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(54) **RACKET**

(57) A racket (2) includes a frame (4), a grip (6), a grommet (10), and a string (12). The frame (4) includes a head (14), a first throat (16a), a second throat (16b), and a shaft (18). A maximum value of a thickness of the frame (4) is less than 26.0 mm. The racket (2) has an in-plane stiffness index G_i of greater than or equal to 5000 and less than or equal to 8000. The in-plane stiffness index G_i is a product of a top pressure stiffness value G_{it} expressed in kgf/cm and a side pressure stiffness value G_{is} expressed in kgf/cm. The racket (2) has an out-of-plane stiffness index G_o of greater than or equal to 45000 and less than or equal to 60000. The out-of-plane stiffness index G_o is a product of a throat stiffness value G_{os} expressed in kgf/cm and a ball-hitting face stiffness value G_{oh} expressed in kgf/cm.

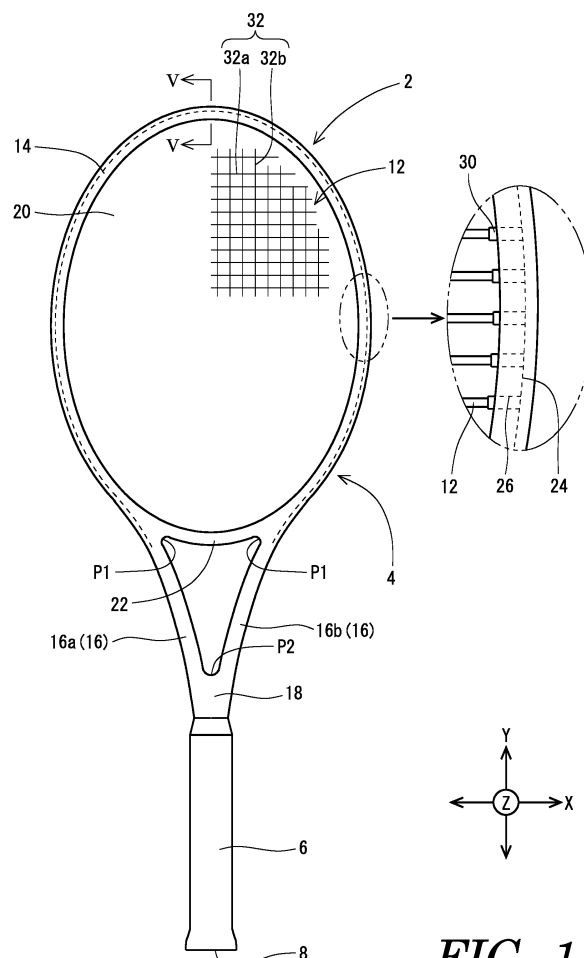


FIG. 1

Description

CROSS-REFERENCE TO RELATED APPLICATION

5 [0001] This application claims priority to and the benefit of Japanese Patent Application No. 2023-184851, filed on October 27, 2023, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 FIELD OF THE INVENTION

[0002] The present specification discloses a racket that is suitable for use in, for example, tennis, soft tennis, squash, padel, and badminton.

15 DESCRIPTION OF THE RELATED ART

[0003] In tennis, a ball is hit by a racket. As a result of the hitting, the kinetic energy of the racket is transferred to the ball, and the ball flies. In a case where a ball is hit by a tennis racket having excellent repulsion performance, the ball can fly at a high velocity. In a game of tennis, a high flying velocity of the ball is advantageous. Japanese Laid-Open Patent Application Publication No. H05-15617 discloses a tennis racket having excellent repulsion performance.

[0004] Tennis players demand not only high repulsion performance but also high controllability for tennis rackets. In particular, there is a strong demand from proficient tennis players for high controllability of tennis rackets.

[0005] It is an intention of the applicant of the present application to provide a racket having excellent repulsion performance and excellent controllability.

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SUMMARY OF THE INVENTION

[0006] A racket disclosed in the present specification includes: a frame including a head; and a string that is stretched on the head and that forms a ball-hitting face. A maximum value of a thickness of the frame is less than 26.0 mm. In the racket, an in-plane stiffness index G_i that is a product of a top pressure stiffness value G_{it} (kgf/cm) and a side pressure stiffness value G_{is} (kgf/cm) is greater than or equal to 5000 and less than or equal to 8000, and an out-of-plane stiffness index G_o that is a product of a throat stiffness value G_{os} (kgf/cm) and a ball-hitting face stiffness value G_{oh} (kgf/cm) is greater than or equal to 45000 and less than or equal to 60000.

[0007] The racket configured as above has excellent repulsion performance. A ball hit by the racket can fly at a high velocity. The racket realizes a long contact time with the ball when hitting it. The racket also has excellent controllability.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

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FIG. 1 is a front view of a tennis racket according to one embodiment.

FIG. 2 is a side view of the tennis racket of FIG. 1.

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FIG. 3 is an enlarged exploded view of a part of the tennis racket of FIG. 1.

FIG. 4 is a perspective view showing a part of a manufacturing process of the racket of FIG. 1.

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FIG. 5 is an enlarged sectional view taken along line V-V of FIG. 1.

FIG. 6 is an enlarged view of a part denoted by an arrow VI of FIG. 5.

FIG. 7 is an enlarged view of a part of a prepreg for first fiber reinforced layers of a frame of FIG. 6.

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FIG. 8 is an enlarged view of a part of a prepreg for second fiber reinforced layers of the frame of FIG. 6.

FIG. 9 is an enlarged view of a part of a prepreg for third fiber reinforced layers of the frame of FIG. 6.

FIG. 10A is a front view showing a method of measuring a top pressure stiffness value of the tennis racket of FIG. 1.

FIG. 10B is a side view showing the measurement method of FIG. 10A.

