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(54) **BADMINTON RACKET**

(57) Provided is a badminton racket 2 that enables suppression of a variation among the trajectories of shuttles both upon a shot that is hit at a hitting point near a bottom and upon a shot that is hit at a hitting point near a top. The badminton racket 2 includes a shaft 4, a frame 6, and a grip 12. A ratio (ω_{o2}/ω_{o1}) of an out-of-plane secondary natural frequency ω_{o2} (Hz) to an out-of-plane primary natural frequency ω_{o1} (Hz) of the racket 2, and

a ratio (ω_{i2}/ω_{i1}) of an in-plane secondary natural frequency ω_{i2} (Hz) to an in-plane primary natural frequency ω_{i1} (Hz) of the racket 2, satisfy the following mathematical expression (1),

$$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2 \quad (1).$$

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present specification discloses a racket used in badminton.

Background Art

[0002] A badminton racket includes a frame, strings, and a shaft. The frame has a top and a bottom. The strings form a face. A player shoots a shuttlecock with the racket. Upon the shot, the face collides with the shuttlecock. Impact generated by the collision is transmitted from the strings via the frame to the shaft. Shots lead to deformation of the frame and the shaft. Japanese Laid-Open Patent Publication No. 2021-23724 describes an attempt to optimize the manner of deformation.

[0003] In badminton games, players hit various types of shots. The shots that are hit by the players include smash, lob, drop shot, clear, and the like.

[0004] A smash is a shot intended to hinder reception by opponent players. For smashes, players need to have skills for causing shuttlecocks to fly along intended trajectories. Players who frequently hit smashes desire to stabilize trajectories of shuttlecocks (in terms of speed, height, and the like).

[0005] Lobs with cuts involve motions of cuts unlike normal lobs. Upon lobs with cuts, shuttlecocks fly at high speeds while rotating at high speeds. In many cases, lobs with cuts are hit from the vicinity of a net on the player side of a court. A lob with a cut is a shot intended to bring a shuttlecock to a rear part of the opponent player side of a court. Upon the lob with cut, the shuttlecock follows a high trajectory. Thus, for lobs with cuts, players need to have high skills for causing shuttlecocks to fly at intended heights. Players who frequently hit lobs with cuts desire to stabilize trajectories of shuttlecocks (in terms of speed, height, and the like).

[0006] According to studies conducted through a statistical technique, typical hitting points for smashes are located near the bottom, and typical hitting points for lobs with cuts are located near the top. Meanwhile, in shots other than smash as well, a shuttlecock could be shot at a hitting point near the bottom. Likewise, in shots other than lob with cut as well, a shuttlecock could be shot at a hitting point near the top.

[0007] The present inventor intends to provide a badminton racket that enables suppression of a variation among the trajectories of shuttlecocks both upon a shot that is hit at a hitting point near a bottom and upon a shot that is hit at a hitting point near a top.

SUMMARY OF THE INVENTION

[0008] A preferable badminton racket includes:

a shaft including a butt and a tip;
a grip attached to the butt of the shaft; and
a frame attached to the tip of the shaft.

[0009] A ratio (ω_2/ω_1) of an out-of-plane secondary natural frequency ω_2 (Hz) to an out-of-plane primary natural frequency ω_1 (Hz) of the badminton racket, and a ratio (ω_i2/ω_i1) of an in-plane secondary natural frequency ω_i2 (Hz) to an in-plane primary natural frequency ω_i1 (Hz) of the badminton racket, satisfy the following mathematical expression (1),

$$(\omega_i2/\omega_i1) \geq 1.3 * (\omega_2/\omega_1) - 0.2 \quad (1).$$

[0010] A player who uses this badminton racket easily hits a shot that is to be hit at a hitting point near the bottom, and also easily hits a shot that is to be hit at a hitting point near the top. This racket could contribute to winning a game.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a front view of a badminton racket according to an embodiment;

FIG. 2 is a right side view of the badminton racket in FIG. 1;
 FIG. 3 is an enlarged cross-sectional view of a part of a shaft of the badminton racket in FIG. 2;
 FIG. 4 is an enlarged cross-sectional view taken along a line IV-IV in FIG. 3;
 FIG. 5 is a perspective cross-sectional view of an example of a prepreg for the shaft of the badminton racket in FIG. 1;
 FIG. 6 is a development of a prepreg configuration for the shaft of the badminton racket in FIG. 1;
 FIG. 7 is a development of a prepreg configuration of type A;
 FIG. 8 is a schematic view of the prepreg configuration of type A;
 FIG. 9 is an enlarged cross-sectional view of a part of the shaft of the badminton racket in FIG. 1;
 FIG. 10 is an enlarged cross-sectional view of a part of the shaft of the badminton racket in FIG. 2;
 FIG. 11 is an enlarged cross-sectional view taken along a line XI-XI in FIG. 10;
 FIG. 12 is an enlarged cross-sectional view taken along a line XII-XII in FIG. 10;
 FIG. 13 is a schematic view of a prepreg configuration of type B;
 FIG. 14 is a diagram for explaining a measurement method for a natural frequency in an out-of-plane direction of the racket in FIG. 1;
 FIG. 15 is a graph showing a result obtained through the measurement in FIG. 14;
 FIG. 16 is a diagram for explaining a measurement method for a natural frequency in an in-plane direction of the racket in FIG. 1;
 FIG. 17 is a graph showing a result obtained through the measurement in FIG. 16;
 FIG. 18 is a graph showing a relationship between a ratio (ω_{o2}/ω_{o1}) and a ratio (ω_{i2}/ω_{i1}) of the badminton racket in FIG. 1;
 FIG. 19 is a schematic view of a prepreg configuration of type C;
 FIG. 20 is a schematic view of a prepreg configuration of type D;
 FIG. 21 is a schematic view of a prepreg configuration of type E;
 FIG. 22 is a schematic view of a prepreg configuration of type F;
 FIG. 23 is a schematic view of a prepreg configuration of type G;
 FIG. 24 is a schematic view of a prepreg configuration of type H;
 FIG. 25 is a schematic view of a prepreg configuration of type I;
 FIG. 26 is a schematic view of a prepreg configuration of type J;
 FIG. 27 is a schematic view of a prepreg configuration of type K;
 FIG. 28 is a development of a prepreg configuration in comparative example 1;
 FIG. 29 is a development of a prepreg configuration in comparative example 2; and
 FIG. 30 is a development of a prepreg configuration in comparative example 3.

DETAILED DESCRIPTION

[0012] Hereinafter, a preferred embodiment will be described in detail with appropriate reference to the drawings.

[0013] FIG. 1 and FIG. 2 show a badminton racket 2. The racket 2 has a shaft 4, a frame 6, a neck 8, a cap 10, a grip 12, and strings 14. In FIG. 1 and FIG. 2, an arrow X indicates a width direction, an arrow Y indicates an axial direction, and an arrow Z indicates a thickness direction. The width direction X is also referred to as an in-plane direction. The thickness direction Z is also referred to as an out-of-plane direction.

[0014] The shaft 4 is hollow. In FIG. 1, an arrow Ls indicates the length of the shaft 4. In the present embodiment, the length Ls is 340 mm. The shaft 4 includes a butt 16, a middle 18, and a tip 20. The shaft 4 further includes a butt end 22 and a tip end 24. In the present specification, the butt 16 is defined as a zone between the butt end 22 and a position apart from the butt end 22 by a distance that is 44% of the length Ls. The middle 18 is defined as a zone between the position apart from the butt end 22 by the distance that is 44% of the length Ls and a position apart from the butt end 22 by a distance that is 71% of the length Ls. The tip 20 is defined as a zone between the position apart from the butt end 22 by the distance that is 71% of the length Ls, and the tip end 24.

[0015] The shaft 4 is formed from a fiber-reinforced resin. The fiber-reinforced resin has a resin matrix and a large number of reinforcing fibers. The shaft 4 includes a plurality of fiber-reinforced layers (described later in detail).

[0016] A base resin of the shaft 4 is exemplified by: thermosetting resins such as epoxy resin, bismaleimide resin, polyimide resin, and phenol resin; and thermoplastic resins such as polyether ether ketone, polyether sulfone, polyetherimide, polyphenylene sulfide, polyamide, and polypropylene. A resin that is particularly suitable for the shaft 4 is the epoxy resin.

[0017] The reinforcing fibers of the shaft 4 are exemplified by carbon fibers, metal fibers, glass fibers, and aramid fibers. Fibers that are particularly suitable for the shaft 4 are the carbon fibers. A plurality of types of fibers may be used in combination.

[0018] The frame 6 has an annular shape and is hollow. The frame 6 is formed from a fiber-reinforced resin. For this fiber-reinforced resin, the same base resin as the base resin of the shaft 4 can be used. For this fiber-reinforced resin,

the same reinforcing fibers as the reinforcing fibers of the shaft 4 can be used. The frame 6 is firmly joined via the neck 8 to the tip end 24 of the shaft 4. The frame 6 has a top 26 and a bottom 28.

[0019] The grip 12 has a hole 30 extending in the axial direction (Y direction). A portion of the shaft 4 that is located near the butt end 22 is inserted into the hole 30. The inner circumferential surface of the hole 30 and the outer circumferential surface of the shaft 4 are adhered to each other with an adhesive.

[0020] The strings 14 are stretched across the frame 6. The strings 14 are stretched along the width direction X and the axial direction Y. Strings that extend along the width direction X among the strings 14 are lateral threads 32. Strings that extend along the axial direction Y among the strings 14 are longitudinal threads 34. The plurality of lateral threads 32 and the plurality of longitudinal threads 34 form a face 36. The face 36 mostly spreads along an X-Y plane.

[0021] FIG. 3 is an enlarged cross-sectional view of a part of the shaft 4 of the racket 2 in FIG. 1. FIG. 4 is an enlarged cross-sectional view taken along a line IV-IV in FIG. 3. As described above, the shaft 4 is hollow. As shown in FIG. 4, the cross-sectional shape of the shaft 4 is a circle. In other words, the shaft 4 has a cylindrical shape. No foreign object is accommodated inside the shaft 4.

[0022] In FIG. 3 and FIG. 4, an arrow D_i indicates the inner diameter of the shaft 4. A typical inner diameter D_i is not smaller than 3 mm and not larger than 10 mm. In the present embodiment, the inner diameter D_i is substantially fixed from the butt end 22 (see FIG. 2) to the tip end 24. In FIG. 3 and FIG. 4, an arrow D_o indicates the outer diameter of the shaft 4. A typical outer diameter D_o is not smaller than 5 mm and not larger than 15 mm. In the present embodiment, the outer diameter D_o is substantially fixed from the butt end 22 to the tip end 24.

[0023] In FIG. 4, a reference character SC indicates the center point of the shaft 4. In the present embodiment, the shaft 4 is divided into four zones for convenience. In FIG. 4, a zone indicated by an arrow Q1 is a first quarter, a zone indicated by an arrow Q2 is a second quarter, a zone indicated by an arrow Q3 is a third quarter, and a zone indicated by an arrow Q4 is a fourth quarter. The center angle of each quarter about the point SC is 90°. The first quarter Q1 is apart in the in-plane direction from the center point SC. The second quarter Q2 is apart in the out-of-plane direction from the center point SC. The third quarter Q3 is apart in the in-plane direction from the center point SC. The fourth quarter Q4 is apart in the out-of-plane direction from the center point SC.

[0024] As described above, the shaft 4 is formed from a fiber-reinforced resin. The shaft 4 can be produced through a sheet winding method. In the sheet winding method, a plurality of prepregs are wound around a mandrel.

[0025] FIG. 5 shows an exemplary prepreg 38. The prepreg 38 has a plurality of fibers 40 and a matrix resin 42. The fibers 40 are arranged so as to be parallel to one another. The matrix resin 42 has not yet been cured. In FIG. 5, an arrow θ indicates the angle of each fiber 40 with respect to the Y direction.

[0026] FIG. 6 is a development of a prepreg configuration for the shaft 4 of the racket 2 in FIG. 1. In this prepreg configuration, nine prepreg sheet groups are provided. Specifically, in this prepreg configuration, a first sheet group S1, a second sheet group S2, a third sheet group S3, a fourth sheet group S4, a fifth sheet group S5, a sixth sheet group S6, a seventh sheet group S7, an eighth sheet group S8, and a ninth sheet group S9 are provided. The left-right direction in FIG. 6 is the axial direction of the shaft 4. In FIG. 6, the positions of the butt end 22 and the tip end 24 are indicated by arrows. For convenience of description, the scale in left-right direction (axial direction) does not match with the scale in the up-down direction in FIG. 6.

[0027] The first sheet group S1 includes a single prepreg 44. The prepreg 44 is present across the entire shaft 4. The shape of the prepreg 44 is substantially a rectangular shape. The prepreg 44 includes a plurality of carbon fibers arranged so as to be parallel to one another. The extension direction of each carbon fiber is tilted with respect to the axial direction. The angle θ of the carbon fiber is 45°. The tensile elastic modulus E of the carbon fiber is 24 tf/mm². The width W of the prepreg 44 is 80 mm.

[0028] The second sheet group S2 includes a single prepreg 46. The prepreg 46 is present across the entire shaft 4. The shape of the prepreg 46 is substantially a rectangular shape. The prepreg 46 includes a plurality of carbon fibers arranged so as to be parallel to one another. The extension direction of each carbon fiber is tilted with respect to the axial direction. The angle θ of the carbon fiber is -45°. The tensile elastic modulus E of the carbon fiber is 24 tf/mm². The width W of the prepreg 46 is 80 mm. The tilt direction of the carbon fiber of the second sheet group S2 is opposite to the tilt direction of the carbon fiber of the first sheet group S1. In the shaft 4, the first sheet group S1 and the second sheet group S2 form a bias structure.

[0029] Each of the third sheet group S3, the fifth sheet group S5, and the seventh sheet group S7 has a prepreg configuration of type A. The prepreg configuration of type A will be described later in detail. Each of the fourth sheet group S4, the sixth sheet group S6, and the eighth sheet group S8 has a prepreg configuration of type B. The prepreg configuration of type B will be described later in detail.

[0030] The ninth sheet group S9 includes a single prepreg 48. The prepreg 48 is present across the entire shaft 4. The shape of the prepreg 48 is substantially a rectangular shape. The prepreg 48 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0°. The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The width W of the prepreg 48 is 54 mm.

[0031] FIG. 7 is a development of the prepreg configuration of type A, and FIG. 8 is a schematic view of the prepreg configuration of type A. In this prepreg configuration, eight prepreps are provided. The width of each prepreg corresponds to 1/4 of the circumferential length of the shaft 4 at the position of the prepreg. The said width in the third sheet group S3 is about 4 mm, the said width in the fifth sheet group S5 is about 5 mm, and the said width in the seventh sheet group S7 is about 5 mm.

[0032] A prepreg A1 is present between the butt end 22 and a position apart from the butt end 22 by a distance of 240 mm. The shape of the prepreg A1 is substantially a rectangular shape. The prepreg A1 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg A1 is present in the first quarter Q1.

[0033] A prepreg A2 is present between the position apart from the butt end 22 by the distance of 240 mm and a position apart from the butt end 22 by a distance of 340 mm. The shape of the prepreg A2 is substantially a rectangular shape. The prepreg A2 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg A2 is present in the first quarter Q1.

[0034] A prepreg A3 is present between the butt end 22 and a position apart from the butt end 22 by a distance of 150 mm. The shape of the prepreg A3 is substantially a rectangular shape. The prepreg A3 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg A3 is present in the second quarter Q2.

[0035] A prepreg A4 is present between the position apart from the butt end 22 by the distance of 150 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg A4 is substantially a rectangular shape. The prepreg A4 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg A4 is present in the second quarter Q2.

[0036] A prepreg A5 is present between the butt end 22 and a position apart from the butt end 22 by the distance of 240 mm. The shape of the prepreg A5 is substantially a rectangular shape. The prepreg A5 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg A5 is present in the third quarter Q3.

[0037] A prepreg A6 is present between the position apart from the butt end 22 by the distance of 240 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg A6 is substantially a rectangular shape. The prepreg A6 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg A6 is present in the third quarter Q3.

[0038] A prepreg A7 is present between the butt end 22 and a position apart from the butt end 22 by the distance of 150 mm. The shape of the prepreg A7 is substantially a rectangular shape. The prepreg A7 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg A7 is present in the fourth quarter Q4.

[0039] A prepreg A8 is present between the position apart from the butt end 22 by the distance of 150 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg A8 is substantially a rectangular shape. The prepreg A8 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg A8 is present in the fourth quarter Q4.

[0040] FIG. 9 to FIG. 12 show the shaft 4. FIG. 9 to FIG. 12 each show a cross section of the third sheet group S3. The other sheet groups are not shown. The third sheet group S3 has the prepreg configuration of type A as described above.

[0041] As shown in FIG. 9 to FIG. 12, the prepreg A1 and the prepreg A2 are positioned in the first quarter Q1, the prepreg A3 and the prepreg A4 are positioned in the second quarter Q2, the prepreg A5 and the prepreg A6 are positioned in the third quarter Q3, and the prepreg A7 and the prepreg A8 are positioned in the fourth quarter Q4.

[0042] As shown in FIG. 9 to FIG. 12, the prepreg A1 is present from the butt 16 to the middle 18, the prepreg A2 is present at the tip 20, the prepreg A3 is present at the butt 16, the prepreg A4 is present from the middle 18 to the tip 20, the prepreg A5 is present from the butt 16 to the middle 18, the prepreg A6 is present at the tip 20, the prepreg A7 is present at the butt 16, and the prepreg A8 is present from the middle 18 to the tip 20.

[0043] FIG. 13 is a schematic view of the prepreg configuration of type B. In this prepreg configuration, eight prepreps are provided. The width of each prepreg corresponds to 1/4 of the circumferential length of the shaft 4 at the position of the prepreg. The said width in the fourth sheet group S4 is about 4 mm, the said width in the sixth sheet group S6 is

about 5 mm, and the said width in the eighth sheet group S8 is about 6 mm.

[0044] A prepreg B1 is present between the butt end 22 (see FIG. 2) and a position apart from the butt end 22 by the distance of 150 mm. The shape of the prepreg B1 is substantially a rectangular shape. The prepreg B1 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg B1 is present in the first quarter Q1.

[0045] A prepreg B2 is present between the position apart from the butt end 22 by the distance of 150 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg B2 is substantially a rectangular shape. The prepreg B2 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg B2 is present in the first quarter Q1.

[0046] A prepreg B3 is present between the butt end 22 and a position apart from the butt end 22 by the distance of 240 mm. The shape of the prepreg B3 is substantially a rectangular shape. The prepreg B3 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg B3 is present in the second quarter Q2.

[0047] A prepreg B4 is present between the position apart from the butt end 22 by the distance of 240 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg B4 is substantially a rectangular shape. The prepreg B4 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg B4 is present in the second quarter Q2.

[0048] A prepreg B5 is present between the butt end 22 and a position apart from the butt end 22 by the distance of 150 mm. The shape of the prepreg B5 is substantially a rectangular shape. The prepreg B5 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg B5 is present in the third quarter Q3.

