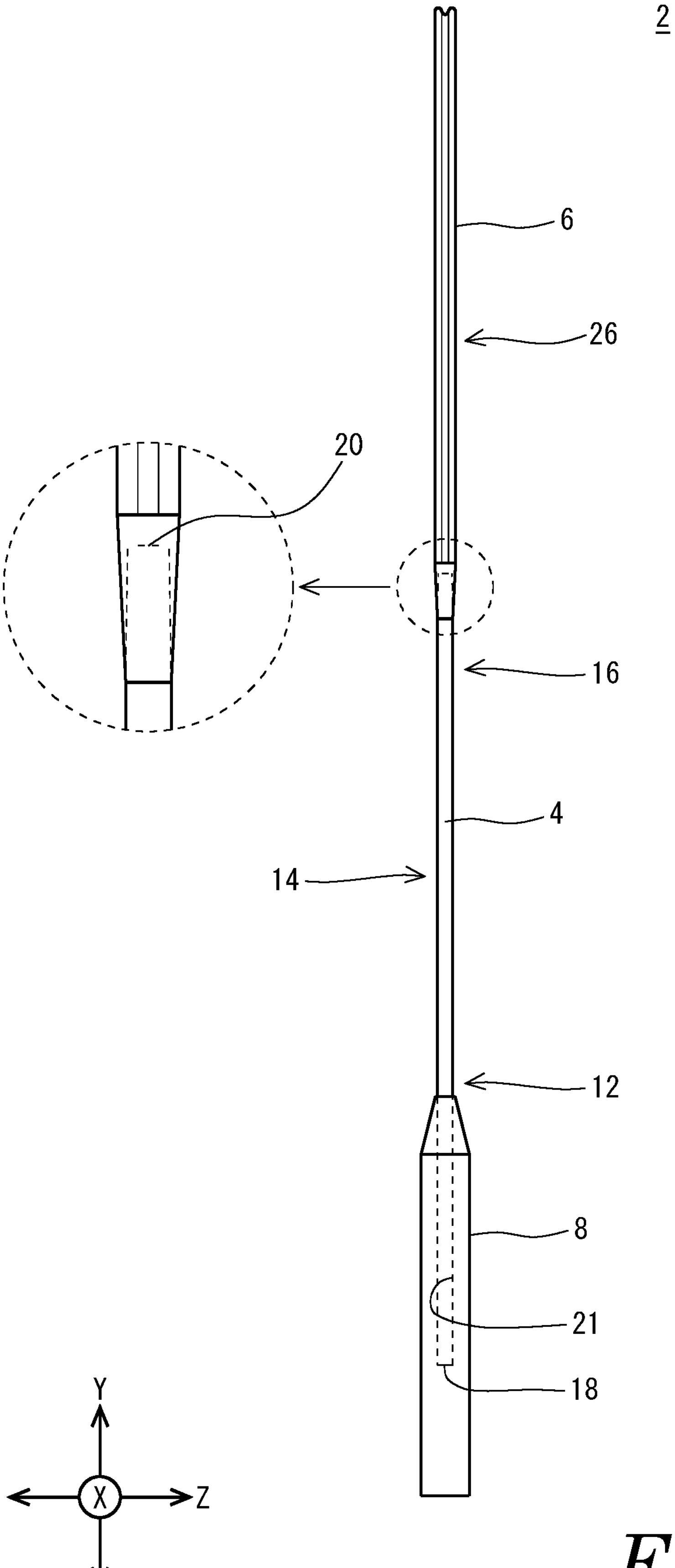

FIG. 2

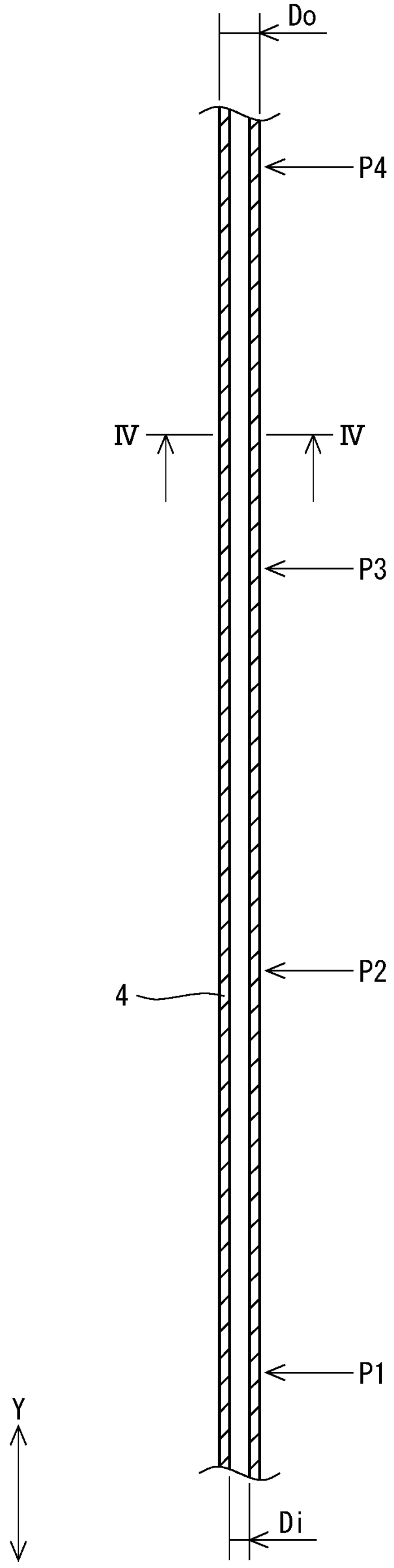

FIG. 3

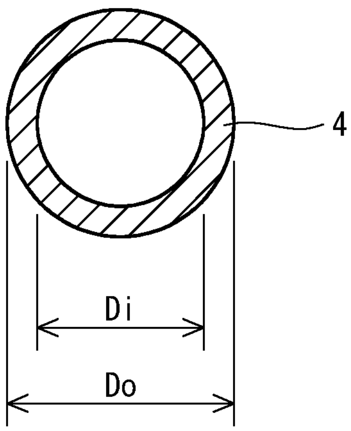

FIG. 4

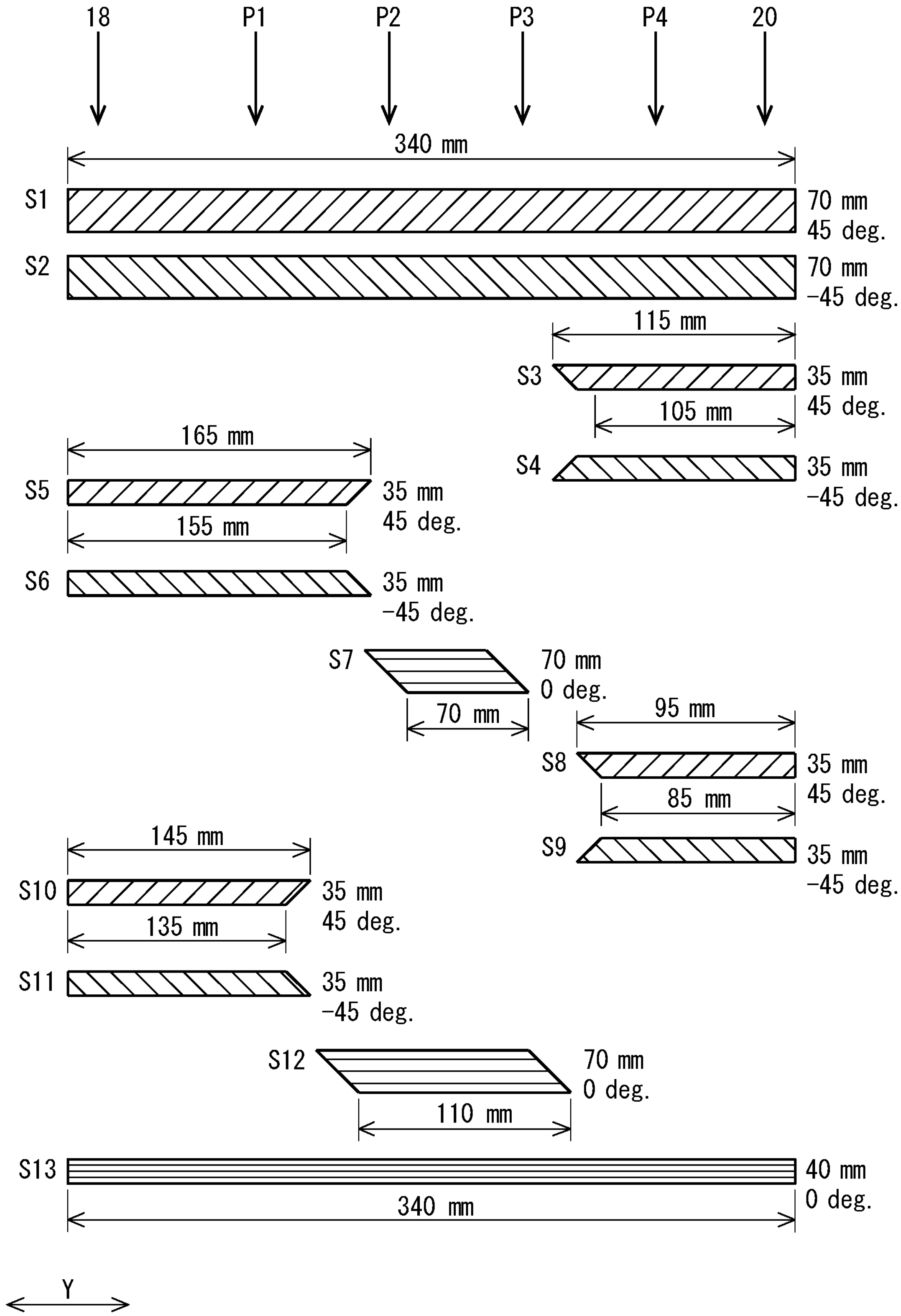
18
P1
P2
P3
P4
20
340 mm
S1
70 mm
45 deg.
S2
70 mm
-45 deg.
115 mm
S3
35 mm
45 deg.
105 mm
165 mm
S4
35 mm
-45 deg.
S5
35 mm
45 deg.
155 mm
S6
35 mm
-45 deg.
S7
70 mm
0 deg.
70 mm
95 mm
S8
35 mm
45 deg.
85 mm
145 mm
S9
35 mm
-45 deg.
S10
35 mm
45 deg.
135 mm
S11
35 mm
-45 deg.
S12
70 mm
0 deg.
110 mm
S13
40 mm
0 deg.
340 mm
Y