FIG. 11 is a front view showing a method of measuring a side pressure stiffness value of the tennis racket of FIG. 1.

FIG. 12A is a plan view showing a method of measuring a throat stiffness value of the tennis racket of FIG. 1.

FIG. 12B is a front view showing the measurement method of FIG. 12A.

FIG. 13A is a plan view showing a method of measuring a ball-hitting face stiffness value of the tennis racket of FIG. 1.

FIG. 13B is a front view showing the measurement method of FIG. 13A.

FIG. 14 is a sectional view of a part of a tennis racket according to another embodiment.

FIG. 15A is a front view showing a method of measuring an out-of-plane natural frequency of the tennis racket of FIG. 14.

FIG. 15B is a side view showing the measurement method of FIG. 15A.

FIG. 16 is a graph showing a relationship between the frequency and transfer function of the tennis racket of FIG. 14.

DETAILED DESCRIPTION

[0009] Hereinafter, preferred embodiments are described in detail with reference to the drawings as necessary.

[Embodiment 1]

[Components]

[0010] Each of FIGS. 1 to 3 shows a tennis racket 2. The racket 2 includes a frame 4, a grip 6, an end cap 8, a grommet 10, and a string 12. The racket 2 can be used in regulation-ball tennis. In FIG. 1, an arrow X represents the width direction of the racket 2; an arrow Y represents the axial direction of the racket 2; and a Z-direction represents the thickness direction of the racket 2. In FIG. 2, the illustration of the grommet 10 and the string 12 is omitted.

[0011] The frame 4 includes a head 14, a first throat 16a, a second throat 16b, and a shaft 18. The head 14 forms the contour of a face 20 (the face 20 will be described below in detail). The front shape of the head 14 is substantially an ellipse. The major axis direction of the ellipse coincides with the axial direction Y of the racket 2. The minor axis direction of the ellipse coincides with the width direction X of the racket 2. The first throat 16a extends from the head 14. The second throat 16b extends from the head 14. The second throat 16b merges with the first throat 16a at a position away from the head 14. The shaft 18 extends from the position where the two throats 16 merge together. The shaft 18 is continuous with the throats 16. A portion of the head 14, the portion being positioned between the two throats 16, is a yoke 22. The frame 4 is hollow.

[0012] The main material of the frame 4 is a fiber reinforced resin. The fiber reinforced resin includes a resin matrix and a large number of reinforcement fibers. The frame 4 includes a plurality of fiber reinforced layers. The fiber reinforced layers will be described below in detail.

[0013] Examples of the base resin of the frame 4 include: thermosetting resins such as epoxy resin, bismaleimide resin, polyimide, and phenolic resin; and thermoplastic resins such as polyether ether ketone, polyether sulphone, polyether imide, polyphenylene sulfide, polyamide, and polypropylene. Epoxy resin is a particularly suitable resin for the frame 4.

[0014] Examples of the reinforcement fibers of the frame 4 include carbon fibers, metal fibers, glass fibers, and aramid fibers. Carbon filament fibers are particularly suitable fibers for the frame 4. Multiple types of fibers may be used in combination as the reinforcement fibers.

[0015] As shown in FIGS. 2 and 3, the head 14 includes a groove 24. The groove 24 is recessed from the outer peripheral surface of the head 14. The groove 24 is formed over substantially the entire periphery of the head 14, except the yoke 22. The head 14 further includes a plurality of holes 26. The plurality of holes 26 are arranged over substantially the entire periphery of the head 14.

[0016] The grip 6 is formed by a tape wound around the shaft 18. The grip 6 suppresses slipping between a hand of a player and the tennis racket 2 when the racket 2 is swung.

[0017] As shown in FIG. 3, the grommet 10 includes a base 28 and a plurality of pipes 30. The base 28 is belt-shaped.

Each pipe 30 is integrated with the base 28. Each pipe 30 rises from the base 28. A typical material of the grommet 10 is a synthetic resin that is softer than the frame 4. The tennis racket 2 may include a plurality of grommets 10. The number of pipes 30 of each grommet 10 may be one.

[0018] The grommet 10 is attached to the head 14. In a state where the grommet 10 is attached to the head 14, the base 28 is accommodated in the groove 24. The base 28 may partly protrude from the groove 24. Further, in the state where the grommet 10 is attached to the head 14, the pipes 30 extend through the respective holes 26.

[0019] As shown in FIG. 1, the string 12 is stretched on the head 14. The string 12 is stretched along the width direction X and the axial direction Y. The string 12 extends through the pipes 30. The string 12 forms a large number of threads 32. Of the string 12, portions extending along the width direction X are referred to as transverse threads 32a. Of the string 12, portions extending along the axial direction Y are referred to as longitudinal threads 32b. The face 20 is formed by a plurality of transverse threads 32a and a plurality of longitudinal threads 32b. The face 20 generally extends along an X-Y plane. The face 20 may be formed by two or more strings 12.

[Manufacturing Method]

[0020] Hereinafter, one example of a method of manufacturing the tennis racket 2 is described with reference to FIG. 4. In this manufacturing method, a mandrel, a tube, and a plurality of preregs 34 are prepared. Each prepreg 34 is made from a plurality of reinforcement fibers arranged in parallel and a matrix resin. In this manufacturing method, first, the mandrel is inserted into the tube. The preregs 34 are sequentially wound around the tube. As a result of the winding, the preregs 34 have a tubular shape. FIG. 4 shows a tubular prepreg 34p and a sheet-shaped prepreg 34s. In FIG. 4, the illustration of the mandrel and the tube is omitted.