[0049] A prepreg B6 is present between the position apart from the butt end 22 by the distance of 150 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg B6 is substantially a rectangular shape. The prepreg B6 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg B6 is present in the third quarter Q3.

[0050] A prepreg B7 is present between the butt end 22 and a position apart from the butt end 22 by the distance of 240 mm. The shape of the prepreg B7 is substantially a rectangular shape. The prepreg B7 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 7.4 tf/mm². The prepreg B7 is present in the fourth quarter Q4.

[0051] A prepreg B8 is present between the position apart from the butt end 22 by the distance of 240 mm and a position apart from the butt end 22 by the distance of 340 mm. The shape of the prepreg B8 is substantially a rectangular shape. The prepreg B8 includes a plurality of carbon fibers arranged so as to be parallel to one another. Each carbon fiber is positioned such that the extension direction thereof is the axial direction. The angle θ of the carbon fiber is 0° . The tensile elastic modulus E of the carbon fiber is 55 tf/mm². The prepreg B8 is present in the fourth quarter Q4.

[0052] The prepreg B1 and the prepreg B2 are positioned in the first quarter Q1, the prepreg B3 and the prepreg B4 are positioned in the second quarter Q2, the prepreg B5 and the prepreg B6 are positioned in the third quarter Q3, and the prepreg B7 and the prepreg B8 are positioned in the fourth quarter Q4.

[0053] The prepreg B1 is present at the butt 16, the prepreg B2 is present from the middle 18 to the tip 20, the prepreg B3 is present from the butt 16 to the middle 18, the prepreg B4 is present at the tip 20, the prepreg B5 is present at the butt 16, the prepreg B6 is present from the middle 18 to the tip 20, the prepreg B7 is present from the butt 16 to the middle 18, and the prepreg B8 is present at the tip 20.

[0054] In the prepreg configuration of type A, the prepregs A1, A2, A5, and A6 are apart from the center point SC (see FIG. 4) in the in-plane direction. In the prepreg configuration of type B, the prepregs B1, B2, B5, and B6 are apart from the center point SC in the in-plane direction. The tensile elastic moduli E of the carbon fibers included in the prepregs A1, A5, B1, and B5 are high, and the tensile elastic moduli E of the carbon fibers included in the prepregs A2, A6, B2, and B6 are low. The elastic modulus E of each carbon fiber influences the flexural rigidity of the shaft 4. The shaft 4 satisfies the following mathematical expression.

$$R_i B > R_i M > R_i T$$

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RiB: the flexural rigidity in the in-plane direction of the butt 16

RiM: the flexural rigidity in the in-plane direction of the middle 18

RiT: the flexural rigidity in the in-plane direction of the tip 20

[0055] In the prepreg configuration of type A, the prepregs A3, A4, A7, and A8 are apart from the center point SC in the out-of-plane direction. In the prepreg configuration of type B, the prepregs B3, B4, B7, and B8 are apart from the center point SC in the out-of-plane direction. The tensile elastic moduli E of the carbon fibers included in the prepregs A3, A7, B3, and B7 are low, and the tensile elastic moduli E of the carbon fibers included in the prepregs A4, A8, B4, and B8 are high. The elastic modulus E of each carbon fiber influences the flexural rigidity of the shaft 4. The shaft 4 satisfies the following mathematical expression.

$$RoB < RoM < RoT$$

RoB: the flexural rigidity in the out-of-plane direction of the butt 16

RoM: the flexural rigidity in the out-of-plane direction of the middle 18

RoT: the flexural rigidity in the out-of-plane direction of the tip 20

[0056] The shaft 4 further satisfies the following mathematical expression at the butt 16.

$$RiB > RoB$$

[0057] The shaft 4 further satisfies the following mathematical expression at the tip 20.

$$RiT < RoT$$

[0058] The tensile elastic modulus E in the present specification is measured according to the standard in "JIS R 7608". The tensile elastic modulus E is calculated on the basis of a change, in stress, that is made when an elongation rate is changed from 0.3% to 0.7%.

[0059] As is obvious from FIG. 6, the prepreg of each of the first sheet group S1, the second sheet group S2, and the ninth sheet group S9 is present from the butt end 22 to the tip end 24. These sheet groups can contribute to the durability of the shaft 4.

[0060] In production of the shaft 4, the sheets shown in FIG. 6 are sequentially wound around the mandrel. Another sheet may be wound around the mandrel along with these sheets. The other sheet is exemplified by a sheet including glass fibers. Wrapping tape is further wound around these sheets. The mandrel, the prepregs (of the sheet groups S1 to S9), and the wrapping tape are heated with an oven or the like. The heating causes the matrix resin to flow. Continued heating causes the resin to undergo a curing reaction, whereby a molded product is obtained. The molded product is subjected to processing such as end surface machining, polishing, and painting, whereby the shaft 4 is completed.

[0061] As described above, the material of the shaft 4 is a fiber-reinforced resin. The material of the shaft 4 may be a resin composition including no fibers. The material of the shaft 4 may be metal, wood, or the like.

[0062] FIG. 14 is a diagram for explaining a measurement method for a natural frequency in the out-of-plane direction of the racket 2 in FIG. 1. In this method, the racket 2 is hung with a cord 50. The racket 2 does not include the strings 14 (see FIG. 1). In other words, the racket 2 in a state of including no string 14 is used for measuring the natural frequency of the racket 2. In FIG. 14, the axial direction (Y direction) of the shaft 4 matches with the vertical direction. In FIG. 14, the frame 6 is positioned above the shaft 4.

[0063] As shown in FIG. 14, an acceleration pickup device 52 is attached to the racket 2. The acceleration pickup device 52 is positioned at an upper end of the grip 12. The acceleration pickup device 52 is oriented in the Z direction. The acceleration pickup device 52 has a mass of 3.5 g. The grip 12 has a point Ph on the opposite side to the acceleration pickup device 52 and is vibrated at the point Ph by using an impact hammer (not shown). Input vibrations measured by a force pickup device of the impact hammer and response vibrations measured by the acceleration pickup device 52 are transmitted via an amplifier to a frequency analyzer ("Dynamic Signal Analyzer" available from Hewlett Packard Enterprise Company). An out-of-plane natural frequency is calculated on the basis of a transfer function obtained by this analyzer. The direction of out-of-plane natural vibrations is mainly the Z direction. In this method, the natural frequency is measured in a state where no firm fixation is performed at any portion of the racket 2. In other words, the out-of-plane natural frequency is measured under a condition of restricting the racket 2 so as to maintain freedom thereof.

[0064] FIG. 15 is a graph showing a result obtained through the measurement in FIG. 14. In FIG. 15, the horizontal axis indicates frequency (Hz), and the vertical axis indicates accelerance ($\text{m/s}^2/\text{N}$). In FIG. 15, a point indicated by a reference character P1 is a primary peak. A frequency at the primary peak P1 is an out-of-plane primary natural frequency ω_1 . In FIG. 15, a point indicated by a reference character P2 is a secondary peak. A frequency at the secondary peak P2 is an out-of-plane secondary natural frequency ω_2 .

[0065] FIG. 16 is a diagram for explaining a measurement method for a frequency of natural vibrations in the in-plane direction of the racket 2. In this measurement method, the racket 2 is hung with the cord 50 in the same manner as in the measurement method shown in FIG. 14. As shown in FIG. 16, the acceleration pickup device 52 is oriented in the X direction. The grip 12 has a point Ph opposed to the acceleration pickup device 52 and is vibrated at the point Ph by using the impact hammer (not shown). Input vibrations measured by the force pickup device of the impact hammer and response vibrations measured by the acceleration pickup device 52 are transmitted via the amplifier to the frequency analyzer ("Dynamic Signal Analyzer" available from Hewlett Packard Enterprise Company). A frequency of in-plane natural vibrations is calculated on the basis of a transfer function obtained by this analyzer. The direction of the in-plane natural vibrations is mainly the X direction. In this method, the in-plane natural frequency is measured under a condition of restricting the racket 2 so as to maintain freedom thereof.

[0066] FIG. 17 is a graph showing a result obtained through the measurement in FIG. 16. In FIG. 17, the horizontal axis indicates frequency (Hz), and the vertical axis indicates accelerance ($\text{m/s}^2/\text{N}$). In FIG. 17, a point indicated by a reference character P1 is a primary peak. A frequency at the primary peak P1 is an in-plane primary natural frequency ω_1 . In FIG. 17, a point indicated by a reference character P2 is a secondary peak. A frequency at the secondary peak P2 is an in-plane secondary natural frequency ω_2 .

[0067] FIG. 18 is a graph showing a relationship between a ratio (ω_2/ω_1) and a ratio (ω_i2/ω_i1) of the badminton racket 2. In this graph, a reference character Pr indicates a point regarding the racket 2 shown in FIG. 1 to FIG. 13.

[0068] In FIG. 18, a straight line indicated by a reference character L1 can be expressed with the following mathematical expression.

$$(\omega_i2/\omega_i1)=1.3*(\omega_2/\omega_1)-0.2$$

[0069] As shown in FIG. 18, the point Pr is positioned above the straight line L1. In other words, coordinates ((ω_2/ω_1) , (ω_i2/ω_i1)) regarding the racket 2 satisfy the following mathematical expression (1).

$$(\omega_i2/\omega_i1) \geq 1.3*(\omega_2/\omega_1)-0.2 \quad (1)$$

[0070] According to a finding obtained by the present inventor, the racket 2 satisfying the mathematical expression (1) is suitable for smashes and lobs with cuts. A player who hits smashes or lobs with cuts by using this racket 2 easily obtains an intended trajectory of a shuttlecock. With this racket 2, a variation among the trajectories of shuttlecocks at the time of smashes is small, and a variation among the trajectories of shuttlecocks at the time of lobs with cuts is also small.

[0071] In the badminton racket 2 satisfying the above mathematical expression, the ratio (ω_2/ω_1) between the frequencies in the out-of-plane direction is relatively low, and the ratio (ω_i2/ω_i1) between the frequencies in the in-plane direction is relatively high.

[0072] According to a finding obtained by the present inventor regarding vibrations in the out-of-plane direction, the out-of-plane secondary natural frequency is mainly generated when a shuttlecock is struck at a portion of the face 36 that is located near the bottom 28. According to a finding obtained by the present inventor, the out-of-plane primary natural frequency is mainly generated when a shuttlecock is struck at a portion of the face 36 that is located near the top 26. The typical hitting points for smashes are located near the bottom 28. Therefore, out-of-plane secondary natural vibrations are mainly generated upon smashes. However, there is a variation also among hitting points for smashes. In the racket 2 having a low ratio (ω_2/ω_1), the out-of-plane primary natural frequency ω_1 is relatively high, and the out-of-plane secondary natural frequency ω_2 is relatively low. According to a finding obtained by the present inventor, smashes hit with the racket 2 having a high out-of-plane primary natural frequency ω_1 and a low out-of-plane secondary natural frequency ω_2 lead to a variation among hitting points but lead to a small variation among the initial velocities of the shuttlecocks. The reason for this is because bounce on the racket 2 does not become extremely low even when a shuttlecock is struck at a position away from an intended position. Since the variation among the initial velocities of the shuttlecocks is small, the variation among the trajectories of the shuttlecocks is also small. This racket 2 is suitable for being used by a player who frequently hits smashes. This racket 2 is also suitable for being used by a player who places importance on smashes.

[0073] As described above, the typical hitting points for smashes are located near the bottom 28. This racket 2 is also suitable for shots, other than smashes, upon each of which a shuttlecock is struck at a portion of the face 36 that is

located near the bottom 28.

[0074] According to a finding obtained by the present inventor regarding vibrations in the in-plane direction, in-plane secondary mode vibrations are mainly generated when a shuttlecock is struck at a portion of the face 36 that is located near the bottom 28. According to a finding obtained by the present inventor, in-plane primary mode vibrations are mainly generated when a shuttlecock is struck at a portion of the face 36 that is located near the top 26. The typical hitting points for lobs with cuts are located near the top 26. Therefore, in-plane primary mode vibrations are mainly generated upon lobs with cuts. However, there is a variation also among hitting points for lobs with cuts. In the racket 2 having a high ratio (ω_i2/ω_i1), the in-plane primary natural frequency ω_i1 is relatively low, and the in-plane secondary natural frequency ω_i2 is relatively high. According to a finding obtained by the present inventor, lobs with cuts hit with the racket 2 having a low in-plane primary natural frequency ω_i1 and a high in-plane secondary natural frequency ω_i2 lead to a variation among hitting points but lead to a small variation among the initial velocities of the shuttlecocks. The reason for this is because bounce on the racket 2 does not become extremely low even when a shuttlecock is struck at a position away from an intended position. Since the variation among the initial velocities of the shuttlecocks is small, the variation among the trajectories of the shuttlecocks is also small. This racket 2 is suitable for being used by a player who frequently hits lobs with cuts. This racket 2 is also suitable for being used by a player who places importance on lobs with cuts.

[0075] As described above, the typical hitting points for lobs with cuts are located near the top 26. This racket 2 is also suitable for shots, other than lobs with cuts, which involve cutting and upon each of which a shuttlecock is struck at a portion of the face 36 that is located near the top 26.

[0076] As described above, in the shaft 4, the flexural rigidity in the in-plane direction of the tip 20 is lower than the flexural rigidity in the in-plane direction of the butt 16, and the flexural rigidity in the out-of-plane direction of the tip 20 is higher than the flexural rigidity in the out-of-plane direction of the butt 16. In the badminton racket 2 including this shaft 4, the above mathematical expression (1) can be satisfied.

[0077] Examples of another means for satisfying the above mathematical expression (1) include adjustment of a rigidity distribution of the frame 6. If a portion of the frame 6 that is located near the bottom 28 has a high flexural rigidity in the in-plane direction and a low flexural rigidity in the out-of-plane direction, the frame 6 can contribute to satisfaction of the above mathematical expression (1).

[0078] Still another means for satisfying the above mathematical expression (1) is exemplified by: adjustment of a rigidity distribution of the entire racket 2; adjustment of a mass distribution of the shaft 4; adjustment of a mass distribution of the frame 6; adjustment of a mass distribution of the entire racket 2; adjustment of a volume distribution of the shaft 4; adjustment of a volume distribution of the frame 6; and adjustment of a volume distribution of the entire racket 2.

[0079] From the viewpoint of suitability for smashes and lobs with cuts, the racket 2 more preferably satisfies the following mathematical expression.

$$(\omega_i2/\omega_i1) \geq 1.3 * (\omega_o2/\omega_o1) - 0.1$$

[0080] From the viewpoint of suitability for smashes and lobs with cuts, the racket 2 particularly preferably satisfies the following mathematical expression.

$$(\omega_i2/\omega_i1) \geq 1.3 * (\omega_o2/\omega_o1) + 0.1$$

[0081] In FIG. 18, a straight line indicated by a reference character L2 can be expressed with the following mathematical expression.

$$(\omega_i2/\omega_i1) = 1.11 * (\omega_o2/\omega_o1) + 0.391$$

[0082] As shown in FIG. 18, the point Pr is positioned above the straight line L2. In other words, the coordinates $((\omega_o2/\omega_o1), (\omega_i2/\omega_i1))$ regarding the racket 2 satisfy the following mathematical expression (2).

$$(\omega_i2/\omega_i1) \geq 1.11 * (\omega_o2/\omega_o1) + 0.391 \quad (2)$$

[0083] According to a finding obtained by the present inventor, the racket 2 satisfying the mathematical expression (2) is suitable for smashes and lobs with cuts. A player who hits smashes or lobs with cuts by using this racket 2 easily obtains an intended trajectory of a shuttlecock. With this racket 2, a variation among the trajectories of shuttlecocks at the time of smashes is small, and a variation among the trajectories of shuttlecocks at the time of lobs with cuts is also small.

[0084] In FIG. 18, a straight line indicated by a reference character L3 can be expressed with the following mathematical expression.

$$(\omega_{i2}/\omega_{i1})=2.5*(\omega_{o2}/\omega_{o1})-3.42$$

[0085] As shown in FIG. 18, the point Pr is positioned on the straight line L3. In other words, coordinates $((\omega_{o2}/\omega_{o1}), (\omega_{i2}/\omega_{i1}))$ regarding the racket 2 satisfy the following mathematical expression (3).

$$(\omega_{i2}/\omega_{i1})\geq 2.5*(\omega_{o2}/\omega_{o1})-3.42 \quad (3)$$

[0086] According to a finding obtained by the present inventor, the racket 2 satisfying the mathematical expression (3) is suitable for smashes and lobs with cuts. A player who hits smashes or lobs with cuts by using this racket 2 easily obtains an intended trajectory of a shuttlecock. With this racket 2, a variation among the trajectories of shuttlecocks at the time of smashes is small, and a variation among the trajectories of shuttlecocks at the time of lobs with cuts is also small.

[0087] In FIG. 18, a straight line indicated by a reference character L4 can be expressed with the following mathematical expression.

$$(\omega_{o2}/\omega_{o1})=2.99$$

[0088] As shown in FIG. 18, the point Pr is positioned on the left side relative to the straight line L4. In other words, the ratio $(\omega_{o2}/\omega_{o1})$ at the point Pr is not higher than 2.99. This racket 2 is suitable for smashes. From this viewpoint, the ratio $(\omega_{o2}/\omega_{o1})$ is more preferably not higher than 2.95 and particularly preferably not higher than 2.94. Meanwhile, the ratio $(\omega_{o2}/\omega_{o1})$ is preferably not lower than 2.50.

[0089] In FIG. 18, a straight line indicated by a reference character L5 can be expressed with the following mathematical expression.

$$(\omega_{i2}/\omega_{i1})=3.61$$

[0090] As shown in FIG. 18, the point Pr is positioned above the straight line L5. In other words, the ratio $(\omega_{i2}/\omega_{i1})$ at the point Pr is not lower than 3.61. This racket 2 is suitable for lobs with cuts. From this viewpoint, the ratio $(\omega_{i2}/\omega_{i1})$ is more preferably not lower than 3.65 and particularly preferably not lower than 3.68. Meanwhile, the ratio $(\omega_{i2}/\omega_{i1})$ is preferably not higher than 4.3.

[0091] Hereinafter, a preferable specification decision method for the badminton racket 2 will be described. The specification decision method includes the steps of:

(A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;

(B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not the aforementioned mathematical expression (1) is satisfied; and

(C) deciding, if the mathematical expression (1) is not satisfied, a characteristic of the shaft 4 or the frame 6 of a target racket 2 such that the target racket 2 has a lower ratio $(\omega_{o2}/\omega_{o1})$ than the standard racket.

[0092] The characteristic to be decided in the step (C) is exemplified by a length of the shaft 4, a thickness of the shaft 4, a rigidity of the shaft 4, a rigidity distribution of the shaft 4, a length of the frame 6, a thickness of the frame 6, a rigidity of the frame 6, and a rigidity distribution of the frame 6.

[0093] Another preferable specification decision method includes the steps of:

(A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;

(B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not the aforementioned mathematical expression (1) is satisfied; and

(C) deciding, if the aforementioned mathematical expression (1) is not satisfied, a characteristic of the shaft 4 or the

frame 6 of a target racket 2 such that the target racket 2 has a higher ratio (ω_2/ω_1) than the standard racket.