FIG. 5

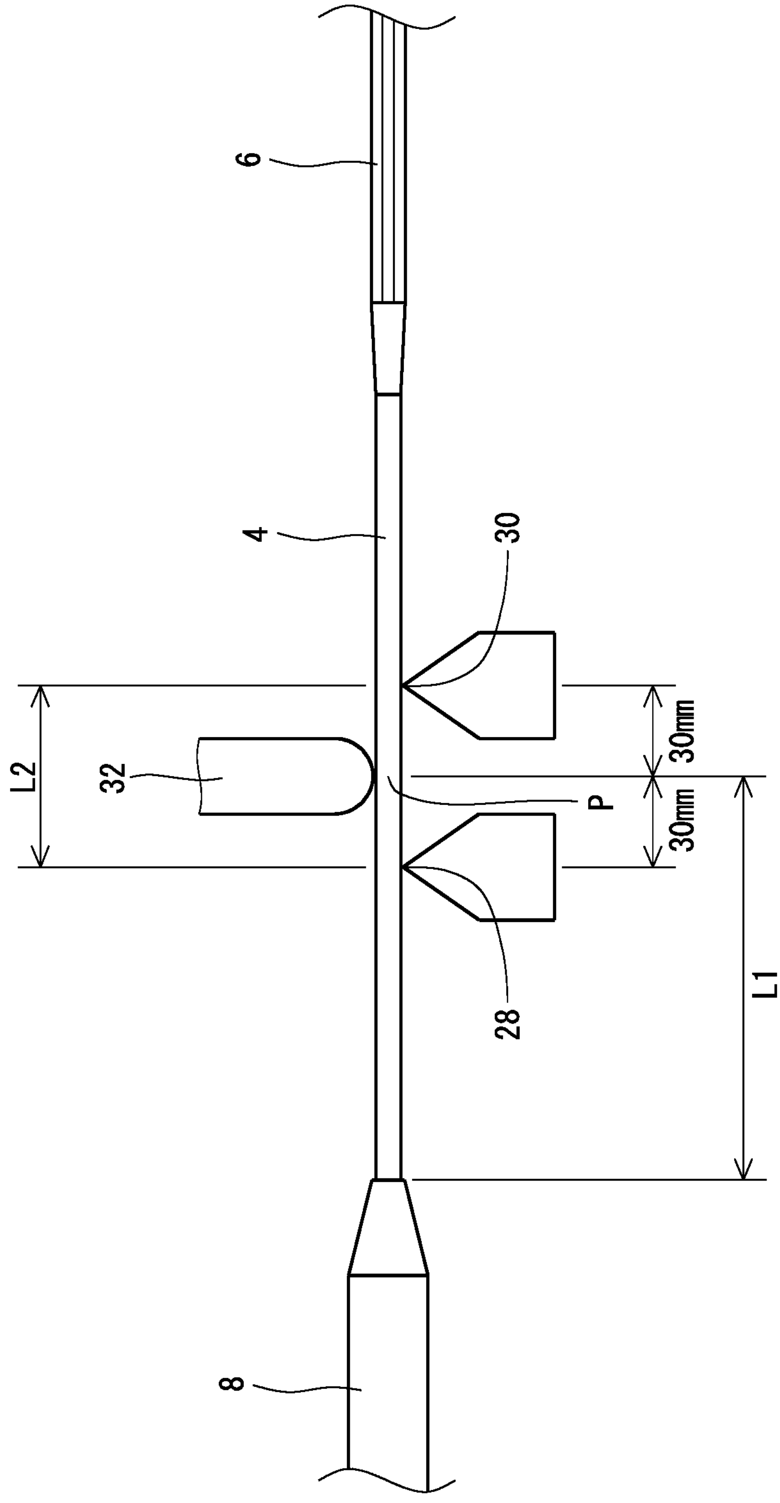

FIG. 6

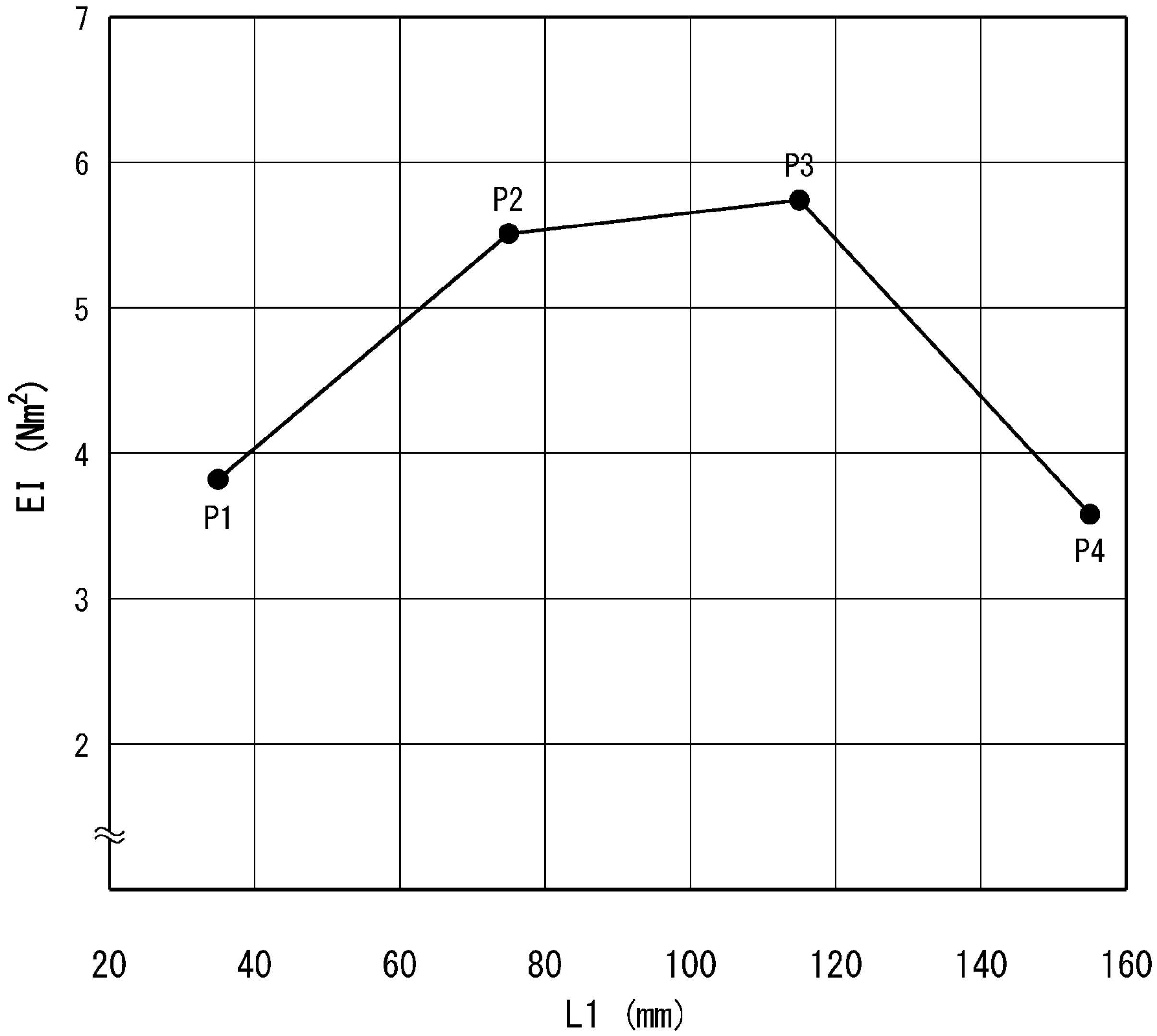

FIG. 7

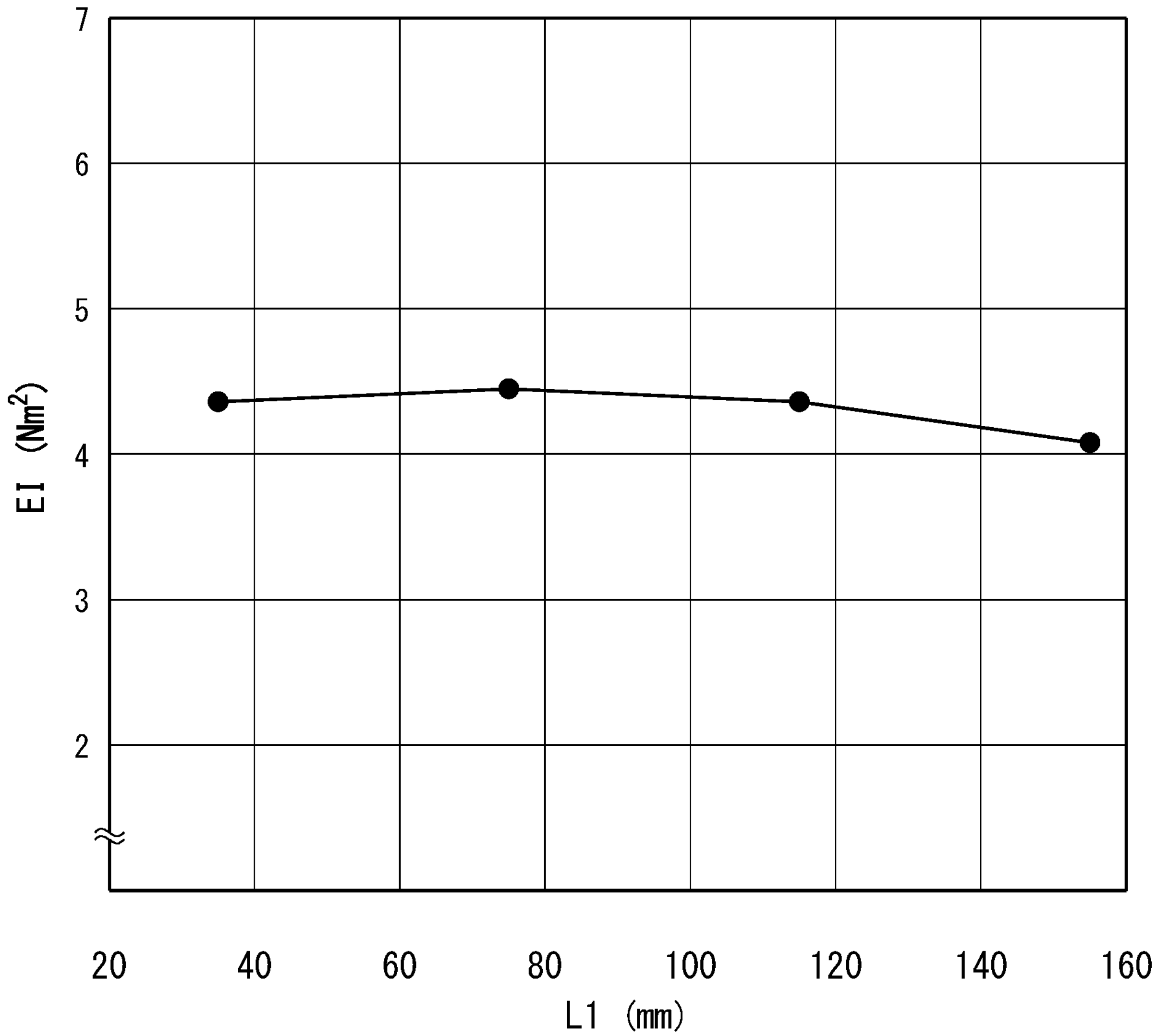

FIG. 8

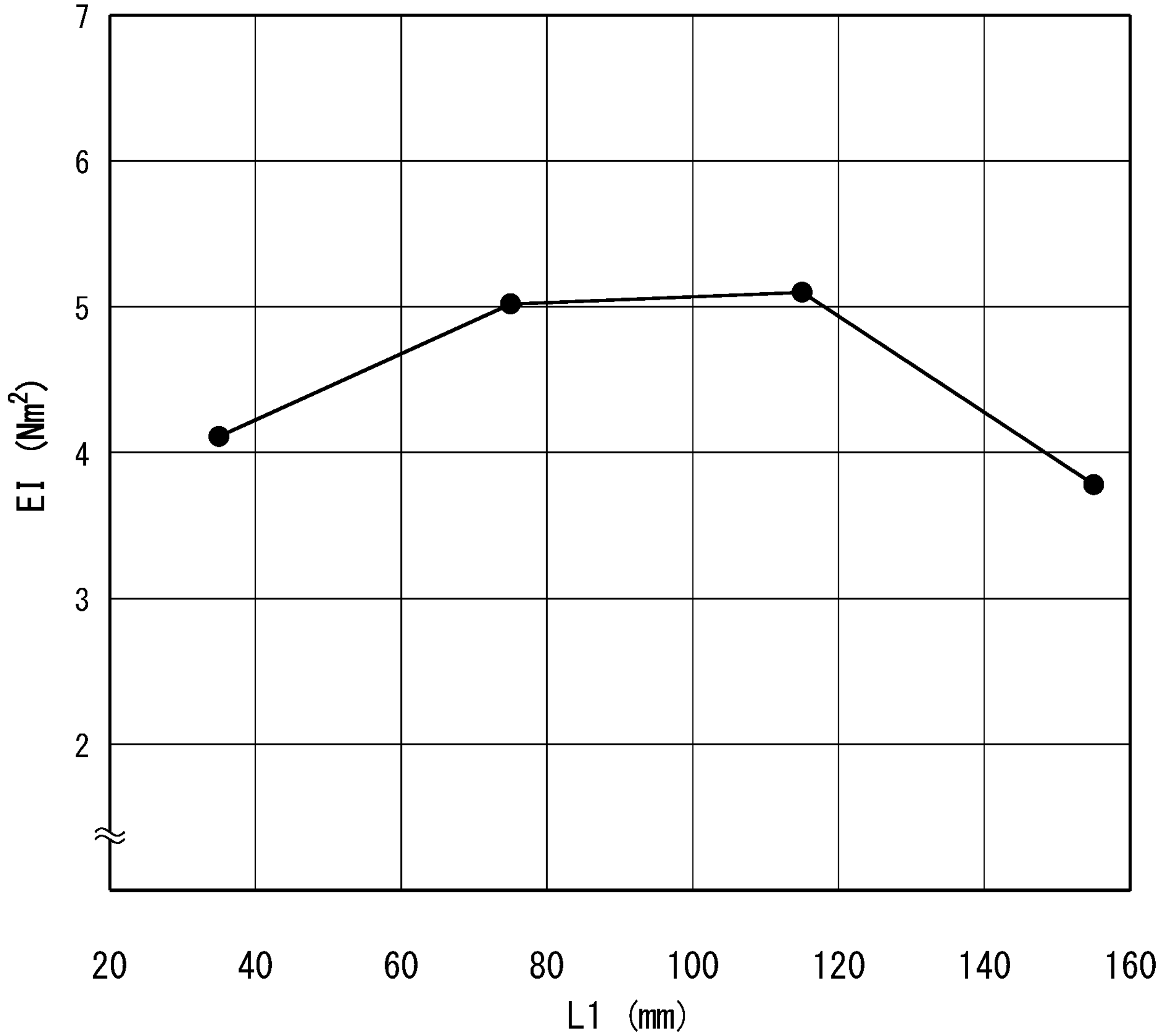

FIG. 9

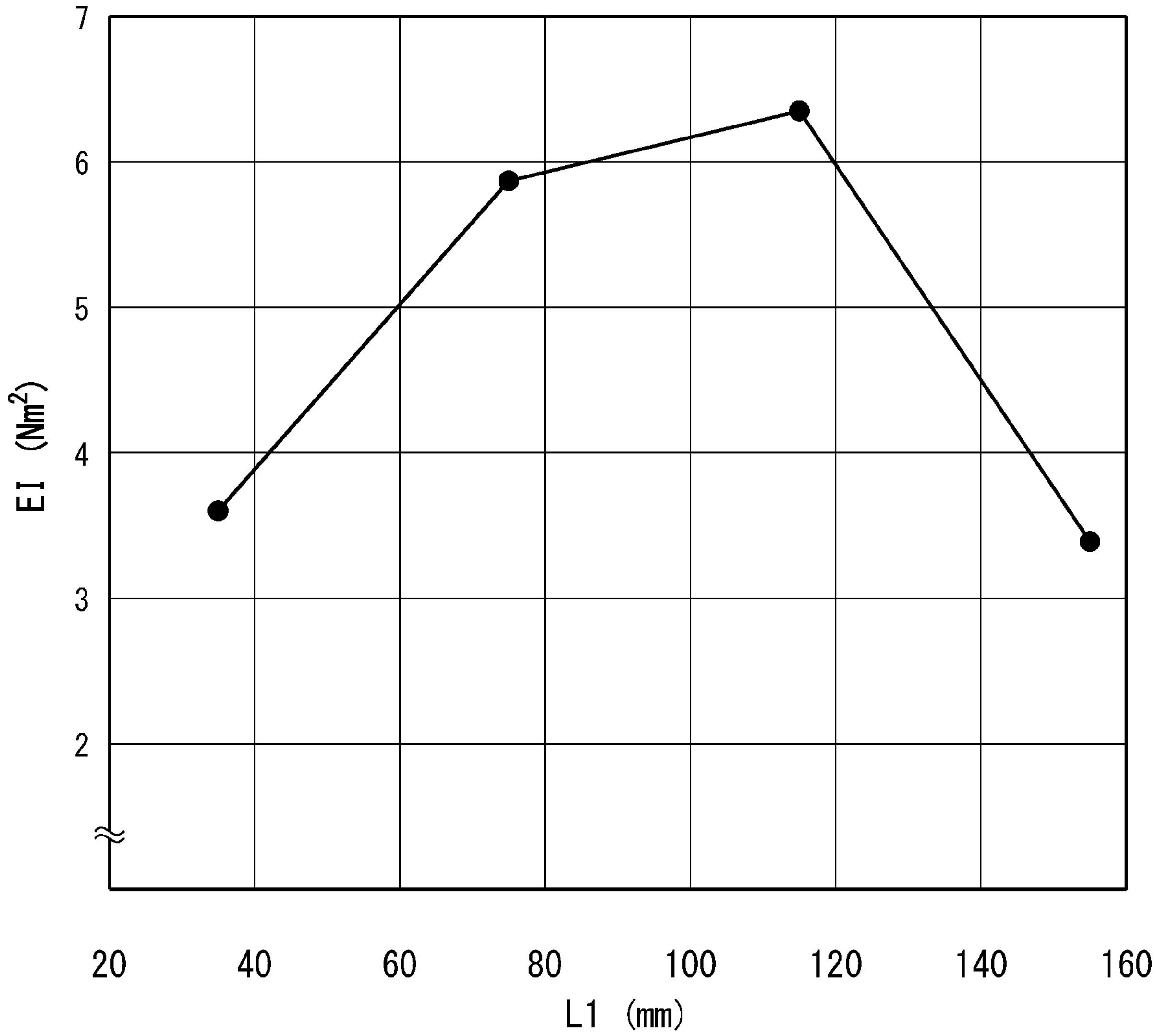

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/001551

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. A63B49/00(2015.01)i, A63B102/04(2015.01)n