[0021] By rotating the mandrel, the prepreg 34s is wound around the prepreg 34p. As a result of the winding, the prepreg 34s has a tubular shape. Another prepreg 34 is wound around the prepreg 34s as necessary, and thereby a layered body 36 is obtained. In FIG. 4, an arrow A1 represents the longitudinal direction of the layered body 36.

[0022] After the mandrel is removed from the tube, the tube and the layered body 36 are set in a mold. In the mold, gas is injected into the tube, thereby inflating the tube. The preregs 34 are pressed against the cavity surface of the mold by the inflation. The preregs 34 are heated to cure the matrix resin. A molded article is obtained by the curing. The molded article has a reverse shape of that of the cavity surface.

[0023] The holes 26 are drilled in the molded article. The molded article is further subjected to treatments such as surface polishing and painting, and thereby the frame 4 is obtained. Components such as the grip 6 and the grommet 10 are attached to the frame 4. Further, the string 12 is stretched on the frame 4, and thus the tennis racket 2 is completed.

[Fiber Reinforced Layer]

[0024] FIG. 5 is an enlarged sectional view taken along line V-V in FIG. 1. FIG. 6 is an enlarged view of a part denoted by an arrow VI of FIG. 5. FIGS. 5 and 6 show the frame 4. As previously described, the frame 4 includes a plurality of fiber reinforced layers 38. In the present embodiment, the frame 4 includes two first fiber reinforced layers 38a, two second fiber reinforced layers 38b, and eight third fiber reinforced layers 38c.

[0025] FIG. 7 shows a first prepreg 34a for the first fiber reinforced layers 38a. The first prepreg 34a includes a matrix 40 and a plurality of first reinforcement fibers 42a arranged in parallel. Each first reinforcement fiber 42a is inclined relative to the longitudinal direction A1. In FIG. 7, an arrow θ_a represents an inclination angle (absolute value) of the first reinforcement fiber 42a relative to the longitudinal direction A1. The inclination angle θ_a is greater than or equal to 30° and less than or equal to 60° . In the present specification, a reinforcement fiber having an inclination angle of greater than or equal to 30° and less than or equal to 60° is referred to as a "bias-type reinforcement fiber". The first fiber reinforced layers 38a include bias-type reinforcement fibers.

[0026] FIG. 8 shows a second prepreg 34b for the second fiber reinforced layers 38b. The second prepreg 34b includes the matrix 40 and a plurality of second reinforcement fibers 42b arranged in parallel. Each second reinforcement fiber 42b is inclined relative to the longitudinal direction A1. The direction in which each second reinforcement fiber 42b is inclined is opposite to the direction in which each first reinforcement fiber 42a is inclined (shown in FIG. 7). In FIG. 8, an arrow θ_b represents an inclination angle (absolute value) of the second reinforcement fiber 42b relative to the longitudinal direction A1. The inclination angle θ_b is greater than or equal to 30° and less than or equal to 60° . Each second reinforcement fiber 42b is a "bias-type reinforcement fiber". The second fiber reinforced layers 38b include bias-type reinforcement fibers.

[0027] FIG. 9 shows a third prepreg 34c for the third fiber reinforced layers 38c. The third prepreg 34c includes the matrix 40 and a plurality of third reinforcement fibers 42c arranged in parallel. Each third reinforcement fiber 42c extends along the longitudinal direction A1. The third reinforcement fibers 42c have a zero inclination angle relative to the longitudinal direction A1. The third reinforcement fibers 42c may be slightly inclined relative to the longitudinal direction A1. In the present specification, a reinforcement fiber having an inclination angle (absolute value) of less than or equal to 10° relative to the longitudinal direction A1 is referred to as a "straight-type reinforcement fiber". The third fiber reinforced layers 38c

include straight-type reinforcement fibers.

[0028] As shown in FIG. 6, the frame 4 includes fiber reinforced layers 38 including bias-type reinforcement fibers and fiber reinforced layers 38 including straight-type reinforcement fibers. The number of fiber reinforced layers 38 including bias-type reinforcement fibers is four, and the number of fiber reinforced layers 38 including straight-type reinforcement fibers is eight.

[In-Plane Stiffness Index G_i]

[0029] The tennis racket 2 has a proper in-plane stiffness index G_i . The in-plane stiffness index G_i is calculated by a mathematical formula shown below.

$$G_i = G_{it} \times G_{is}$$

[0030] In the above mathematical formula, G_{it} is a top pressure stiffness value (kgf/cm), and G_{is} is a side pressure stiffness value (kgf/cm).

[0031] FIGS. 10A and 10B show a method of measuring the top pressure stiffness value G_{it} . In FIG. 10, the tennis racket 2 is fixed to a support 44. The support 44 includes a spacer 46. The yoke 22 is placed on the spacer 46. The width direction X of the racket 2 coincides with the horizontal direction. The axial direction Y of the racket 2 coincides with the vertical direction. A plate 48, which is a rigid body, is in contact with the top of the racket. The plate 48 is lowered, and thereby a load is applied to the racket 2. A displacement (cm) of the plate 48 is measured from when the load is 25 kgf to when the load is 50 kgf. The top pressure stiffness value G_{it} is calculated by dividing the load difference 25 kgf by the displacement (cm). The top pressure stiffness value G_{it} is measured in a state where the string 12 is removed from the frame 4.

[0032] In light of repulsion performance, the top pressure stiffness value G_{it} is preferably greater than or equal to 60 kgf/cm, more preferably greater than or equal to 70 kgf/cm, and particularly preferably greater than or equal to 80 kgf/cm. In light of controllability, the top pressure stiffness value G_{it} is preferably less than or equal to 110 kgf/cm, more preferably less than or equal to 100 kgf/cm, and particularly preferably less than or equal to 90 kgf/cm.