[0094] The characteristic to be decided in the step (C) is exemplified by a length of the shaft 4, a thickness of the shaft 4, a rigidity of the shaft 4, a rigidity distribution of the shaft 4, a length of the frame 6, a thickness of the frame 6, a rigidity of the frame 6, and a rigidity distribution of the frame 6.

EXAMPLES

[0095] Hereinafter, advantageous effects of badminton rackets in examples will be clarified, but the scope disclosed in the present specification should not be interpreted as being limited to the examples.

[Example 1]

[0096] A badminton racket shown in FIG. 1 to FIG. 13 was produced. The racket had an out-of-plane primary natural frequency ω_1 of 59 Hz, an out-of-plane secondary natural frequency ω_2 of 172 Hz, an in-plane primary natural frequency ω_1 of 51 Hz, and an in-plane secondary natural frequency ω_2 of 200 Hz. The coordinates regarding the racket are indicated by the reference character Pr in FIG. 18.

[Example 2]

[0097] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. In the shaft, a prepreg configuration of type C was employed for the sheet groups S3 to S8. Further, in the shaft, a prepreg having a width of 54 mm was used for the ninth sheet group S9. The prepreg configuration of type C is shown in FIG. 19.

[Example 3]

[0098] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. In the shaft, the following types of prepreg configurations were employed.

Third sheet group S3: type D
Fourth sheet group S4: type E
Fifth sheet group S5: type F
Sixth sheet group S6: type G
Seventh sheet group S7: type H
Eighth sheet group S8: type G

[0099] These types of prepreg configurations are shown in FIG. 20 to FIG. 24. Further, in the shaft, a prepreg in which the elastic modulus of each fiber was 16 tf/mm² was used for the ninth sheet group S9.

[Example 4]

[0100] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. In the shaft, a prepreg in which the elastic modulus of each fiber was 30 tf/mm² was used for each of the first sheet group S1 and the second sheet group S2. In the shaft, the following types of prepreg configurations were employed.

Third sheet group S3: type I
Fourth sheet group S4: type I
Fifth sheet group S5: type I
Sixth sheet group S6: type I
Seventh sheet group S7: type J
Eighth sheet group S8: type K

[0101] These types of prepreg configurations are shown in FIG. 25 to FIG. 27. Further, in the shaft, a prepreg in which the elastic modulus of each fiber was 30 tf/mm² was used for the ninth sheet group S9.

[Comparative Example 1]

[0102] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. This prepreg configuration is shown in FIG. 28.

[Comparative Example 2]

[0103] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. This prepreg configuration is shown in FIG. 29.

[Comparative Example 3]

[0104] A badminton racket was obtained in the same manner as in example 1, except that the prepreg configuration of a shaft of the badminton racket was changed. This prepreg configuration is shown in FIG. 30.

[Smash]

[0105] A shuttlecock was shot from a shuttlecock shooting machine. A player was asked to strike the shuttlecock so as to hit a smash, and the trajectory of the shuttlecock was imaged. Images were analyzed, and the height of the shuttlecock passing over a net was measured. The measurement was performed 20 times, and a standard deviation among heights obtained through the 20 times of the measurement was obtained. The given racket was rated on the basis of the standard deviation. Criteria for the rating are as follows. The results of the rating are indicated in Tables 1 and 2 presented below.

- 3: the standard deviation being smaller than 0.06 m
- 2: the standard deviation being not smaller than 0.06 m and smaller than 0.10 m
- 1: the standard deviation being not smaller than 0.10 m

[Lob with Cut]

[0106] A shuttlecock was shot from the shuttlecock shooting machine. A player was asked to strike the shuttlecock to hit a lob with a cut, and the trajectory of the shuttlecock was imaged. Images were analyzed, and the height of the shuttlecock passing over the net was measured. The measurement was performed 20 times, and a standard deviation among heights obtained through the 20 times of the measurement was obtained. The given racket was rated on the basis of the standard deviation. Criteria for the rating are as follows. The results of the rating are indicated in Tables 1 and 2 presented below.

- 3: the standard deviation being smaller than 0.14 m
- 2: the standard deviation being not smaller than 0.14 m and smaller than 0.20 m
- 1: the standard deviation being not smaller than 0.20 m

[Table 1] Evaluation Results

	Example 1	Example 2	Example 3	Example 4
ω_{o1} [Hz]	59	65	58	65
ω_{o2} [Hz]	172	185	173	187
ω_{i1} [Hz]	51	54	54	58
ω_{i2} [Hz]	200	198	199	209
ω_{o2}/ω_{o1}	2.94	2.84	2.99	2.90
ω_{i2}/ω_{i1}	3.93	3.68	3.71	3.61
Smash	2	3	2	2
Lob with cut	3	2	2	2

[Table 2] Evaluation Results

	Comparative example 1	Comparative example 2	Comparative example 3
ω_{o1} [Hz]	57	66	64
ω_{o2} [Hz]	174	190	190
ω_{i1} [Hz]	56	65	62
ω_{i2} [Hz]	198	224	220
ω_{o2}/ω_{o1}	3.03	2.88	2.97
ω_{i2}/ω_{i1}	3.52	3.45	3.55
Smash	1	3	2
Lob with cut	1	1	1

[0107] As is obvious from Tables 1 and 2, the badminton racket in each example was evaluated as "3" or "2" regarding stability of smash and was evaluated as "3" or "2" regarding stability of lob with cut. Meanwhile, the racket in each comparative example was evaluated as "1" regarding both or either of stability of smash and stability of lob with cut. From the results, superiority of the badminton racket of the present disclosure is obvious.

[Disclosed Aspects]

[0108] The following aspects are disclosed as preferred embodiments.

[Aspect 1]

[0109] A badminton racket including:

a shaft including a butt and a tip;
 a grip attached to the butt of the shaft; and
 a frame attached to the tip of the shaft, wherein
 a ratio (ω_{o2}/ω_{o1}) of an out-of-plane secondary natural frequency ω_{o2} (Hz) to an out-of-plane primary natural frequency ω_{o1} (Hz), and a ratio (ω_{i2}/ω_{i1}) of an in-plane secondary natural frequency ω_{i2} (Hz) to an in-plane primary natural frequency ω_{i1} (Hz), satisfy the following mathematical expression (1),

$$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2 \quad (1).$$

[Aspect 2]

[0110] The badminton racket according to aspect 1, wherein the ratio (ω_{o2}/ω_{o1}) and the ratio (ω_{i2}/ω_{i1}) satisfy the following mathematical expression (2),

$$(\omega_{i2}/\omega_{i1}) \geq 1.11 * (\omega_{o2}/\omega_{o1}) + 0.391 \quad (2).$$

[Aspect 3]

[0111] The badminton racket according to aspect 1, wherein the ratio (ω_{o2}/ω_{o1}) and the ratio (ω_{i2}/ω_{i1}) satisfy the following mathematical expression (3),

$$(\omega_{i2}/\omega_{i1}) \geq 2.5 * (\omega_{o2}/\omega_{o1}) - 3.42 \quad (3).$$

[Aspect 4]

[0112] The badminton racket according to any one of aspects 1 to 3, wherein the ratio (ω_{o2}/ω_{o1}) is not higher than 2.99.

[Aspect 5]

[0113] The badminton racket according to any one of aspects 1 to 4, wherein the ratio (ω_{i2}/ω_{i1}) is not lower than 3.61.

[Aspect 6]

[0114] The badminton racket according to any one of aspects 1 to 5, wherein a material of the shaft is a fiber-reinforced resin including a plurality of reinforcing fibers.

[Aspect 7]

[0115] The badminton racket according to aspect 6, wherein, at the butt, a tensile elastic modulus of any of the reinforcing fibers that is included in a zone apart in an in-plane direction from a center point of the shaft is higher than a tensile elastic modulus of any of the reinforcing fibers that is included in a zone apart in an out-of-plane direction from the center point of the shaft.

[Aspect 8]

[0116] The badminton racket according to aspect 6 or 7, wherein, at the tip, a tensile elastic modulus of any of the reinforcing fibers that is included in a zone apart in an in-plane direction from a center point of the shaft is lower than a tensile elastic modulus of any of the reinforcing fibers that is included in a zone apart in an out-of-plane direction from the center point of the shaft.

[Aspect 9]

[0117] The badminton racket according to any one of aspects 6 to 8, wherein, in a zone apart in an in-plane direction from a center point of the shaft, a tensile elastic modulus of any of the reinforcing fibers that is included in the butt is higher than a tensile elastic modulus of any of the reinforcing fibers that is included in the tip.

[Aspect 10]

[0118] The badminton racket according to any one of aspects 6 to 9, wherein, in a zone apart in an out-of-plane direction from a center point of the shaft, a tensile elastic modulus of any of the reinforcing fibers that is included in the butt is lower than a tensile elastic modulus of any of the reinforcing fibers that is included in the tip.

[Aspect 11]

[0119] A specification decision method for a badminton racket, the badminton racket comprising

a shaft including a butt and a tip,
a grip attached to the butt of the shaft, and
a frame attached to the tip of the shaft,
the specification decision method comprising the steps of:

- (A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;
- (B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not a mathematical expression (1) indicated below is satisfied; and
- (C) deciding, if the mathematical expression (1) indicated below is not satisfied, a characteristic of the shaft or the frame of a target racket such that the target racket has a lower ratio (ω_{o2}/ω_{o1}) than the standard racket,

$$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2 \quad (1).$$

[Aspect 12]

[0120] A specification decision method for a badminton racket, the badminton racket comprising

a shaft including a butt and a tip,
 a grip attached to the butt of the shaft, and
 a frame attached to the tip of the shaft,
 the specification decision method comprising the steps of:

- (A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;
 (B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not a mathematical expression (1) indicated below is satisfied; and
 (C) deciding, if the mathematical expression (1) indicated below is not satisfied, a characteristic of the shaft or the frame of a target racket such that the target racket has a higher ratio (ω_{i2}/ω_{i1}) than the standard racket,

$$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2 \quad (1).$$

[0121] The aforementioned badminton racket is suitable for being used by a player with a style of frequently hitting smashes and lobs with cuts. This racket is also suitable for being used by a player with a style of frequently hitting: another type of shot that is to be hit at a hitting point near the bottom; and still another type of shot that is to be hit at a hitting point near the top and that involves a cut.

Claims

1. A badminton racket (2) comprising:

a shaft (4) including a butt (16) and a tip (20);
 a grip (12) attached to the butt (16) of the shaft (4); and
 a frame (6) attached to the tip (20) of the shaft (4), wherein
 a ratio (ω_{o2}/ω_{o1}) of an out-of-plane secondary natural frequency ω_{o2} (Hz) to an out-of-plane primary natural frequency ω_{o1} (Hz), and a ratio (ω_{i2}/ω_{i1}) of an in-plane secondary natural frequency ω_{i2} (Hz) to an in-plane primary natural frequency ω_{i1} (Hz), satisfy the following mathematical expression (1),

$$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2 \quad (1).$$

2. The badminton racket (2) according to claim 1, wherein the ratio (ω_{o2}/ω_{o1}) and the ratio (ω_{i2}/ω_{i1}) satisfy the following mathematical expression (2),

$$(\omega_{i2}/\omega_{i1}) \geq 1.11 * (\omega_{o2}/\omega_{o1}) + 0.391 \quad (2).$$

3. The badminton racket (2) according to claim 1, wherein the ratio (ω_{o2}/ω_{o1}) and the ratio (ω_{i2}/ω_{i1}) satisfy the following mathematical expression (3),

$$(\omega_{i2}/\omega_{i1}) \geq 2.5 * (\omega_{o2}/\omega_{o1}) - 3.42 \quad (3).$$

4. The badminton racket (2) according to any one of claims 1 to 3, wherein the ratio (ω_{o2}/ω_{o1}) is not higher than 2.99.

5. The badminton racket (2) according to any one of claims 1 to 4, wherein the ratio (ω_{i2}/ω_{i1}) is not lower than 3.61.

6. The badminton racket (2) according to any one of claims 1 to 5, wherein a material of the shaft (4) is a fiber-reinforced resin including a plurality of reinforcing fibers (40).

7. The badminton racket (2) according to claim 6, wherein, at the butt (16), a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in a zone (Q1, Q3) apart in an in-plane direction (X) from a center point (SC) of the shaft (4) is higher than a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in a zone (Q2, Q4) apart in an out-of-plane direction (Z) from the center point (SC) of the shaft (4).

8. The badminton racket (2) according to claim 6 or 7, wherein, at the tip (20), a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in a zone (Q1, Q3) apart in an in-plane direction (X) from a center point (SC) of the shaft (4) is lower than a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in a zone (Q2, Q4) apart in an out-of-plane direction (Z) from the center point (SC) of the shaft (4).

9. The badminton racket (2) according to any one of claims 6 to 8, wherein, in a zone (Q1, Q3) apart in an in-plane direction (X) from a center point (SC) of the shaft (4), a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in the butt (16) is higher than a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in the tip (20).

10. The badminton racket (2) according to any one of claims 6 to 9, wherein, in a zone (Q2, Q4) apart in an out-of-plane direction (Z) from a center point (SC) of the shaft (4), a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in the butt (16) is lower than a tensile elastic modulus (E) of any of the reinforcing fibers (40) that is included in the tip (20).

11. The badminton racket (2) according to any one of claims 1 to 10, wherein the out-of-plane primary natural frequency ω_{o1} is selected in the range of 55 to 70 Hz, especially in the range of 57 to 66 Hz; and/or wherein the out-of-plane secondary natural frequency ω_{o2} is selected in the range of 165 Hz to 195 Hz, especially in the range of 171 Hz to 188 Hz.

12. The badminton racket (2) according to any one of claims 1 to 11, wherein the in-plane primary natural frequency ω_{i1} is selected in the range of 45 to 60 Hz, especially in the range of 50 to 60 Hz; and/or wherein the in-plane secondary natural frequency ω_{i2} is selected in the range of 190 to 220 Hz, especially in the range of 195 to 215 Hz.

13. The badminton racket (2) according to any one of claims 6 to 12, wherein, in the shaft, an elastic modulus of each fiber of a prepreg is selected in the range of 10 to 35 tf/mm²; and/or wherein a tensile elastic modulus E of a carbon fiber of the badminton racket is selected in the range of 5 to 60 tf/mm², especially in the range of 7 to 56 tf/mm².

14. A specification decision method for a badminton racket (2), the badminton racket (2) comprising

a shaft (4) including a butt (16) and a tip (20),
a grip (12) attached to the butt (16) of the shaft (4), and
a frame (6) attached to the tip (20) of the shaft (4),
the specification decision method comprising the steps of:

(A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;

(B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not a mathematical expression (1) indicated below is satisfied; and

(C) deciding, if the mathematical expression (1) indicated below is not satisfied, a characteristic of the shaft (4) or the frame (6) of a target racket (2) such that the target racket (2) has a lower ratio (ω_{o2}/ω_{o1}) than the standard racket,

$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2$ (1), optionally wherein the badminton racket is in accordance with any one of claims 1 to 13.

15. A specification decision method for a badminton racket (2), the badminton racket (2) comprising

a shaft (4) including a butt (16) and a tip (20),
a grip (12) attached to the butt (16) of the shaft (4), and
a frame (6) attached to the tip (20) of the shaft (4),
the specification decision method comprising the steps of:

(A) measuring an out-of-plane primary natural frequency ω_{o1} (Hz), an out-of-plane secondary natural frequency ω_{o2} (Hz), an in-plane primary natural frequency ω_{i1} (Hz), and an in-plane secondary natural frequency ω_{i2} (Hz) of a standard racket;

(B) determining, on the basis of these natural frequencies ω_{o1} , ω_{o2} , ω_{i1} , and ω_{i2} , whether or not a mathematical expression (1) indicated below is satisfied; and

(C) deciding, if the mathematical expression (1) indicated below is not satisfied, a characteristic of the shaft (4) or the frame (6) of a target racket (2) such that the target racket (2) has a higher ratio (ω_{i2}/ω_{i1}) than the standard racket,

$(\omega_{i2}/\omega_{i1}) \geq 1.3 * (\omega_{o2}/\omega_{o1}) - 0.2$ (1), optionally wherein the badminton racket is in accordance with any one of claims 1 to 13.