FI: A63B49/00, A63B102:04

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)
Int.Cl. A63B49/00-A63B51/16, A63B55/00-A63B60/64, A63B102/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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.
X Y	CN 107261439 A (WU, H. L.) 20 October 2017 (2017-10-20), paragraphs [0003]-[0010], fig. 1	1-12 13
Y A	JP 2014-45947 A (GLOBERIDE INC.) 17 March 2014 (2014-03-17), paragraph [0039], fig. 4	13 1-12
A	CN 2754672 Y (QIAOXING INDUSTRY CO., LTD.) 01 February 2006 (2006-02-01), entire text, all drawings	1-13
A	CN 205340022 U (XU, J. S.) 29 June 2016 (2016-06-29), entire text, all drawings	1-13
E, X E, A	JP 2021-23724 A (SUMITOMO RUBBER INDUSTRIES, LTD.) 22 February 2021 (2021-02-22), paragraphs [0025]-[0032], fig. 11	1, 11 2-20, 12-13

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
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"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
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"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	Date of mailing of the international search report
09 March 2021	23 March 2021

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	 Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/001551

CN 107261439 A	20 October 2017	(Family: none)
JP 2014-45947 A	17 March 2014	(Family: none)
CN 2754672 Y	01 February 2006	(Family: none)
CN 205340022 U	29 June 2016	(Family: none)
JP 2021-23724 A	22 February 2021	(Family: none)

Form PCT/ISA/210 (patent family annex) (January 2015)

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- CN 107115641 **[0003] [0004]**