[0033] FIG. 11 shows a method of measuring the side pressure stiffness value G_{is} . In FIG. 11, the tennis racket 2 is placed on a base 50, which is a rigid body. The width direction X of the racket 2 coincides with the vertical direction. The axial direction Y of the racket 2 coincides with the horizontal direction. A plate 52, which is a rigid body, is lowered, and thereby a load is applied to the racket 2. A displacement (cm) of the plate 52 is measured from when the load is 25 kgf to when the load is 50 kgf. The side pressure stiffness value G_{is} is calculated by dividing the load difference 25 kgf by the displacement (cm). The side pressure stiffness value G_{is} is measured in a state where the string 12 is removed from the frame 4.

[0034] In light of repulsion performance, the side pressure stiffness value G_{is} is preferably greater than or equal to 45 kgf/cm, more preferably greater than or equal to 50 kgf/cm, and particularly preferably greater than or equal to 60 kgf/cm. In light of controllability, the side pressure stiffness value G_{is} is preferably less than or equal to 100 kgf/cm, more preferably less than or equal to 90 kgf/cm, and particularly preferably less than or equal to 80 kgf/cm.

[0035] Preferably, the in-plane stiffness index G_i is greater than or equal to 5000 and less than or equal to 8000. The tennis racket 2 having an in-plane stiffness index G_i of greater than or equal to 5000 has excellent repulsion performance. In light of this, the in-plane stiffness index G_i is more preferably greater than or equal to 5100, and particularly preferably greater than or equal to 5150. The tennis racket 2 having an in-plane stiffness index G_i of less than or equal to 8000 has excellent controllability. In light of this, the in-plane stiffness index G_i is more preferably less than or equal to 7500, and particularly preferably less than or equal to 7200.

[0036] The ratio (G_{it} / G_{is}) of the top pressure stiffness value G_{it} to the side pressure stiffness value G_{is} is preferably greater than or equal to 1.0 and less than or equal to 1.8. When a ball is hit by the tennis racket 2 having the ratio (G_{it} / G_{is}) within this range, the tennis racket 2 suitably bends in the in-plane direction. Therefore, torsion of the face 20 is less likely to occur. This racket 2 has excellent repulsion performance. In light of repulsion performance, the ratio (G_{it} / G_{is}) is more preferably greater than or equal to 1.1, and particularly preferably greater than or equal to 1.2. In light of repulsion performance, the ratio (G_{it} / G_{is}) is more preferably less than or equal to 1.7, and particularly preferably less than or equal to 1.6.

[Out-of-Plane Stiffness Index G_o]

[0037] The tennis racket 2 has a proper out-of-plane stiffness index G_o . The out-of-plane stiffness index G_o is calculated by a mathematical formula shown below.

$$G_o = G_{os} \times G_{oh}$$

In the above mathematical formula, Gos is a throat stiffness value (kgf/cm), and Goh is a ball-hitting face stiffness value (kgf/cm).

[0038] FIGS. 12A and 12B show a method of measuring the throat stiffness value Gos . In this measurement, a first bar 54a, a second bar 54b, and a third bar 54c are prepared. The material of these bars 54 is steel. Each bar 54 has a circular cross-sectional shape having a radius of 5.0 mm. Each bar 54 extends along the width direction X. The distance between the first bar 54a and the third bar 54c in the axial direction Y is 100 mm, and the distance between the third bar 54c and the second bar 54b in the axial direction Y is 100 mm. The position of the first bar 54a is shifted toward the head 14 side from one end P1 of each throat 16. The position of the second bar 54b is shifted toward the grip 6 side from the other end P2 of each throat 16. The racket 2 is placed on the first bar 54a and the second bar 54b. The width direction X and the axial direction Y of the racket 2 coincide with the horizontal direction. The third bar 54c is lowered, and thereby a load is applied to the tennis racket 2. A displacement (cm) of the third bar 54c is measured from when the load is 25 kgf to when the load is 50 kgf. The throat stiffness value Gos is calculated by dividing the load difference 25 kgf by the displacement (cm). The throat stiffness value Gos is measured in a state where the string 12 is removed from the frame 4.

[0039] In light of repulsion performance, the throat stiffness value Gos is preferably greater than or equal to 350 kgf/cm, more preferably greater than or equal to 370 kgf/cm, and particularly preferably greater than or equal to 400 kgf/cm. In light of controllability, the throat stiffness value Gos is preferably less than or equal to 480 kgf/cm, more preferably less than or equal to 460 kgf/cm, and particularly preferably less than or equal to 440 kgf/cm.

[0040] FIGS. 13A and 13B show a method of measuring the ball-hitting face stiffness value Goh . In this measurement, a first bar 56a, a second bar 56b, and a third bar 56c are prepared. The material of these bars 56 is steel. Each bar 56 has a circular cross-sectional shape having a radius of 10.0 mm. Each bar 56 extends along the width direction X. The distance between the first bar 56a and the third bar 56c in the axial direction Y is 170 mm, and the distance between the third bar 56c and the second bar 56b in the axial direction Y is 170 mm. The first bar 56a is positioned at the top of the head 14. The racket 2 is placed on the first bar 56a and the second bar 56b. The width direction X and the axial direction Y of the racket 2 coincide with the horizontal direction. The third bar 56c is lowered, and thereby a load is applied to the tennis racket 2. A displacement (cm) of the third bar 56c is measured from when the load is 25 kgf to when the load is 50 kgf. The ball-hitting face stiffness value Goh is calculated by dividing the load difference 25 kgf by the displacement (cm). The ball-hitting face stiffness value Goh is measured in a state where the string 12 is removed from the frame 4.