Fig.1

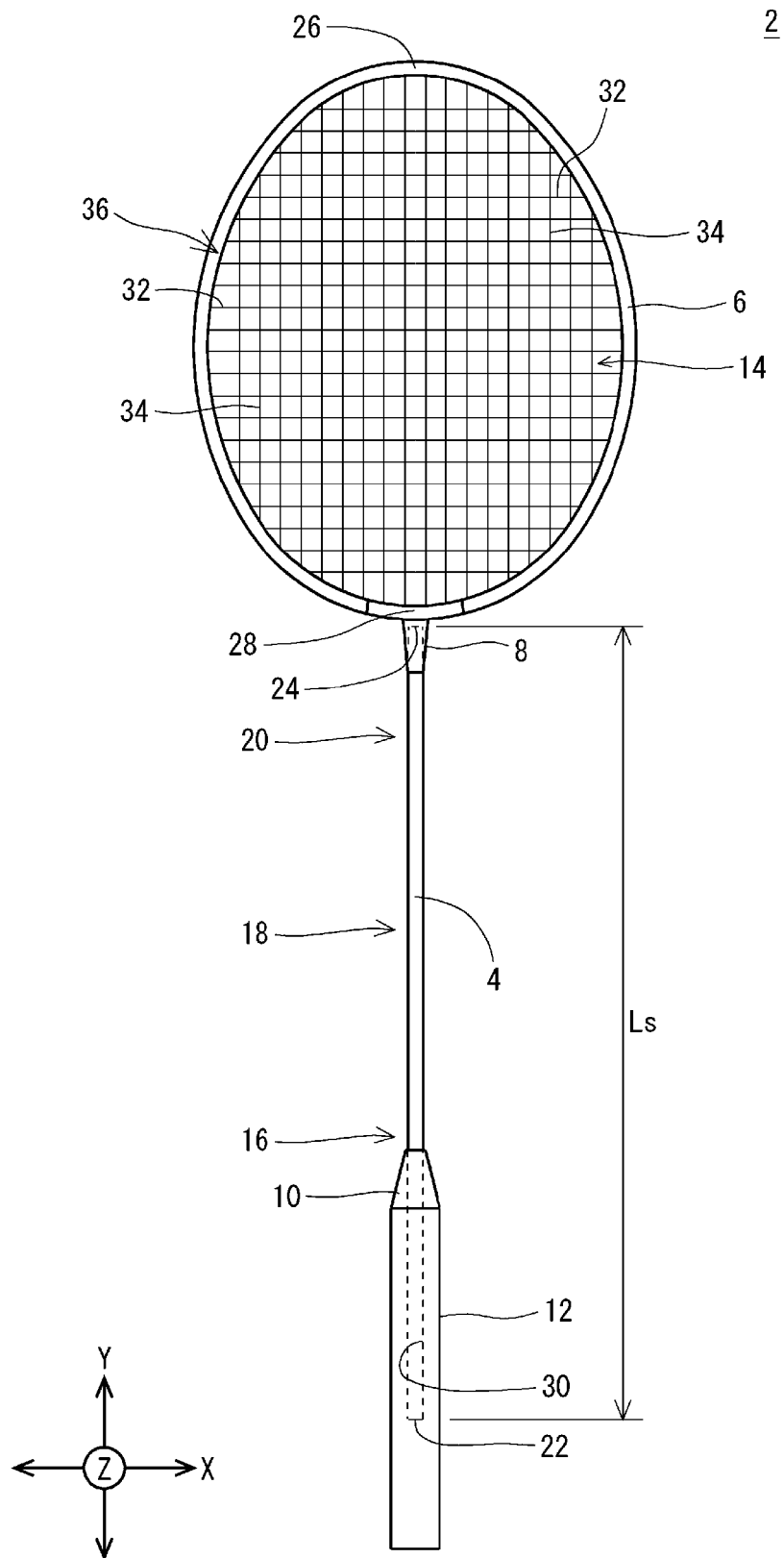


Fig.2

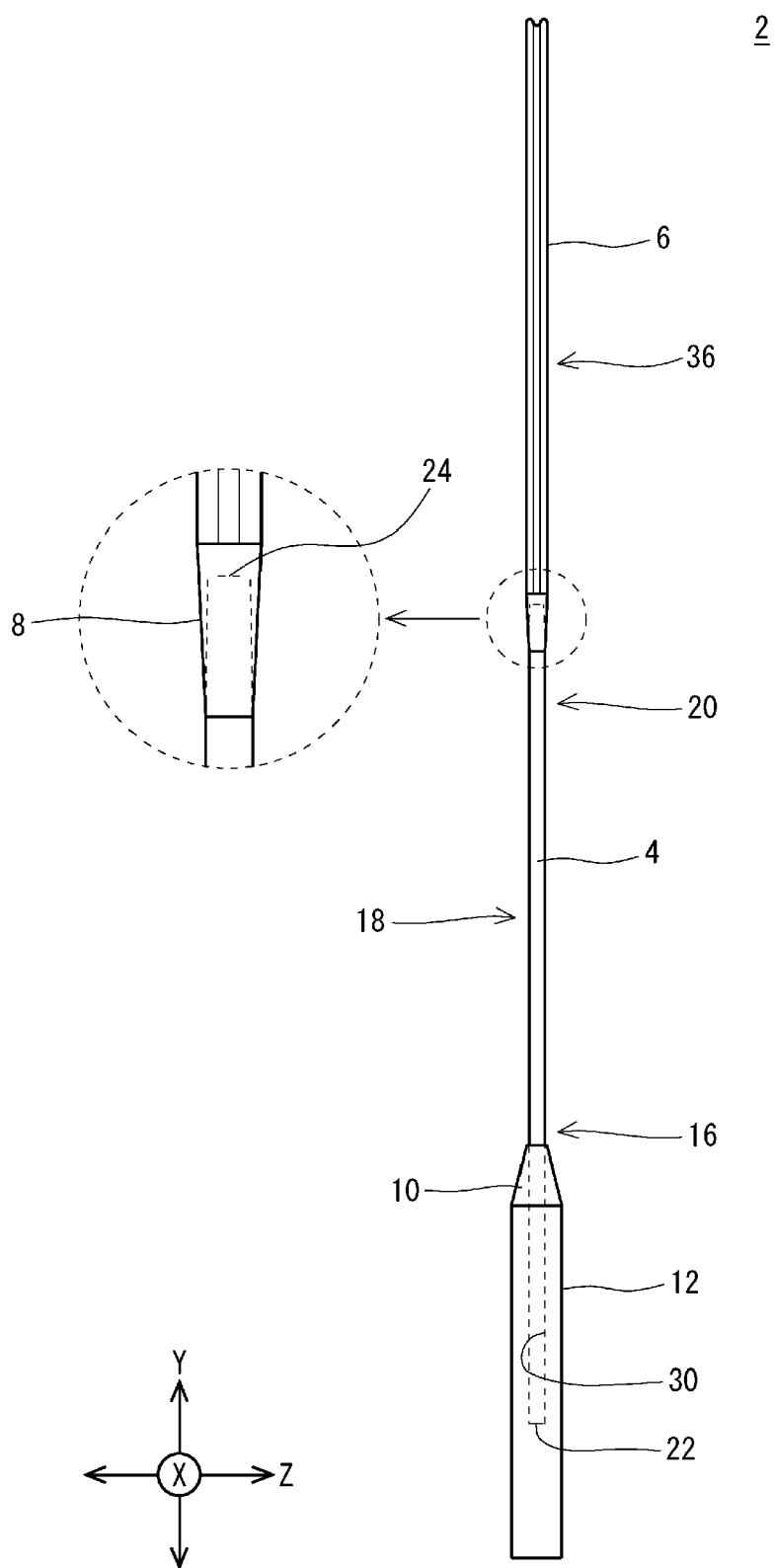


Fig.3

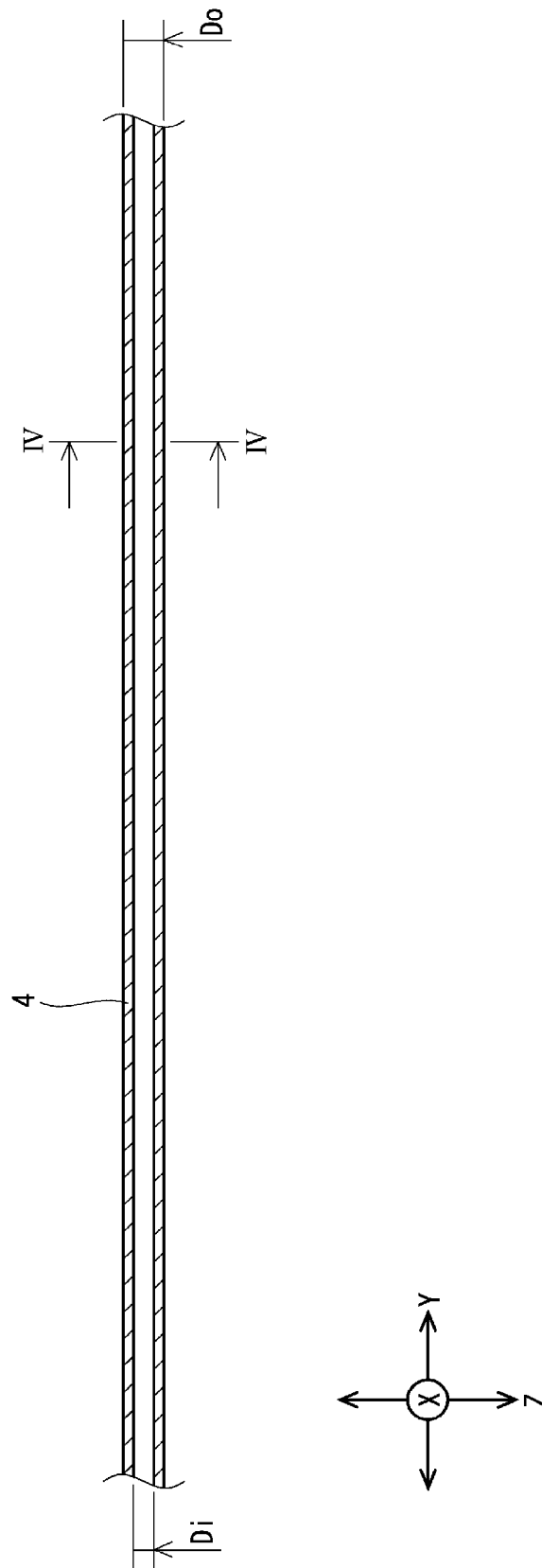


Fig.4

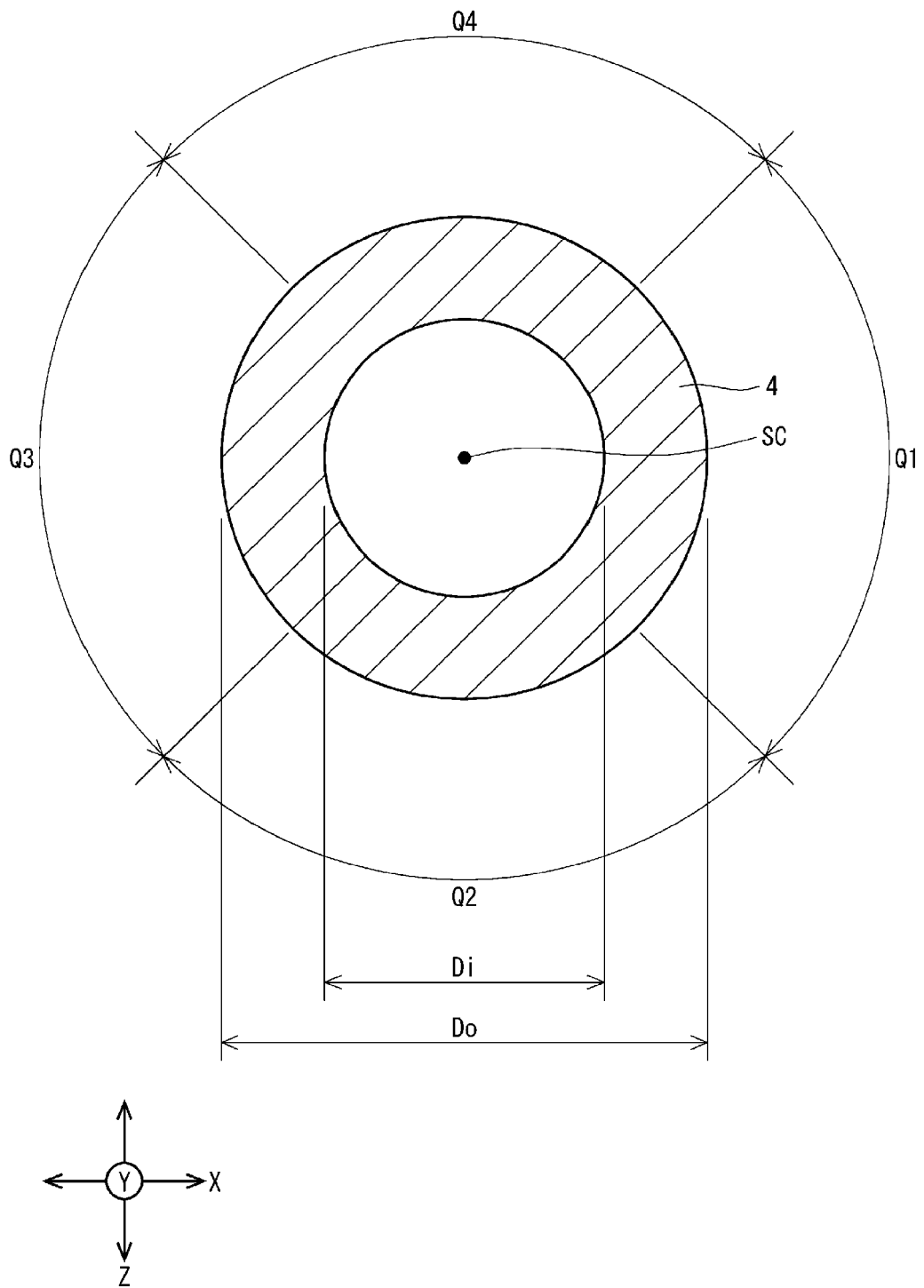


Fig.5

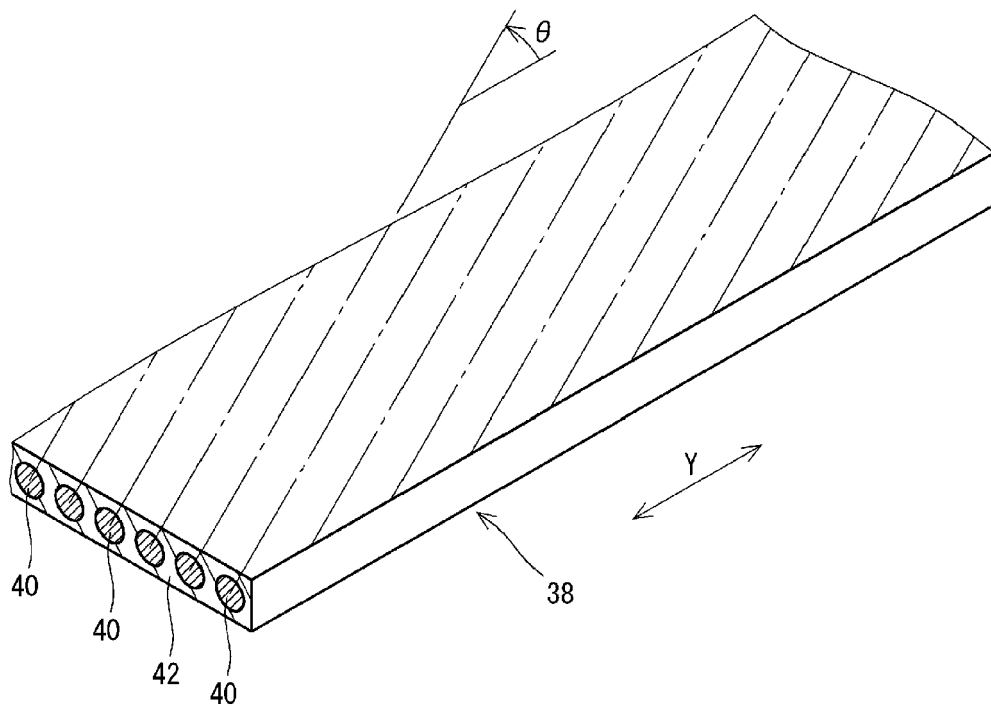


Fig.6

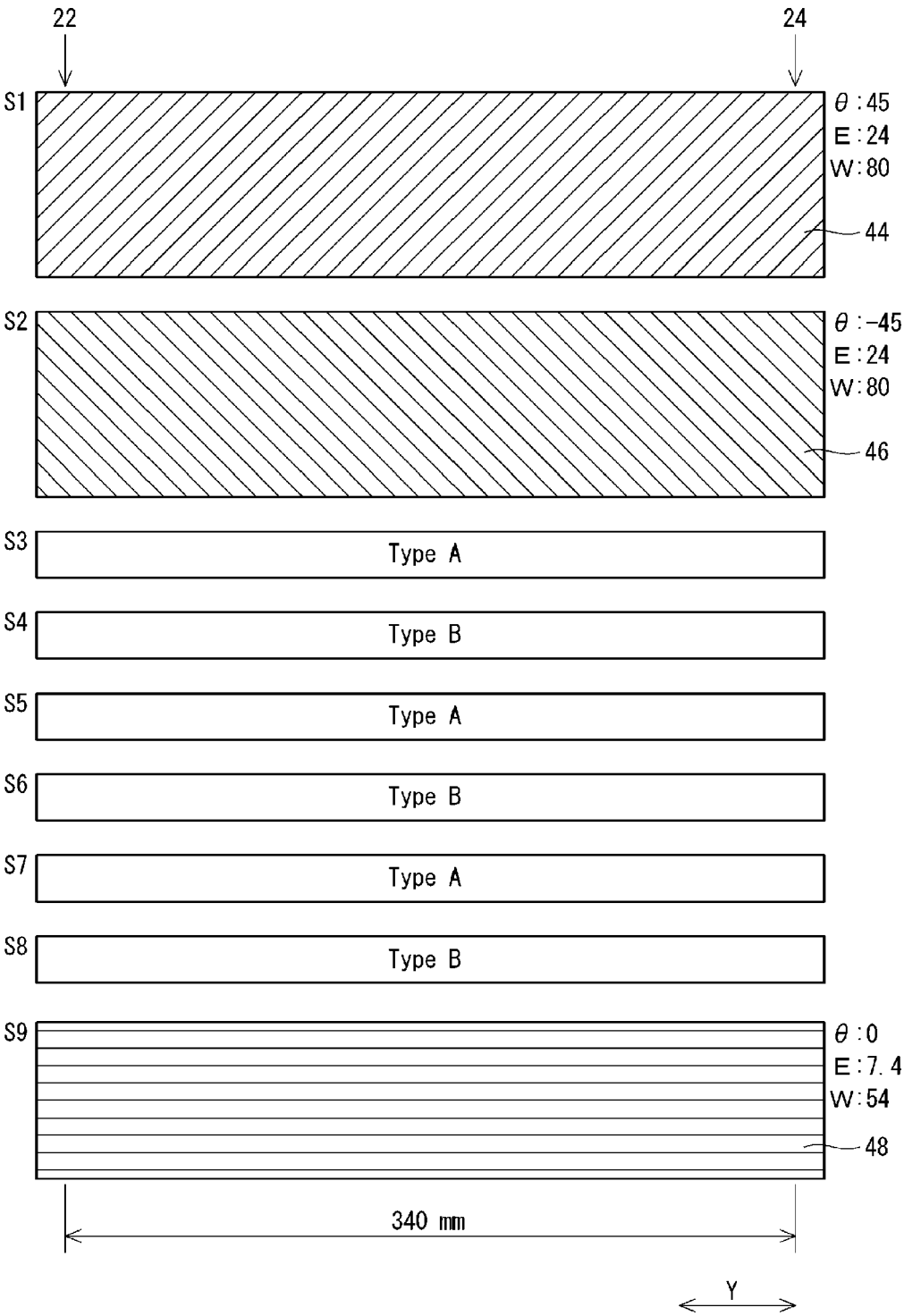