[0041] In light of repulsion performance, the ball-hitting face stiffness value Goh is preferably greater than or equal to 100 kgf/cm, more preferably greater than or equal to 110 kgf/cm, and particularly preferably greater than or equal to 120 kgf/cm. In light of controllability, the ball-hitting face stiffness value Goh is preferably less than or equal to 170 kgf/cm, more preferably less than or equal to 160 kgf/cm, and particularly preferably less than or equal to 150 kgf/cm.

[0042] The out-of-plane stiffness index Go is preferably greater than or equal to 45000 and less than or equal to 60000. The tennis racket 2 having an out-of-plane stiffness index Go of greater than or equal to 45000 has excellent repulsion performance. In light of this, the out-of-plane stiffness index Go is more preferably greater than or equal to 46000, and particularly preferably greater than or equal to 47000. The tennis racket 2 having an out-of-plane stiffness index Go of less than or equal to 60000 has excellent controllability. In light of this, the out-of-plane stiffness index Go is more preferably less than or equal to 55000, and particularly preferably less than or equal to 51000.

[Performance of Tennis Racket]

[0043] The tennis racket 2 achieves both the in-plane stiffness index Gi falling within the range of greater than or equal to 5000 and less than or equal to 8000 and the out-of-plane stiffness index Go falling within the range of greater than or equal to 45000 and less than or equal to 60000. The tennis racket 2 is not only excellent in terms of repulsion performance, but also realizes a long contact time with a ball when hitting it. The repulsion performance and controllability of the tennis racket 2 are both excellent.

[0044] As previously described, the tennis racket 2 includes bias-type reinforcement fibers. The bias-type reinforcement fibers can contribute to achieving both the in-plane stiffness index Gi falling within the range of greater than or equal to 5000 and less than or equal to 8000 and the out-of-plane stiffness index Go falling within the range of greater than or equal to 45000 and less than or equal to 60000. In light of this, the ratio of the mass of the bias-type reinforcement fibers to the total mass of the reinforcement fibers is preferably greater than or equal to 15%, more preferably greater than or equal to 20%, and particularly preferably greater than or equal to 23%. This ratio is preferably less than or equal to 50%, more preferably less than or equal to 40%, and particularly preferably less than or equal to 35%.

[0045] The achievement of both the in-plane stiffness index Gi falling within the range of greater than or equal to 5000 and less than or equal to 8000 and the out-of-plane stiffness index Go falling within the range of greater than or equal to 45000 and less than or equal to 60000 can also be realized through adjustments of the material, thickness, density, etc. of the reinforcement fibers.

[0046] In FIG. 2, reference sign Pt denotes the top of the head 14; reference sign P1 denotes one end of each throat 16; and reference sign P2 denotes the other end of each throat 16. The end P1 is joint where the head 14 is joined to the throat

16. It is clear from FIG. 2 that the head 14 has a constant thickness from the top to the joint P1 (see also FIG. 1). In FIG. 2, an arrow T1 indicates the thickness of the top. The throats 16 have a constant thickness from the end P1 to the other end P2 (see also FIG. 1). In FIG. 2, an arrow T2 indicates the thickness of the throats 16. The shaft 18 has a constant thickness over its entirety. In FIG. 2, an arrow T3 indicates the thickness of the shaft 18. The thickness T2 and the thickness T3 are each equal to the thickness T1. In other words, the thickness of the frame 4 is constant except the yoke 22. The tennis racket 2 thus configured can achieve both the in-plane stiffness index Gi falling within the range of greater than or equal to 5000 and less than or equal to 8000 and the out-of-plane stiffness index Go falling within the range of greater than or equal to 45000 and less than or equal to 60000.

[0047] The maximum value of the thickness of the frame 4 is preferably less than 26.0 mm. In other words, preferably, at any part of the frame 4, the thickness thereof is less than 26.0 mm. The tennis racket 2 thus configured can achieve both the in-plane stiffness index Gi falling within the range of greater than or equal to 5000 and less than or equal to 8000 and the out-of-plane stiffness index Go falling within the range of greater than or equal to 45000 and less than or equal to 60000. In light of this, the maximum value of the thickness of the frame 4 is more preferably less than or equal to 24.5 mm, and particularly preferably less than or equal to 23.5 mm. In light of the durability of the tennis racket 2, the maximum value of the thickness of the frame 4 is preferably greater than or equal to 17.0 mm, more preferably greater than or equal to 19.0 mm, and particularly preferably greater than or equal to 20.0 mm.

[Embodiment 2]

[0048] FIG. 14 is a sectional view of a part of a tennis racket 58 according to another embodiment. FIG. 14 shows a frame 60. The frame 60 includes a damper 62. The damper 62 is sandwiched between fiber reinforced layers. The damper 62 can suppress vibration that propagates to the tennis player holding the tennis racket 58. This allows the player to have an excellent hitting feeling. The components of the racket 58, except the damper 62, are the same in configuration as those of the racket 2 shown in FIGS. 1 to 9.

[0049] The damper 62 is formed from a polymer composition. The polymer composition contains a base polymer. The polymer composition may contain additive agents as necessary. Examples of a suitable base polymer for the damper 62 include polyurethanes, styrene-based elastomers, and acrylic elastomers. The damper 62 may be foam.

[0050] A preferable position of the damper 62 is a position in the outer side of the head in the width direction X. Another preferable position of the damper 62 is a position in each throat.

[0051] Preferably, the vibration damping rate of the tennis racket 58 in the out-of-plane direction thereof is greater than or equal to 0.5%. The racket 58 having a vibration damping rate of greater than or equal to 0.5% in the out-of-plane direction provides an excellent hitting feeling. In light of this, the vibration damping rate in the out-of-plane direction is more preferably greater than or equal to 0.6%, and particularly preferably greater than or equal to 0.7%.