Fig.7

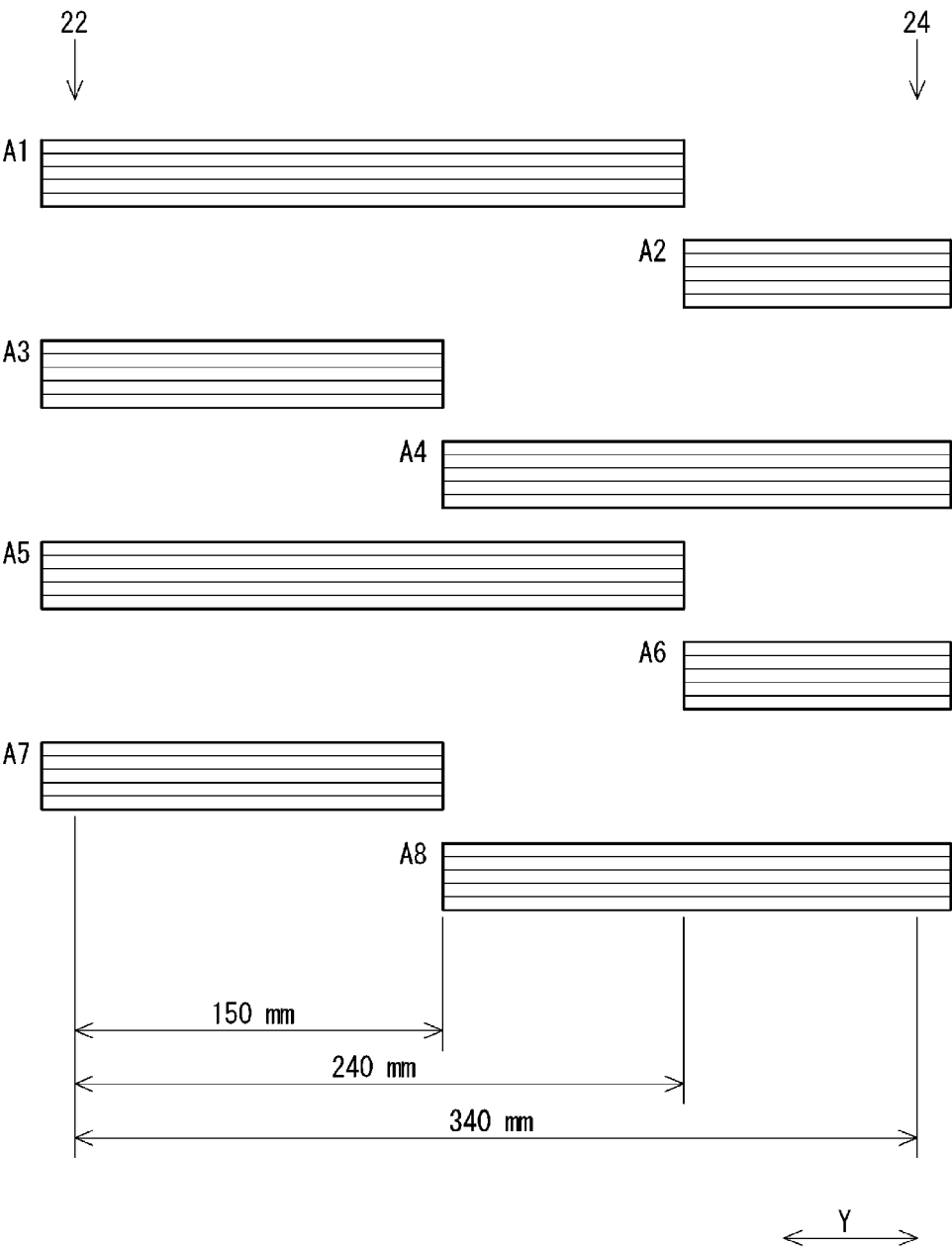


Fig.8

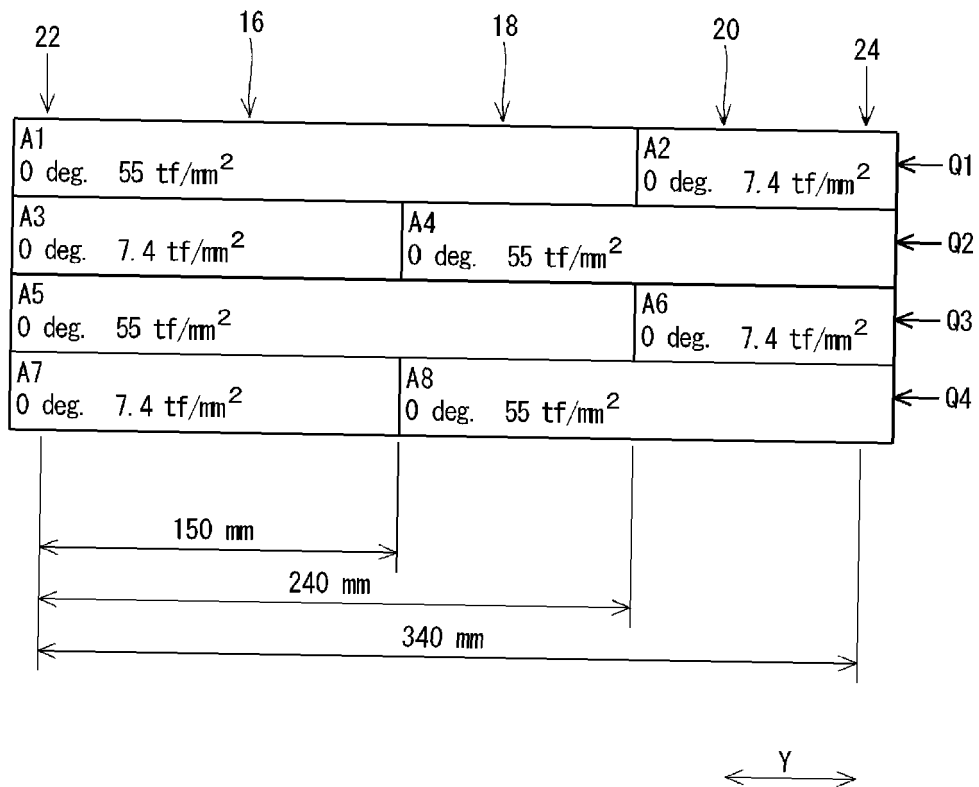
Type A

Fig.9

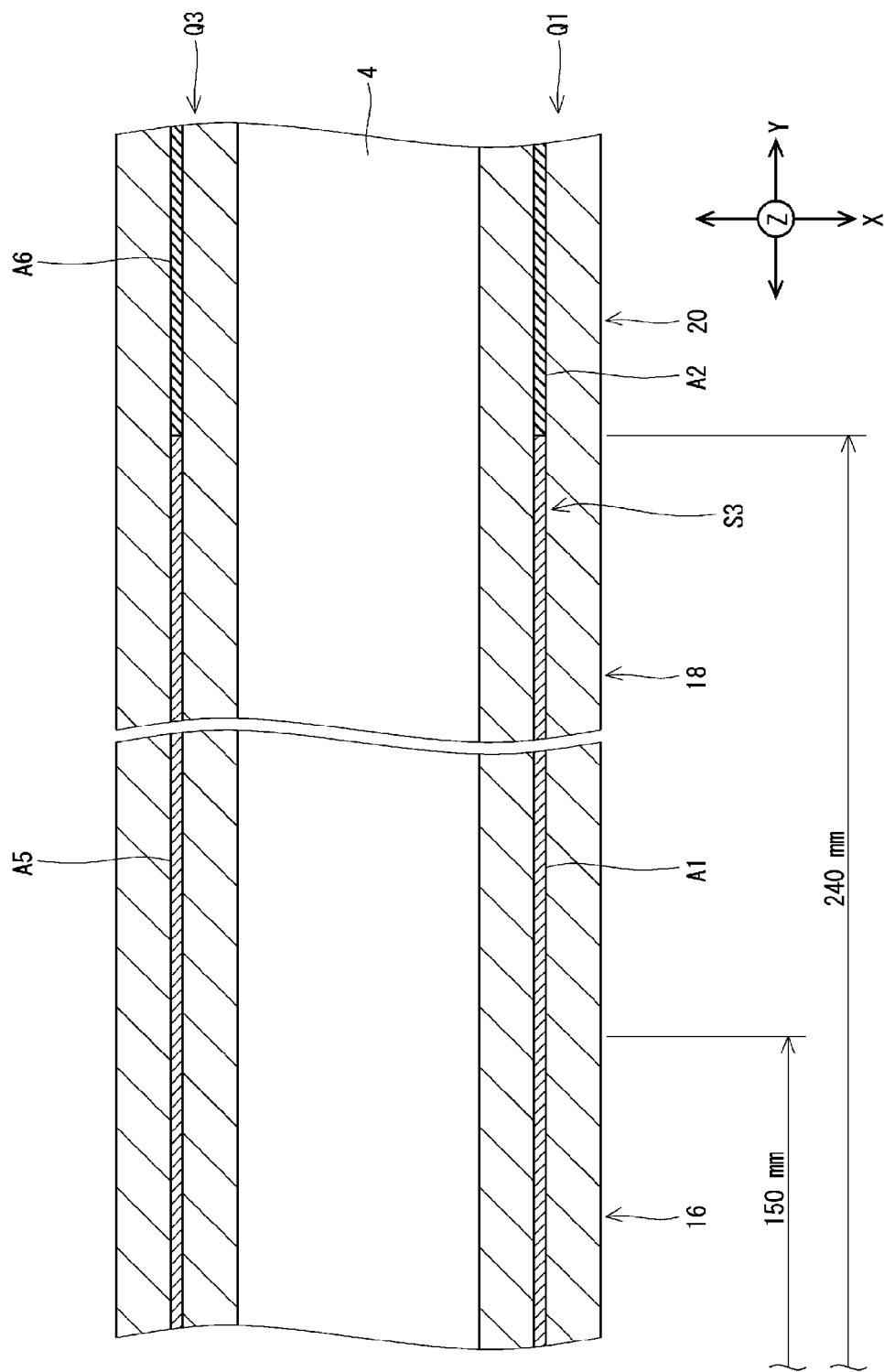


Fig.10

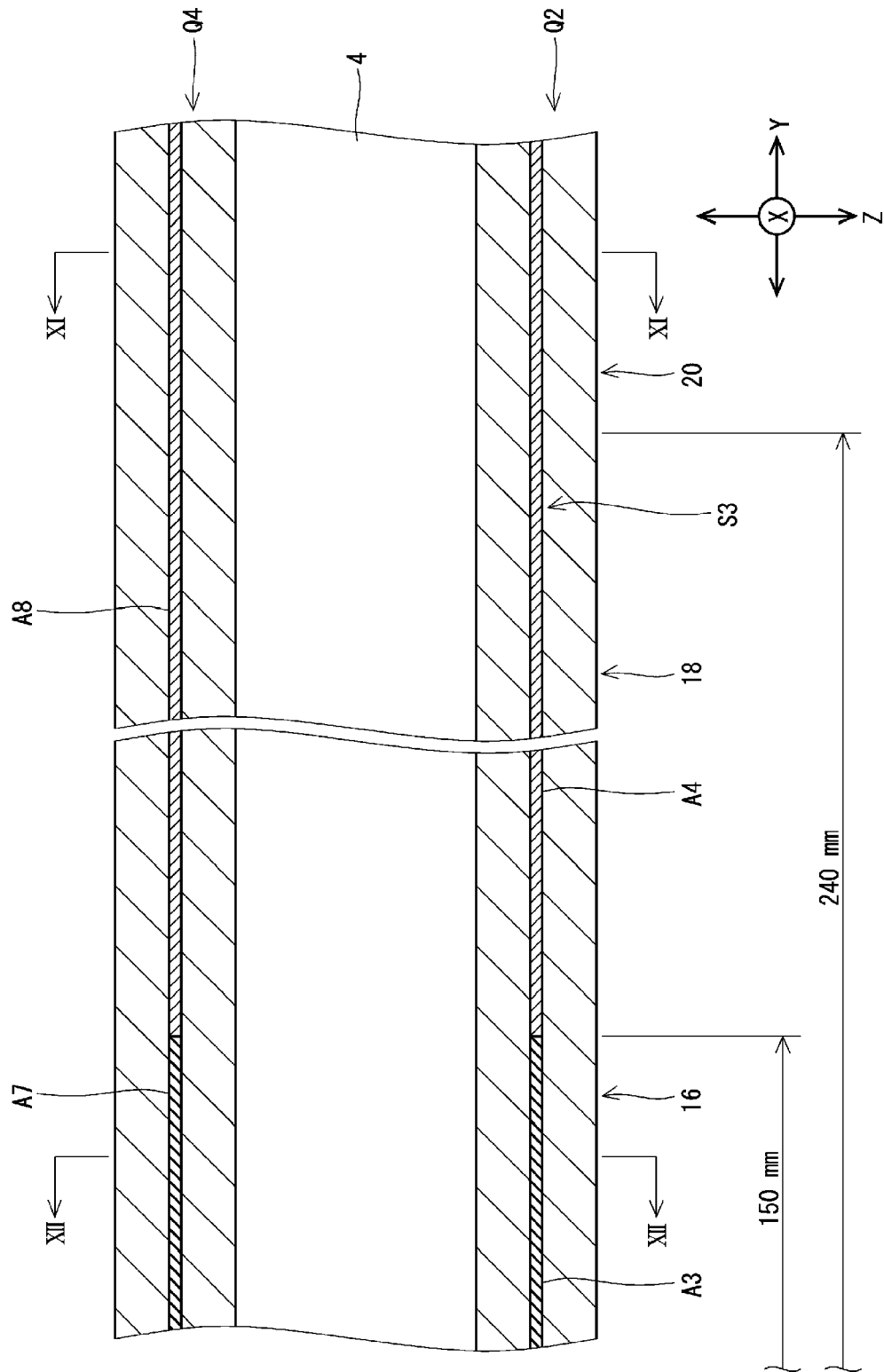


Fig.11

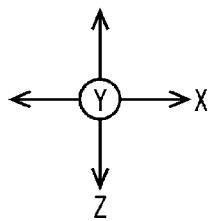
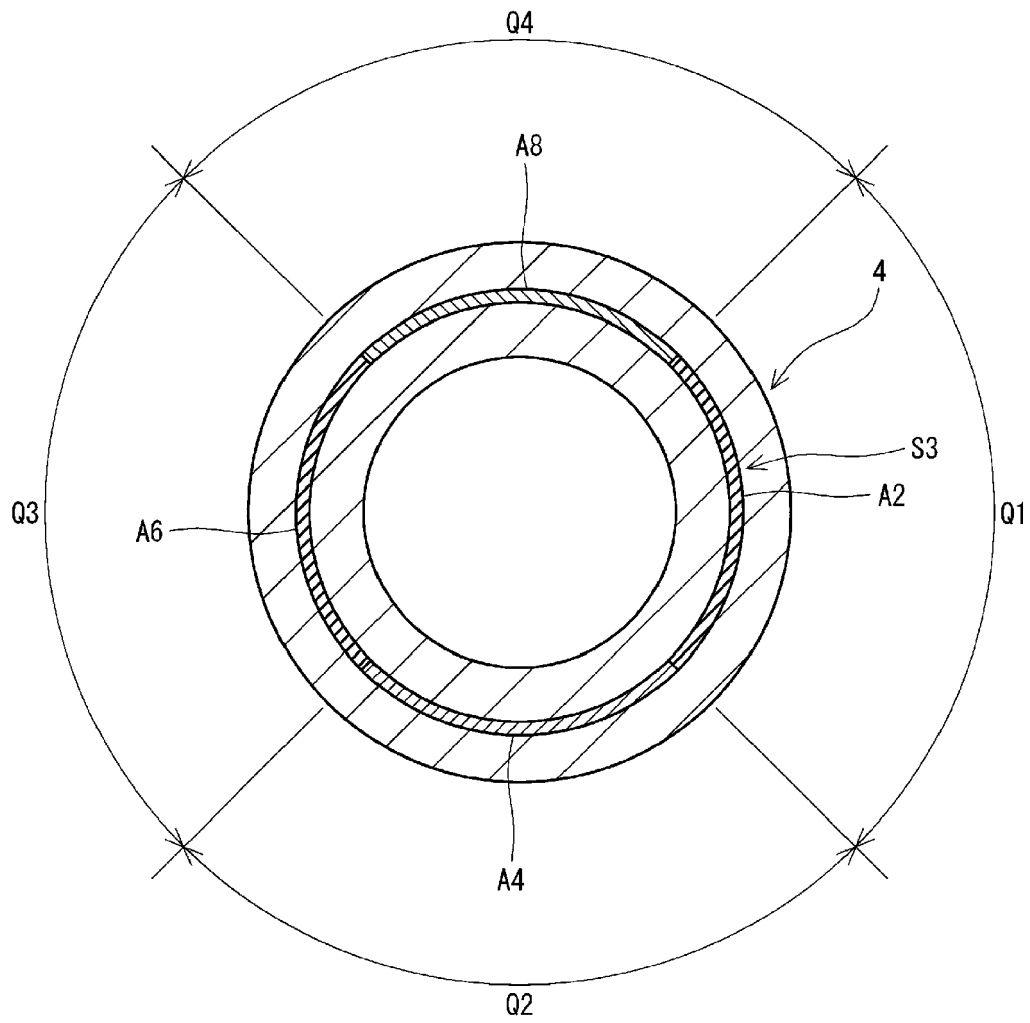


Fig.12

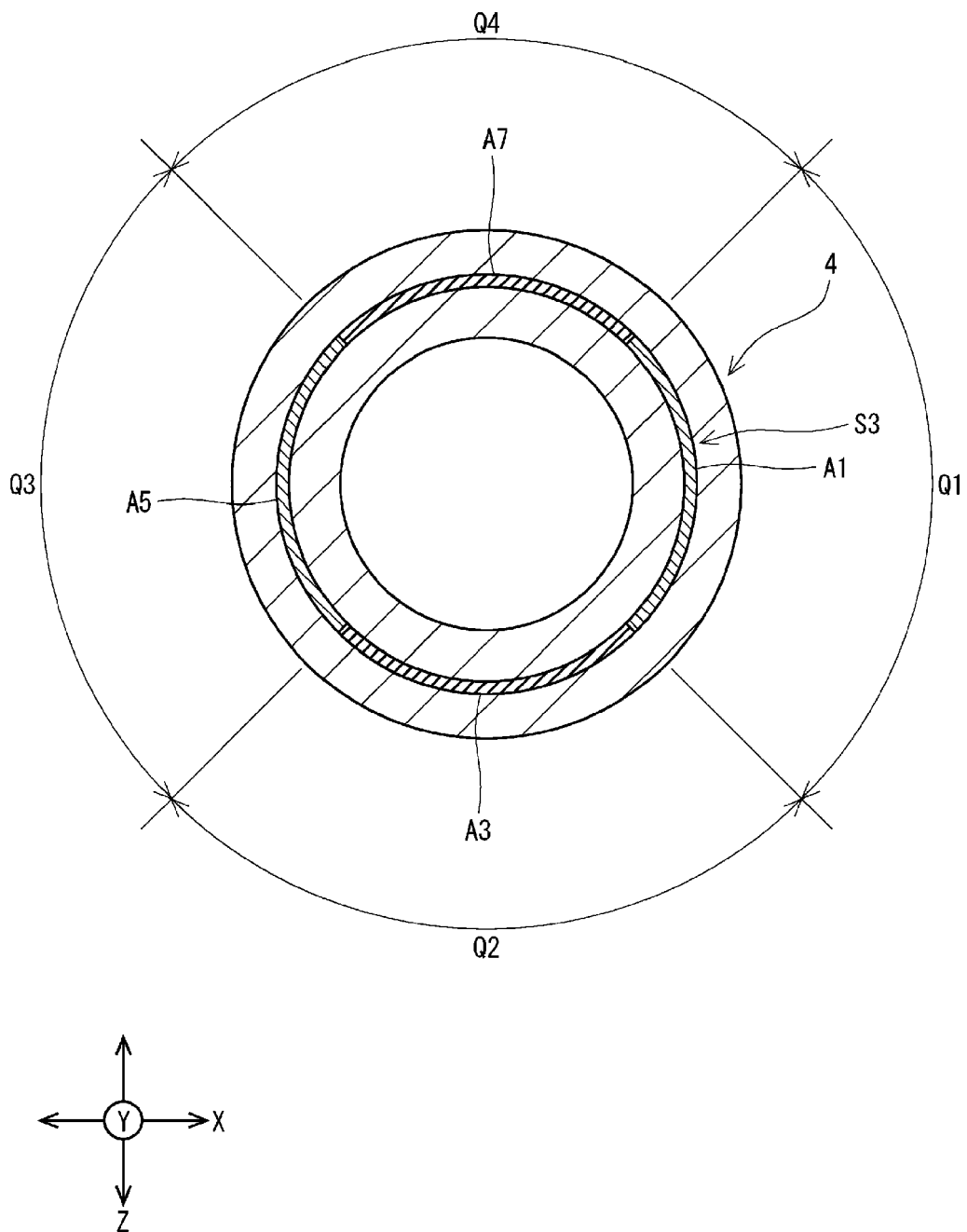


Fig.13

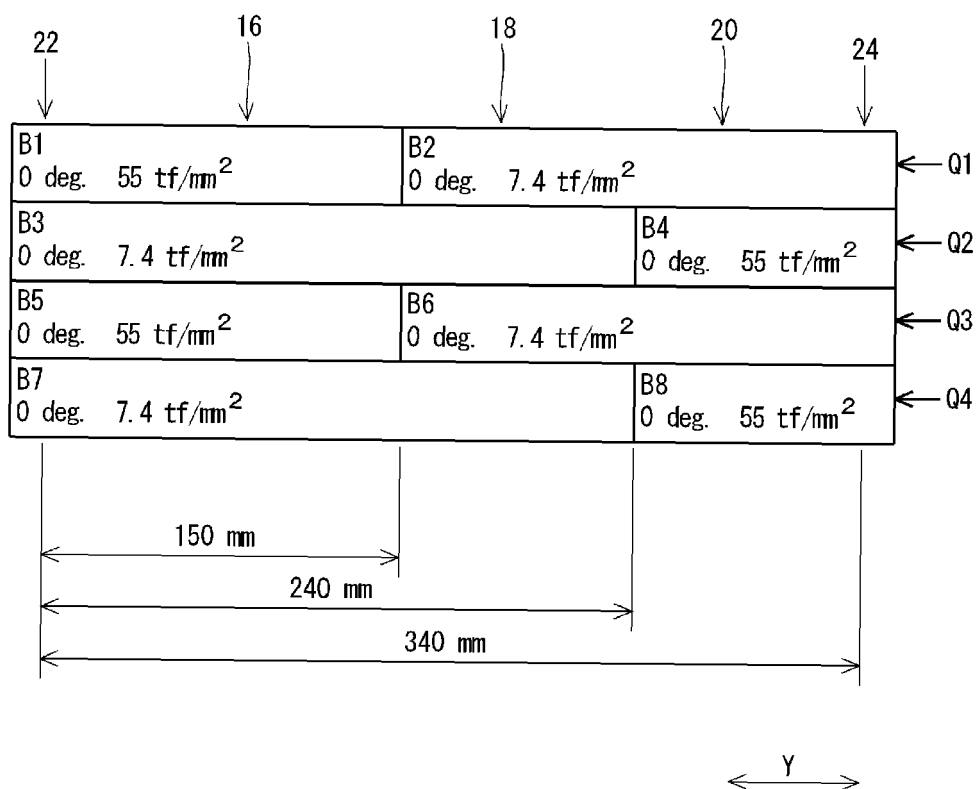
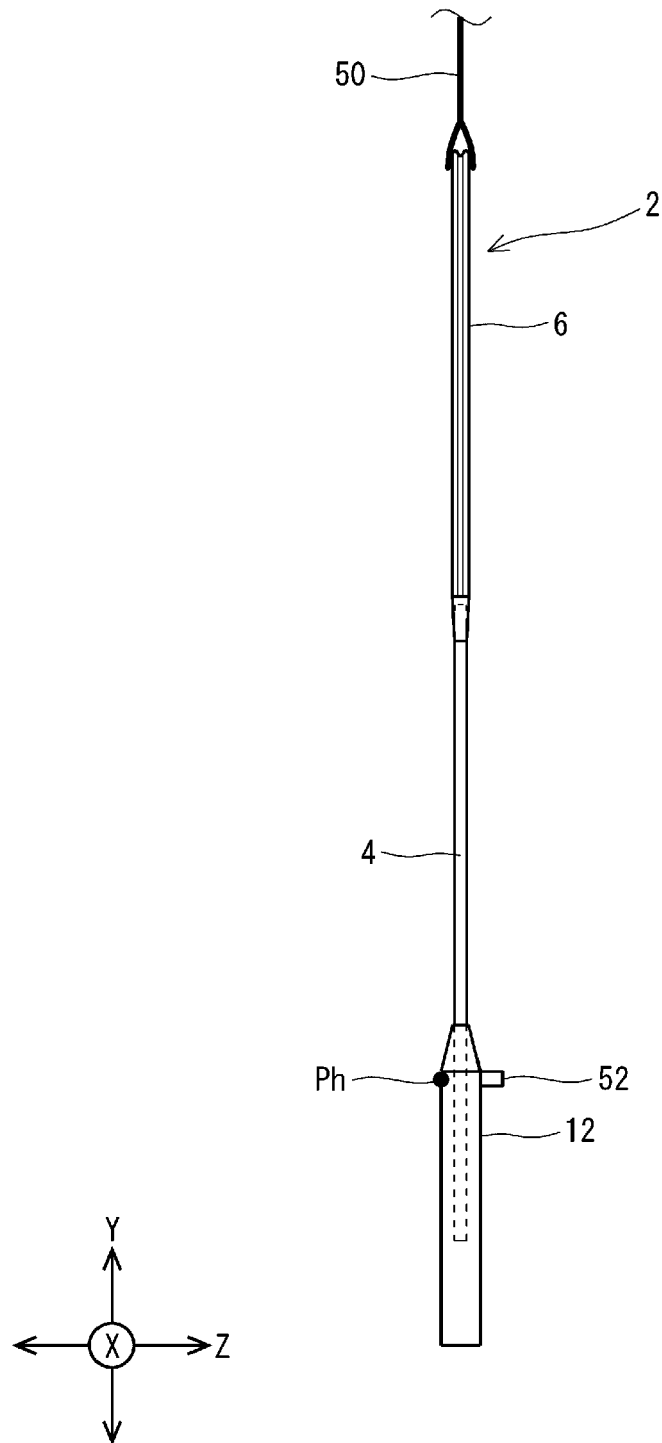
Type B

Fig.14



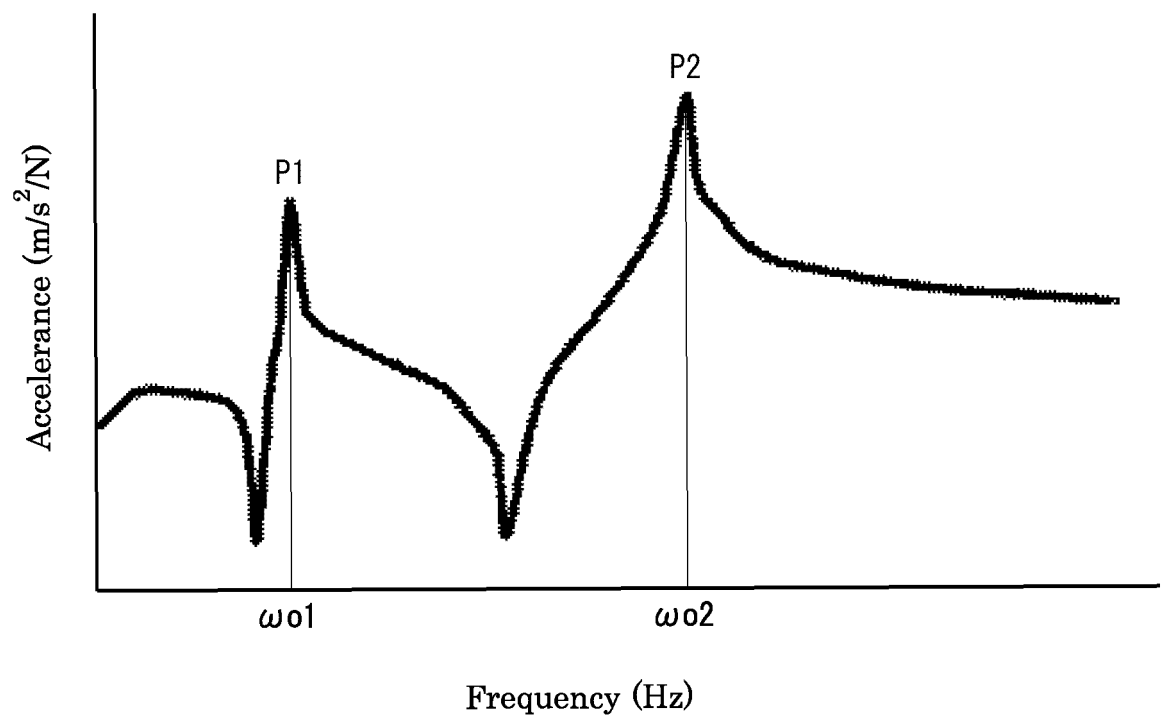
*FIG. 15*

Fig.16

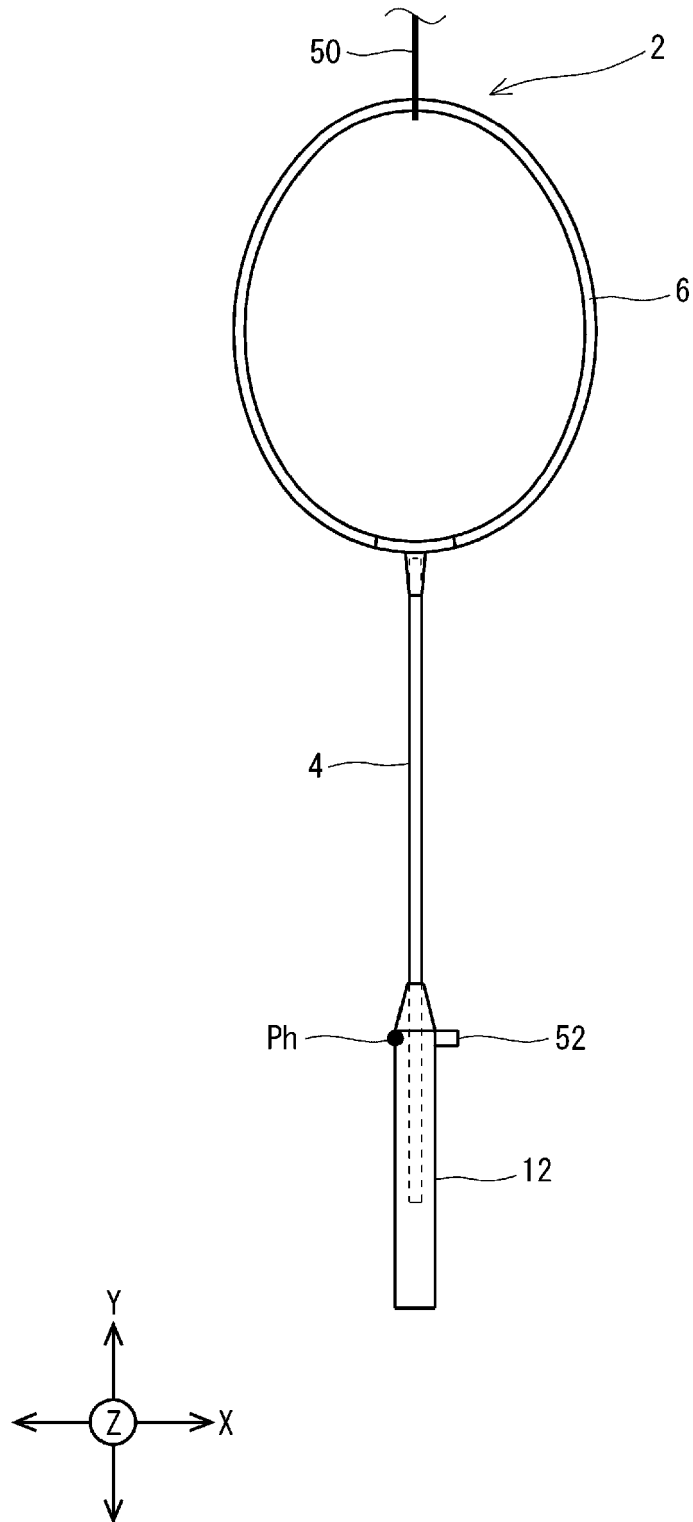


Fig.17

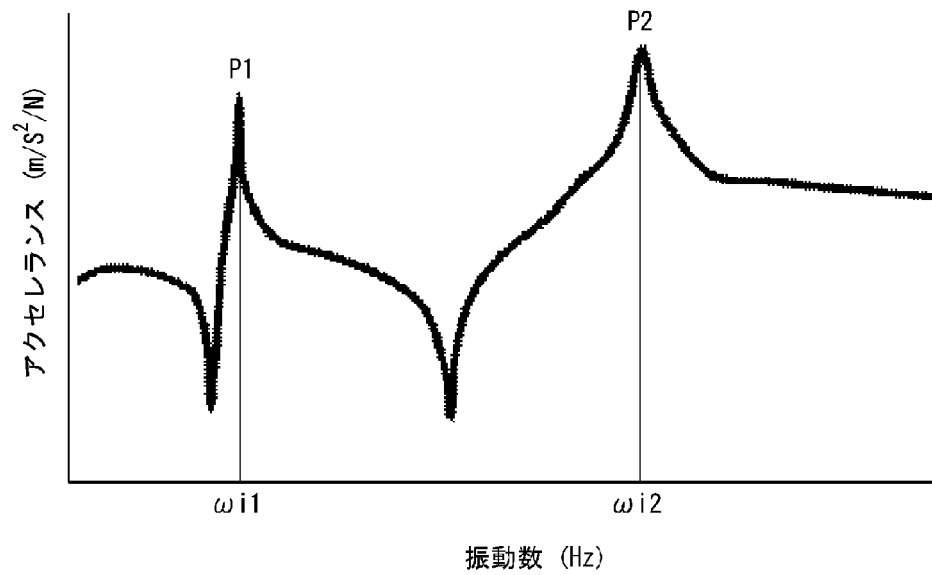
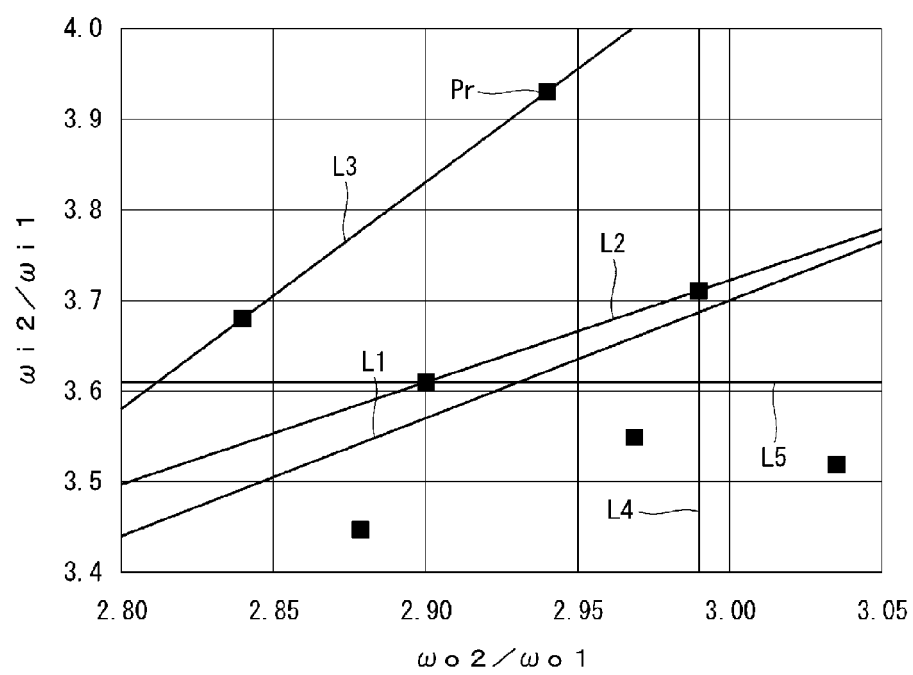