[0052] FIGS. 15A and 15B show a method of measuring an out-of-plane natural frequency of the tennis racket 58. In this method, the racket 58 is suspended by a cord 64. The axial direction Y of the racket 58 coincides with the vertical direction. A head 66 is positioned above a shaft 68. A grip tape has been peeled off from the shaft 68. A string has been removed from the head 66. An acceleration pickup 70 is mounted to the head 66. The acceleration pickup 70 is mounted such that it is positioned on the outermost side of the head 66 in the width direction X. The acceleration pickup 70 is oriented in the thickness direction Z. The acceleration pickup 70 has a mass of 3.5 g. A point Ph on the opposite side of the head 66 from the acceleration pickup 70 is excited by an impulse hammer (not shown). A typical impulse hammer is available from PCB Piezotronics, Inc. Input vibration measured by a force pickup included in the impulse hammer and response vibration measured by the acceleration pickup 70 are fed to a frequency analyzer via an amplifier. A typical frequency analyzer is "Dynamic Signal Analyzer" available from Hewlett-Packard Company. Based on a transfer function obtained by the frequency analyzer, an out-of-plane natural vibration damping rate is calculated. The vibration damping rate (ζ) is calculated by a mathematical formula shown below.

$$\zeta = (1 / 2) \times (\Delta\omega / \omega_n)$$

[0053] In the above mathematical formula, ω_n is out-of-plane primary natural vibration, and $\Delta\omega$ is a peak width in the case of a transfer function To (see FIG. 16). The transfer function To is calculated by a mathematical formula shown below.

$$To = Tn / (2^{1/2})$$

[0054] In the above mathematical formula, Tn is the transfer function of the out-of-plane primary natural vibration.

Examples

[0055] The following elucidates the effects of the racket according to Examples. However, the scope of the disclosure in the present specification should not be restrictively construed based on the description of the Examples below.

[Example 1]

[0056] A tennis racket of Example 1 was fabricated. The frame of the racket was fabricated to include a plurality of fiber reinforced layers including reinforcement fibers. The ratio of the mass of bias-type reinforcement fibers to the total mass of the reinforcement fibers was 25%. The maximum thickness of the racket was 21.5 mm.

[Examples 2 and 3 and Comparative Examples 1 to 6]

[0057] Tennis rackets of Examples 2 and 3 and Comparative Examples 1 to 6 were obtained. Tables 1 and 2 below show the specifications of these tennis rackets.

[Initial Velocity]

[0058] Two advanced-level tennis players did a rally by using each tennis racket. The velocity of a ball hit by the racket during the rally was measured. The measurement was performed a plurality of times, and the measurement results are shown in Tables 1 and 2 below.

[Hitting Feeling]

[0059] The tennis players evaluated and rated the hitting feeling of each tennis racket during the rally in accordance with the following grading system.

- A: Good
- B: Not too bad
- C: Bad

[0060] The evaluation results are shown in Tables 1 and 2 below.

Table 1 Evaluation Results

	Example 1	Example 2	Example 3	Comp. Example 1	Comp. Example 2
Face Area [sqin]	98	95	100	98	98
Mass [mm]	305	310	300	305	305
Balance [mm]	315	310	320	315	315
Overall Length [mm]	686	686	686	686	686
Maximum Thickness [mm]	21.5	20.5	23.0	21.5	21.0
Gi	5,171	7,184	7,185	6,586	3,680
Go	50,174	47,484	49,987	41,779	39,214
Initial Velocity [km/h]	120.4	120.6	120.4	120.0	120.2
Controllability	A	A	A	A	A

Table 2 Evaluation Results

	Comp. Example 3	Comp. Example 4	Comp. Example 5	Comp. Example 6
Face Area [sqin]	98	100	95	100
Mass [mm]	305	300	320	300
Balance [mm]	315	320	310	320
Overall Length [mm]	686	686	686	686

(continued)

	Comp. Example 3	Comp. Example 4	Comp. Example 5	Comp. Example 6
Maximum Thickness [mm]	23.0	25.0	21.0	26.0
Gi	9,377	7,491	8,268	8,265
Go	73,673	62,069	51,477	81,249
Initial Velocity [km/h]	122.9	121.8	118.5	123.3
Controllability	C	B	B	C

[0061] It is clear from Tables 1 and 2 that the tennis racket of each Example is excellent in terms of both repulsion performance and controllability. These evaluation results clearly indicate the superiority of the racket of each Example.

[Disclosure Items]

[0062] The following items each disclose a preferred embodiment.

[Item 1]

[0063] A racket including: a frame including a head; and a string that is stretched on the head and that forms a ball-hitting face, wherein: a maximum value of a thickness of the frame is less than 26.0 mm; an in-plane stiffness index Gi that is a product of a top pressure stiffness value Git (kgf/cm) and a side pressure stiffness value Gis (kgf/cm) is greater than or equal to 5000 and less than or equal to 8000; and an out-of-plane stiffness index Go that is a product of a throat stiffness value Gos (kgf/cm) and a ball-hitting face stiffness value Goh (kgf/cm) is greater than or equal to 45000 and less than or equal to 60000.

[Item 2]

[0064] The racket according to item 1, wherein: the frame includes a pair of throats that are continuous with the head and a shaft that is continuous with the throats; the head has a constant thickness T1 from a top of the head to joints where the head is joined to the respective throats; the throats have a constant thickness T2; the shaft has a constant thickness T3; and the thickness T2 and the thickness T3 are each equal to the thickness T1.

[Item 3]

[0065] The racket according to item 1 or 2, wherein a ratio (Git / Gis) of the top pressure stiffness value Git to the side pressure stiffness value Gis is greater than or equal to 1.0.

[Item 4]

[0066] The racket according to any one of items 1 to 3, wherein: the frame includes a damper; and a vibration damping rate of the racket in an out-of-plane direction thereof is greater than or equal to 0.5%.