Fig.18



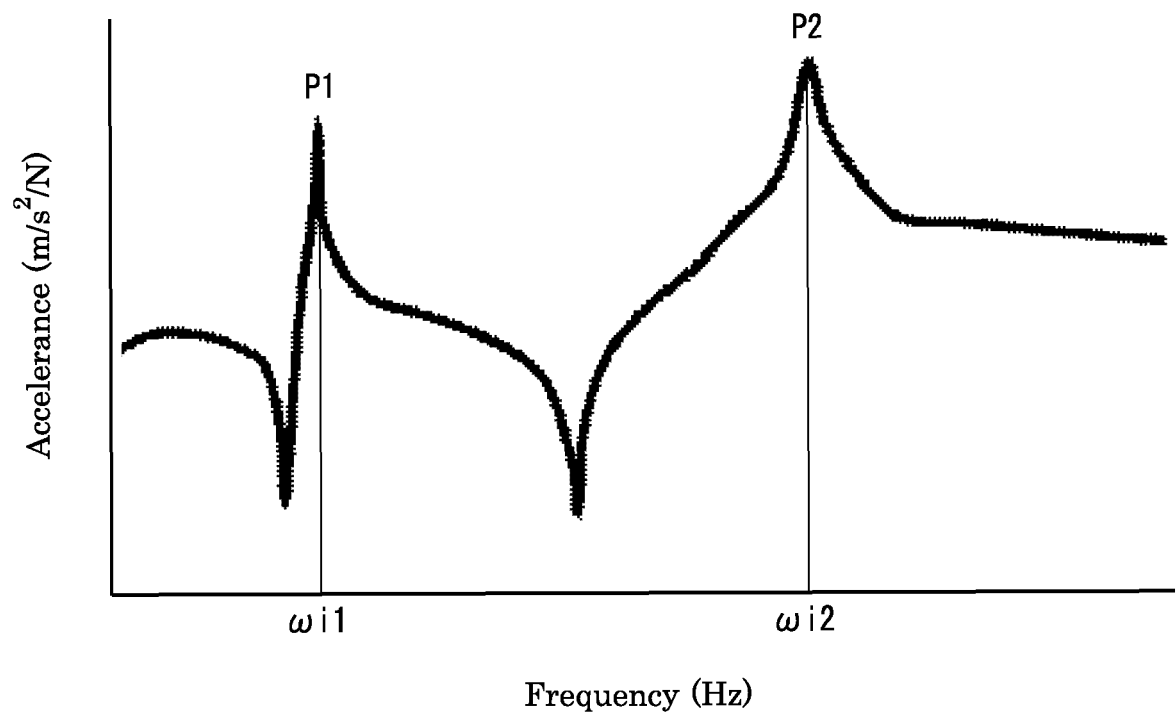


FIG. 17

Fig.17

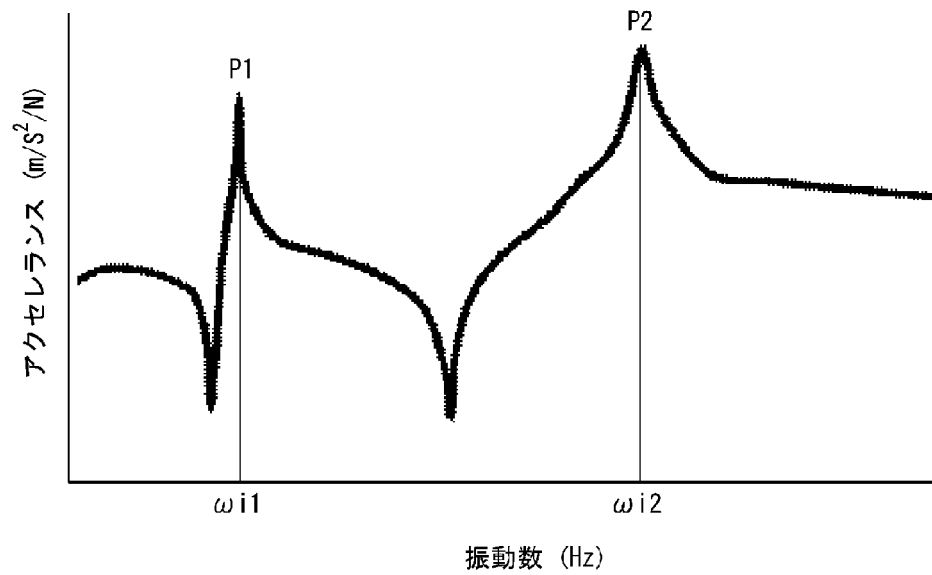


Fig.18

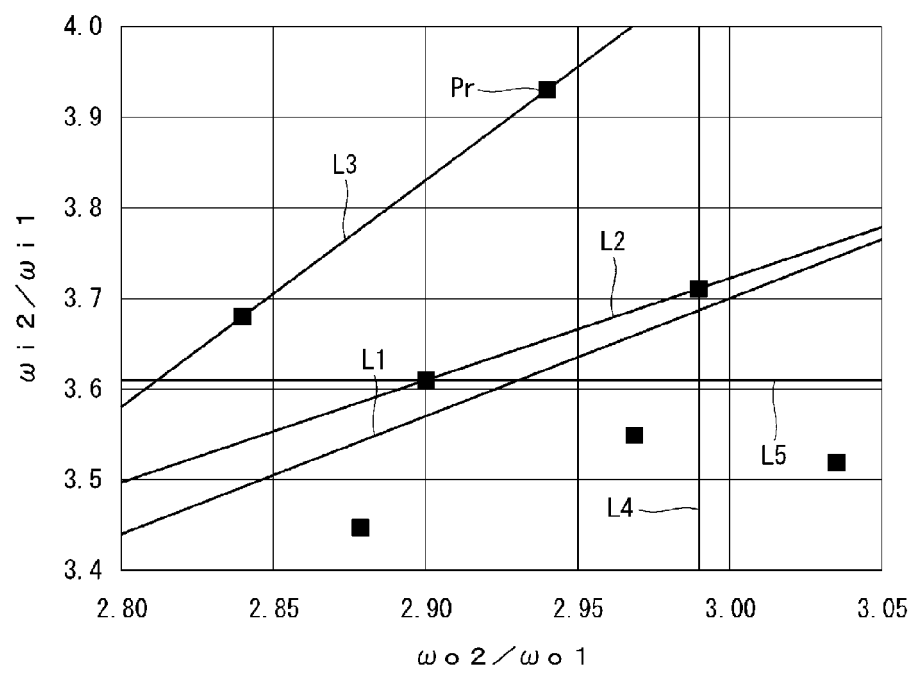


Fig.19

Type C

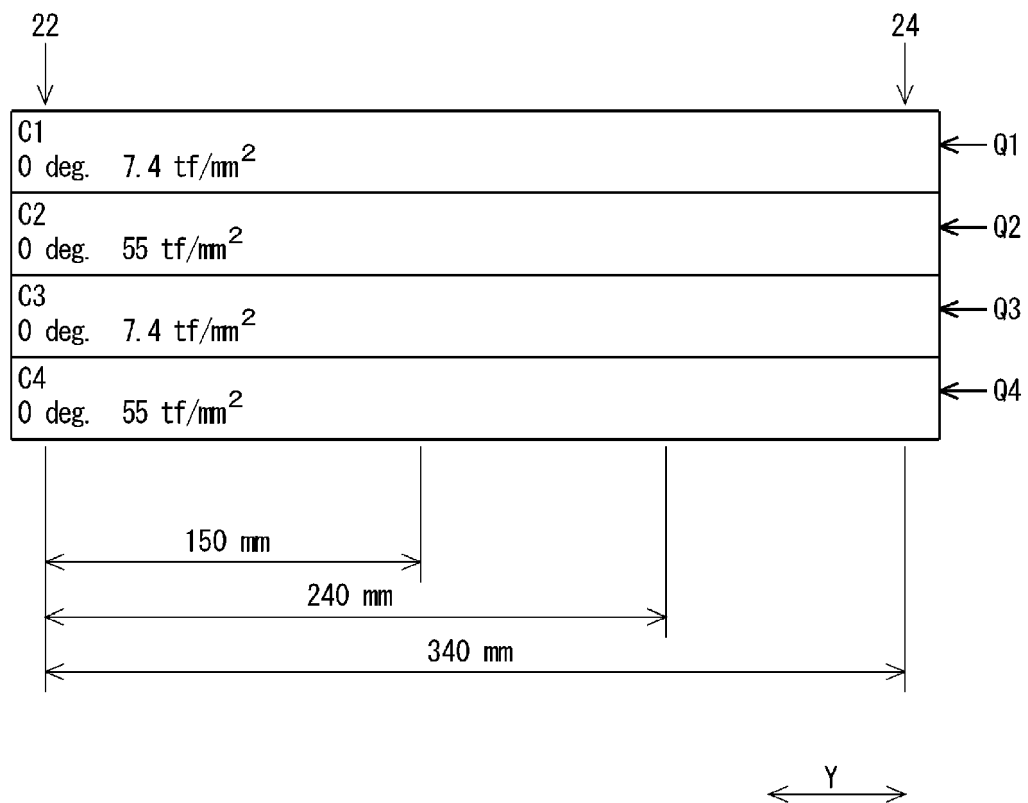


Fig.20

Type D

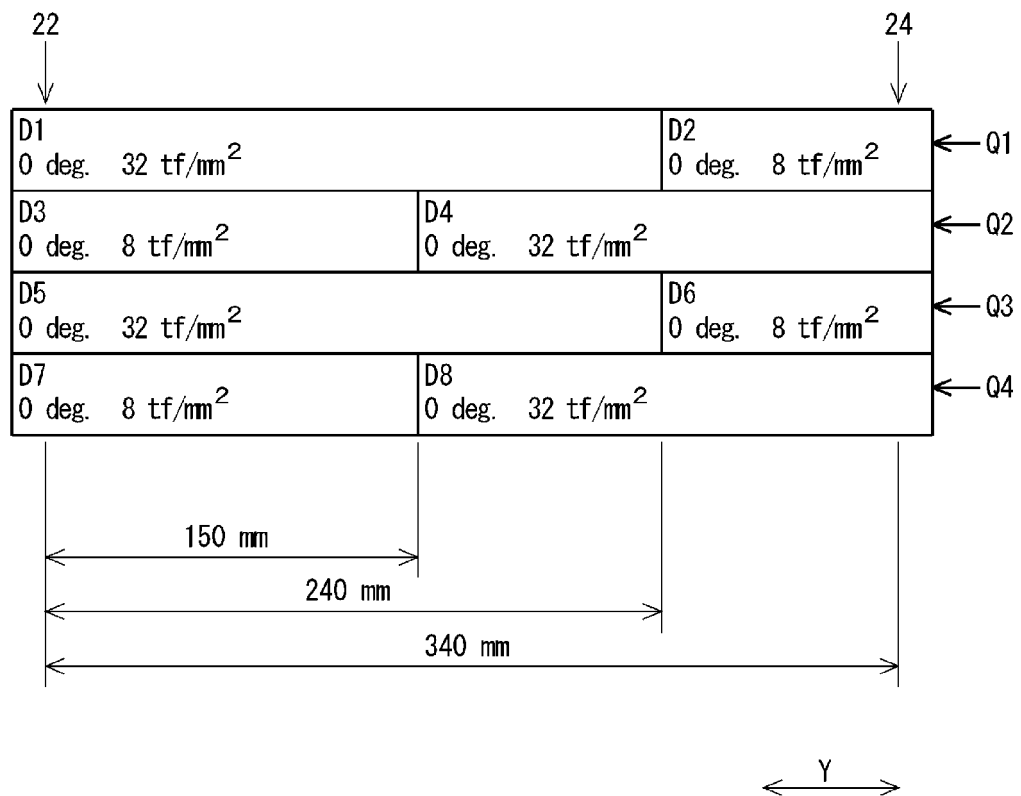


Fig.21

Type E

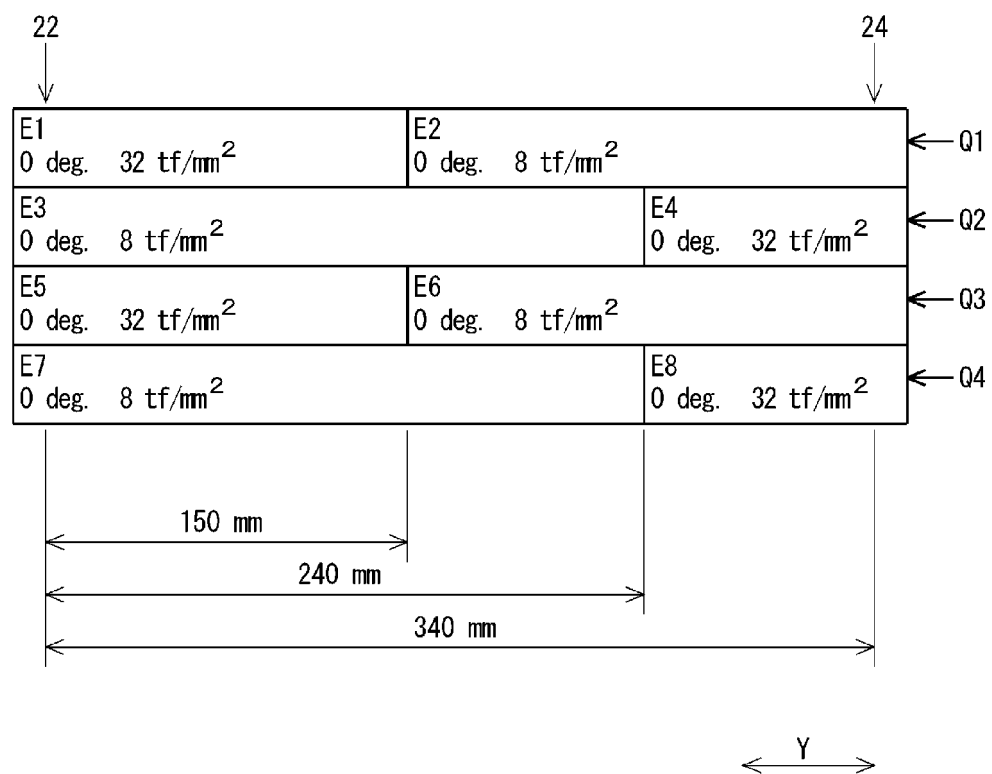


Fig.22

Type F

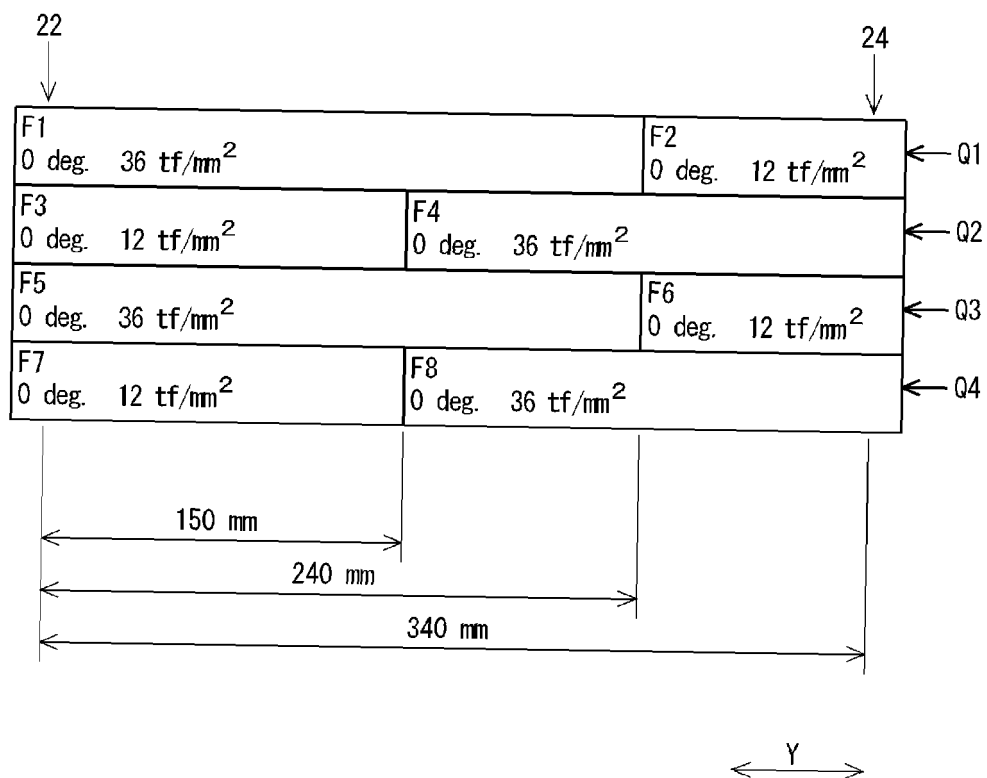


Fig.23

Type G

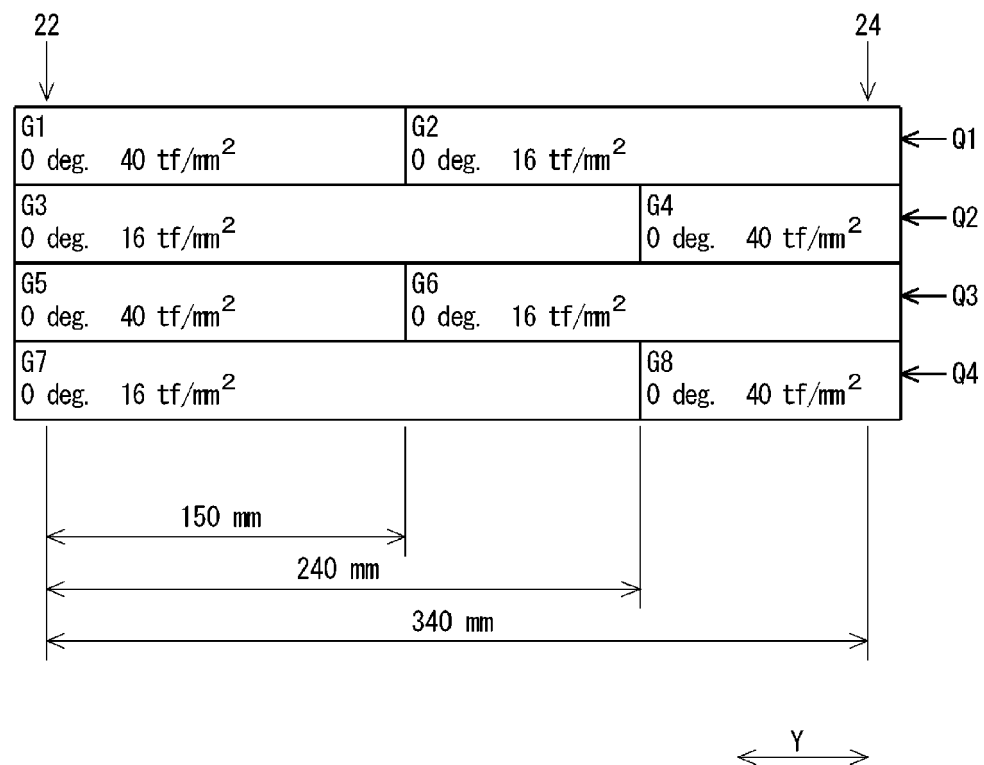


Fig.24

Type H

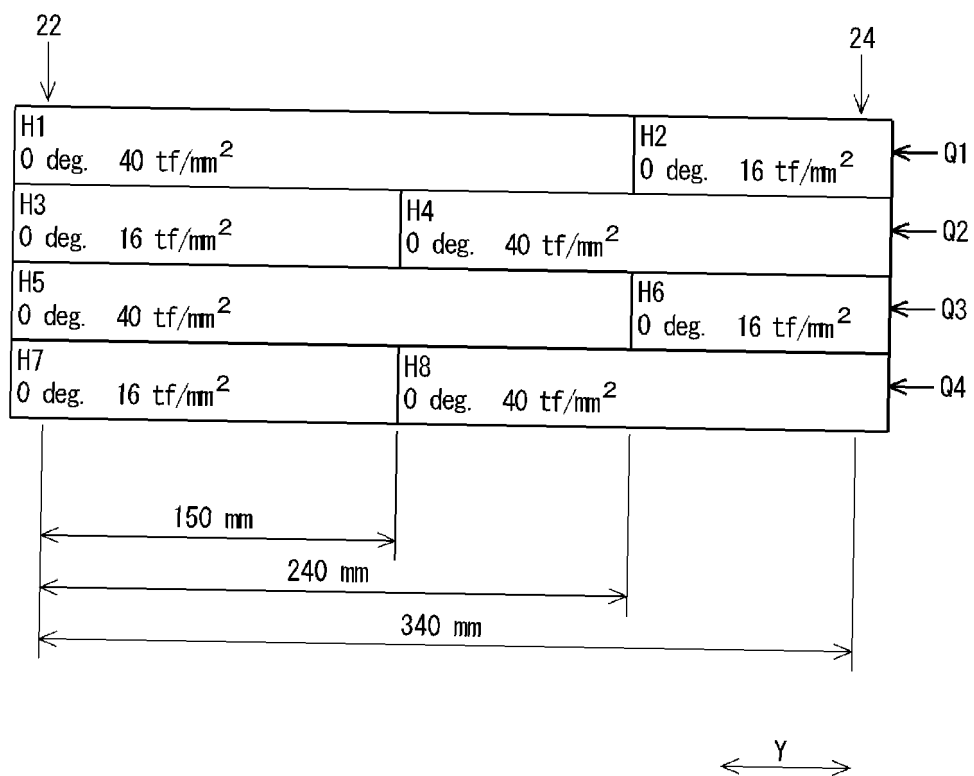


Fig.25

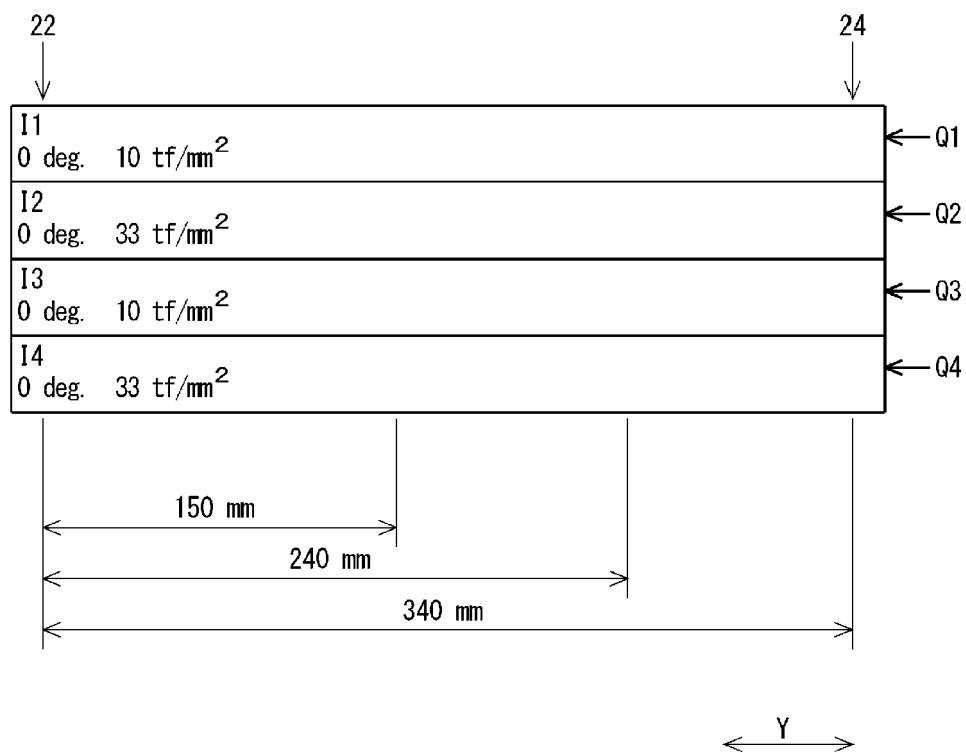
Type I

Fig.26

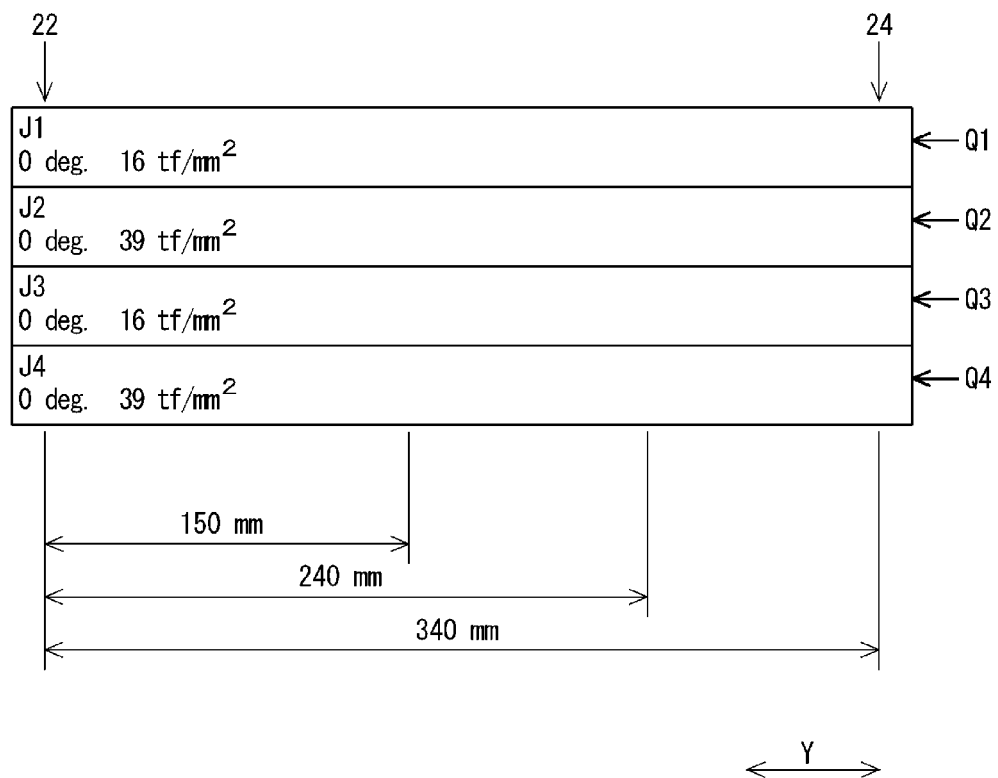
Type J

Fig.27

Type K

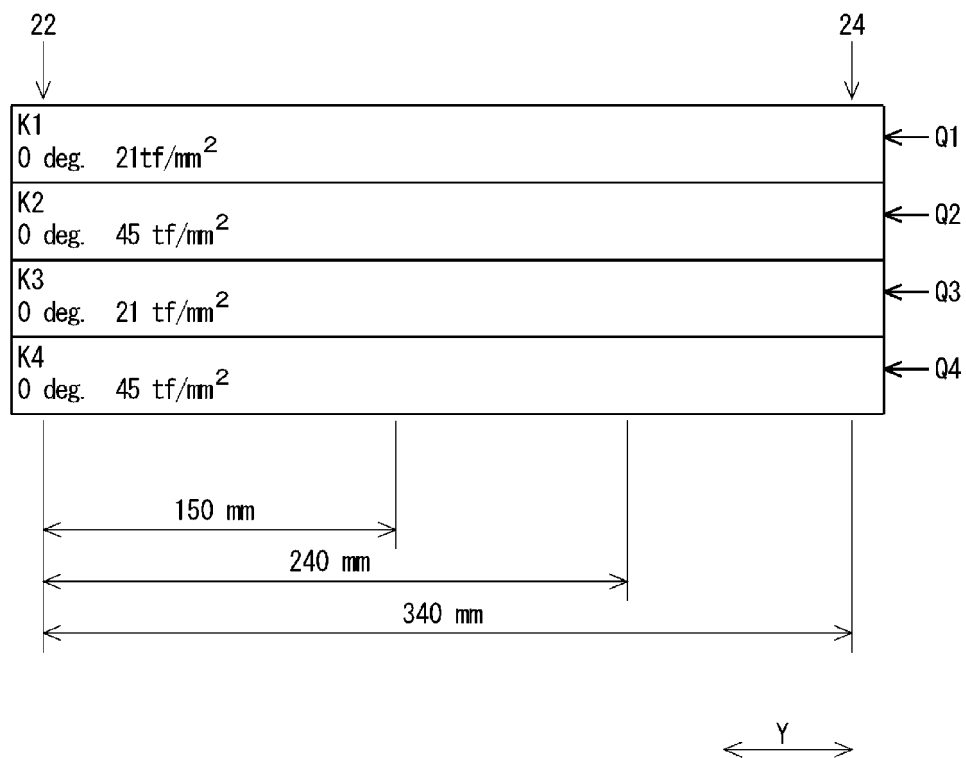


Fig.28

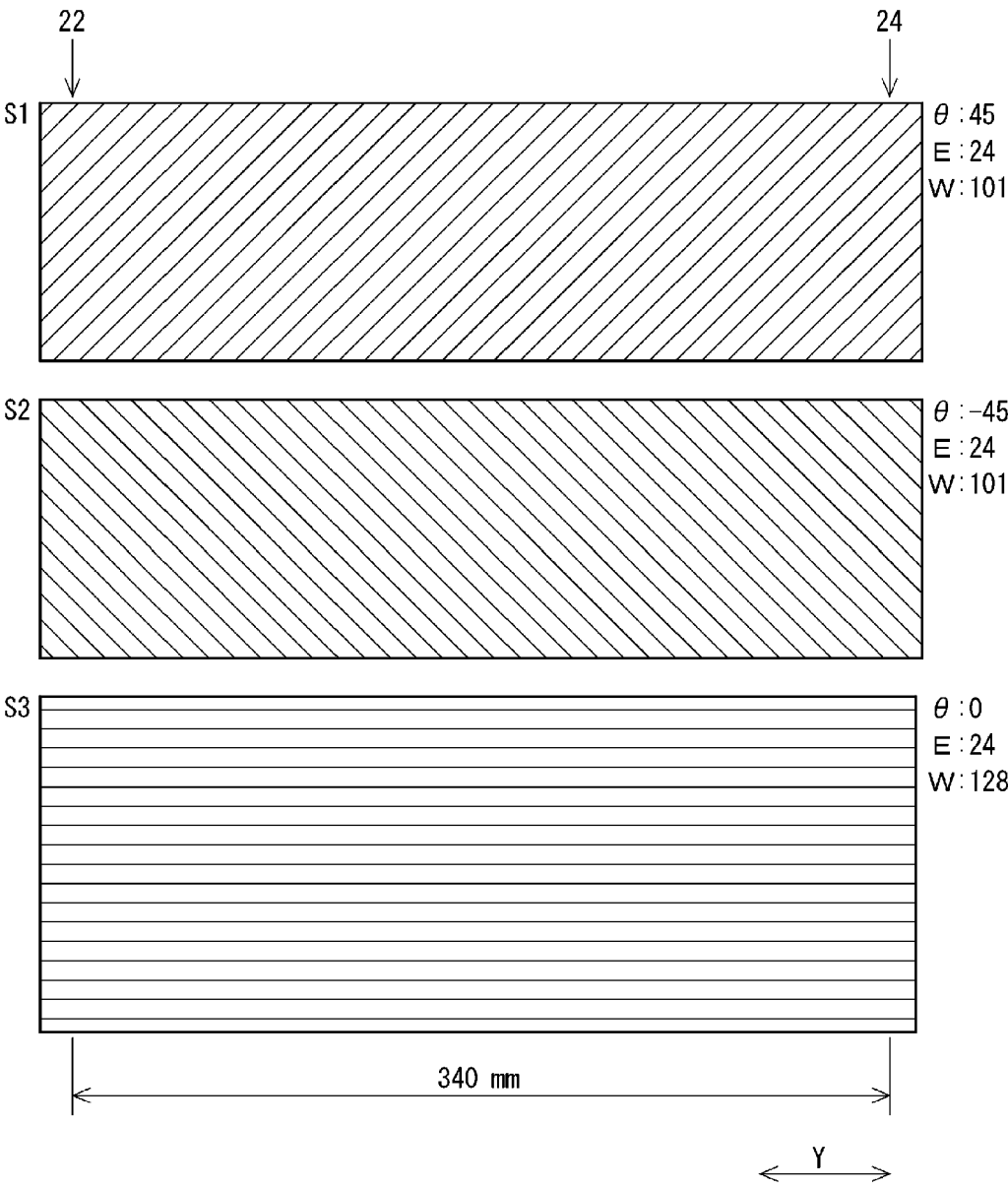


Fig.29

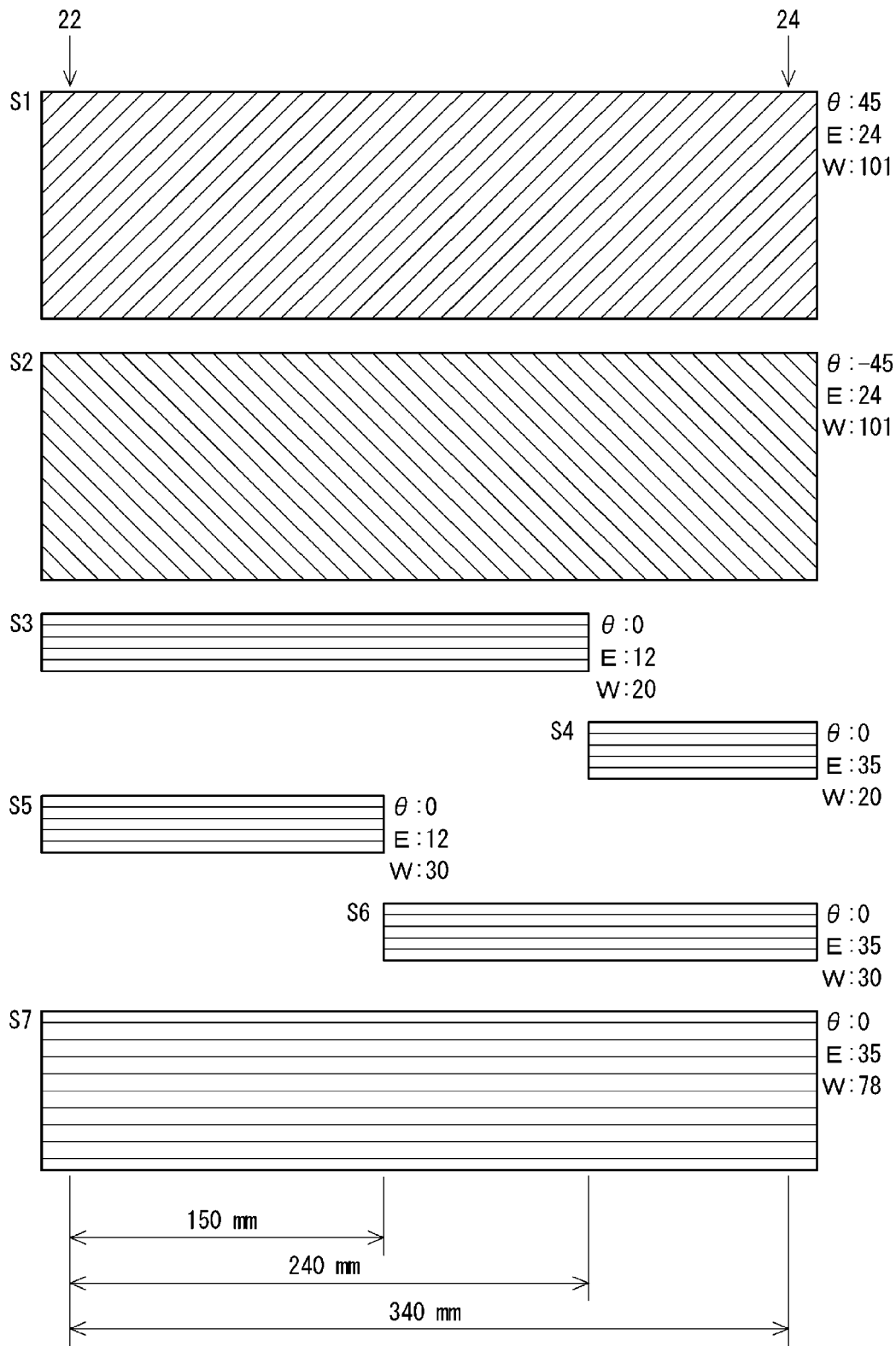
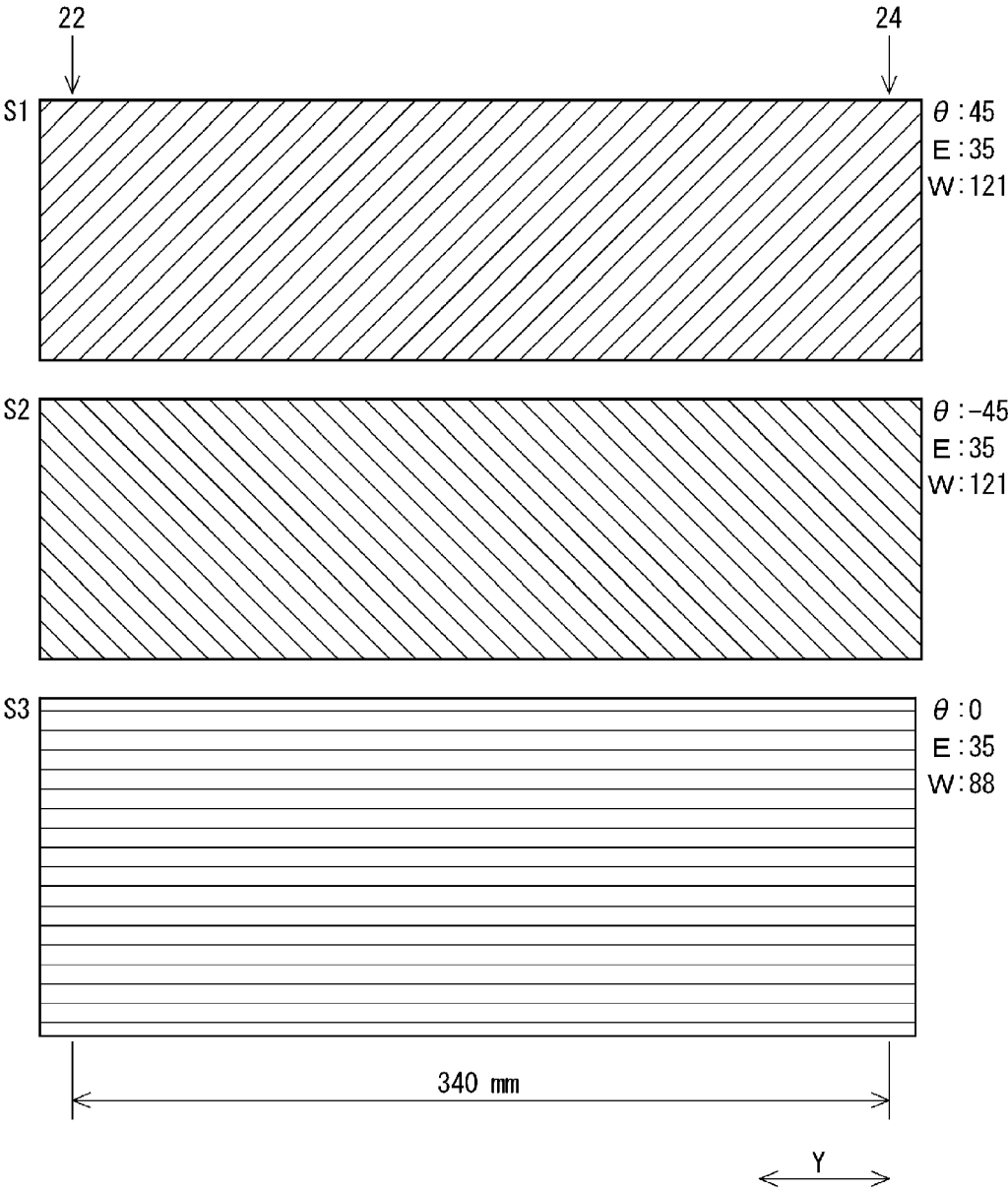


Fig.30





EUROPEAN SEARCH REPORT

Application Number

EP 22 19 6478

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 5 778506 B2 (GOSEN KK) 16 September 2015 (2015-09-16) * paragraph [0008] - paragraph [0066]; figures 1-13 *	1-15	INV. A63B49/02 A63B49/10 A63B60/00 A63B60/42
A	JP 4 444442 B2 (SUMITOMO RUBBER IND) 31 March 2010 (2010-03-31) * paragraph [0005] - paragraph [0069]; figures 1-13 *	1-15	A63B69/00 A63B102/04
A	US 2004/048698 A1 (KANEMITSU YUMI [JP] ET AL) 11 March 2004 (2004-03-11) * paragraph [0021] - paragraph [0177]; figures 1-10 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

A63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	12 January 2023	Jekabsons, Armands
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 22 19 6478

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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12-01-2023

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