[0067] The racket as described above is suitable also for use in, for example, soft tennis, squash, padel, and badminton. The above descriptions are merely illustrative examples, and various modifications can be made without departing from the principles of the present invention.

Claims

1. A racket (2) comprising:

a frame (4) including a head (14); and

a string (12) that is stretched on the head (14) and that forms a ball-hitting face, wherein:

a maximum value of a thickness of the frame (4) is less than 26.0 mm;

an in-plane stiffness index (Gi) that is a product of a top pressure stiffness value (Git) (kgf/cm) and a side pressure stiffness value Gis (kgf/cm) is greater than or equal to 5000 and less than or equal to 8000; and

an out-of-plane stiffness index (G_o) that is a product of a throat stiffness value (G_{os}) (kgf/cm) and a ball-hitting face stiffness value G_{oh} (kgf/cm) is greater than or equal to 45000 and less than or equal to 60000.

2. The racket (2) according to claim 1, wherein:

the frame (4) includes a pair of throats (16a, 16b) that are continuous with the head (14) and a shaft (18) that is continuous with the throats (16a, 16b);
the head (14) has a constant thickness T_1 from a top of the head to joints where the head (14) is joined to the respective throats (16a, 16b);
the throats (16a, 16b) have a constant thickness T_2 ;
the shaft (18) has a constant thickness T_3 ; and
the thickness T_2 and the thickness T_3 are each equal to the thickness T_1 .

3. The racket (2) according to claim 1 or 2, wherein

a ratio (G_{it} / G_{is}) of the top pressure stiffness value G_{it} to the side pressure stiffness value G_{is} is greater than or equal to 1.0.

4. The racket (2) according to claim 3, wherein the ratio (G_{it} / G_{is}) of the top pressure stiffness value (G_{it}) to the side pressure stiffness value (G_{is}) is less than or equal to 1.8.

5. The racket (2) according to any one of claims 1 to 4, wherein:

the frame includes a damper; and
a vibration damping rate of the racket in an out-of-plane direction thereof is greater than or equal to 0.5%.

6. The racket (2) according to any one of claims 1 to 5, wherein the top pressure stiffness value (G_{it}) is greater than or equal to 60 kgf/cm.

7. The racket (2) according to any one of claims 1 to 6, wherein the top pressure stiffness value (G_{it}) is less than or equal to 110 kgf/cm.

8. The racket (2) according to one of claims 1 to 7, wherein the side pressure stiffness value (G_{is}) is greater than or equal to 45 kgf/cm.

9. The racket (2) according to one of claims 1 to 8, wherein the side pressure stiffness value G_{is} is less than or equal to 100 kgf/cm.

10. The racket (2) according to one of claims 1 to 9, wherein the throat stiffness value (G_{os}) is greater than or equal to 350 kgf/cm.

11. The racket (2) according to one of claims 1 to 10 wherein the throat stiffness value (G_{os}) is less than or equal to 480 kgf/cm.

12. The racket (2) according to one of claims 1 to 11, wherein the ball-hitting face stiffness value (G_{oh}) is greater than or equal to 100 kgf/cm.

13. The racket (2) according to one of claims 1 to 12, wherein the ball-hitting face stiffness value (G_{oh}) is less than or equal to 170 kgf/cm.

14. The racket (2) according to one of claims 1 to 13, wherein the frame (4) includes a plurality of fiber reinforced layers.

15. The racket (2) according to claim 14, wherein the plurality of fiber reinforced layers of the frame (4) comprises between two or more kinds of fiber reinforced layers, optionally with at least one kind comprising bias-type reinforcement fibers and straight type reinforcement fibers.

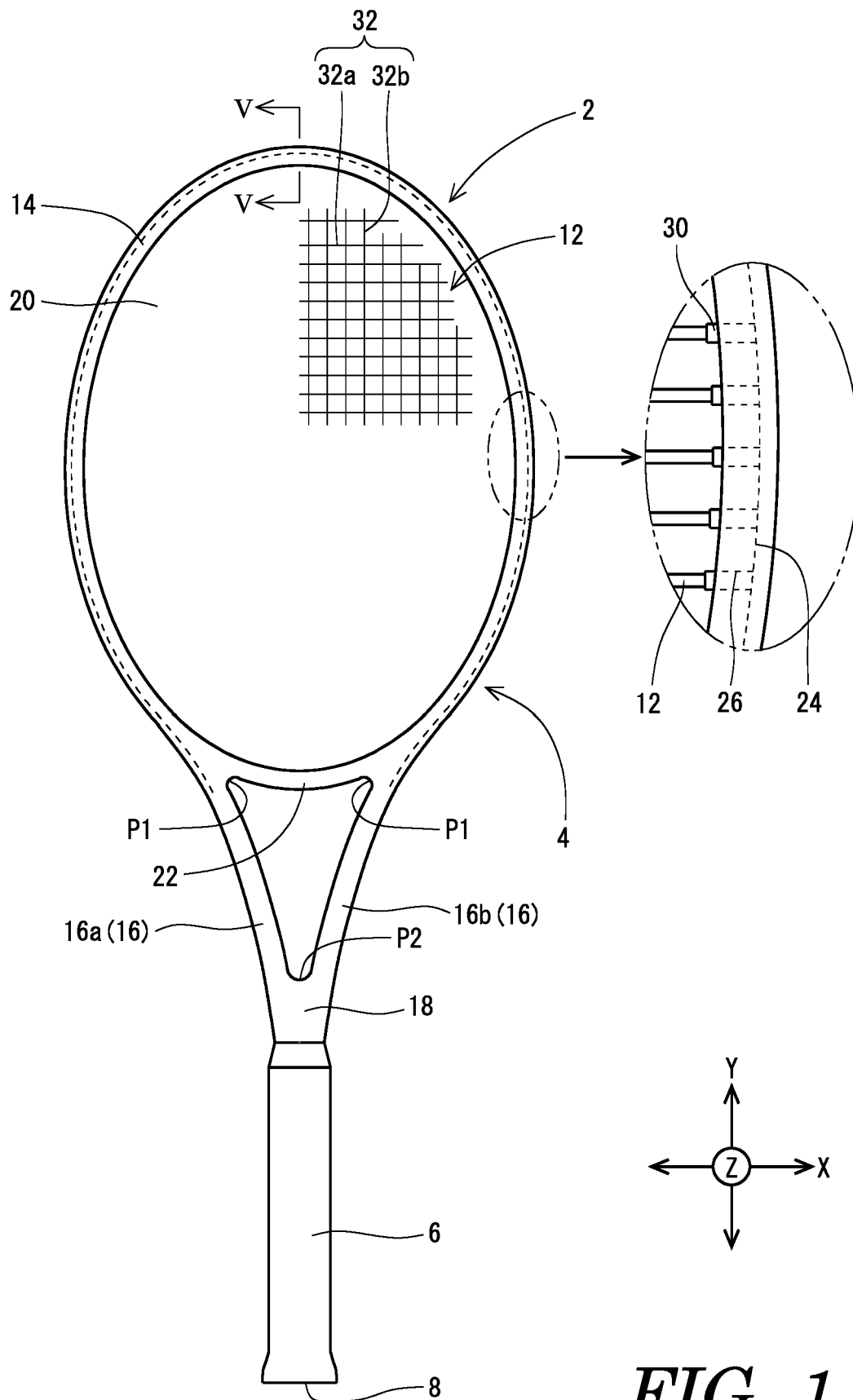


FIG. 1

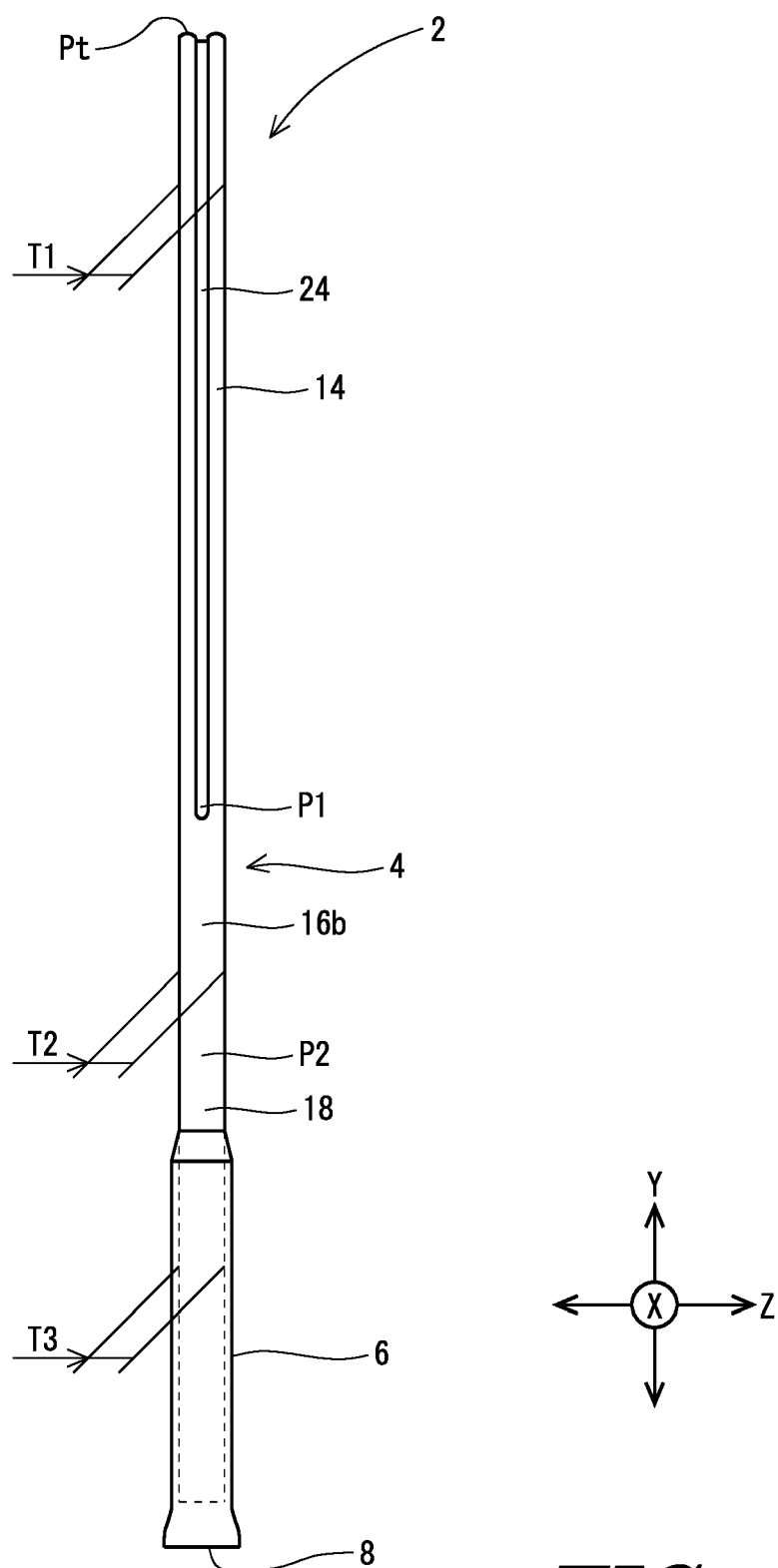


FIG. 2

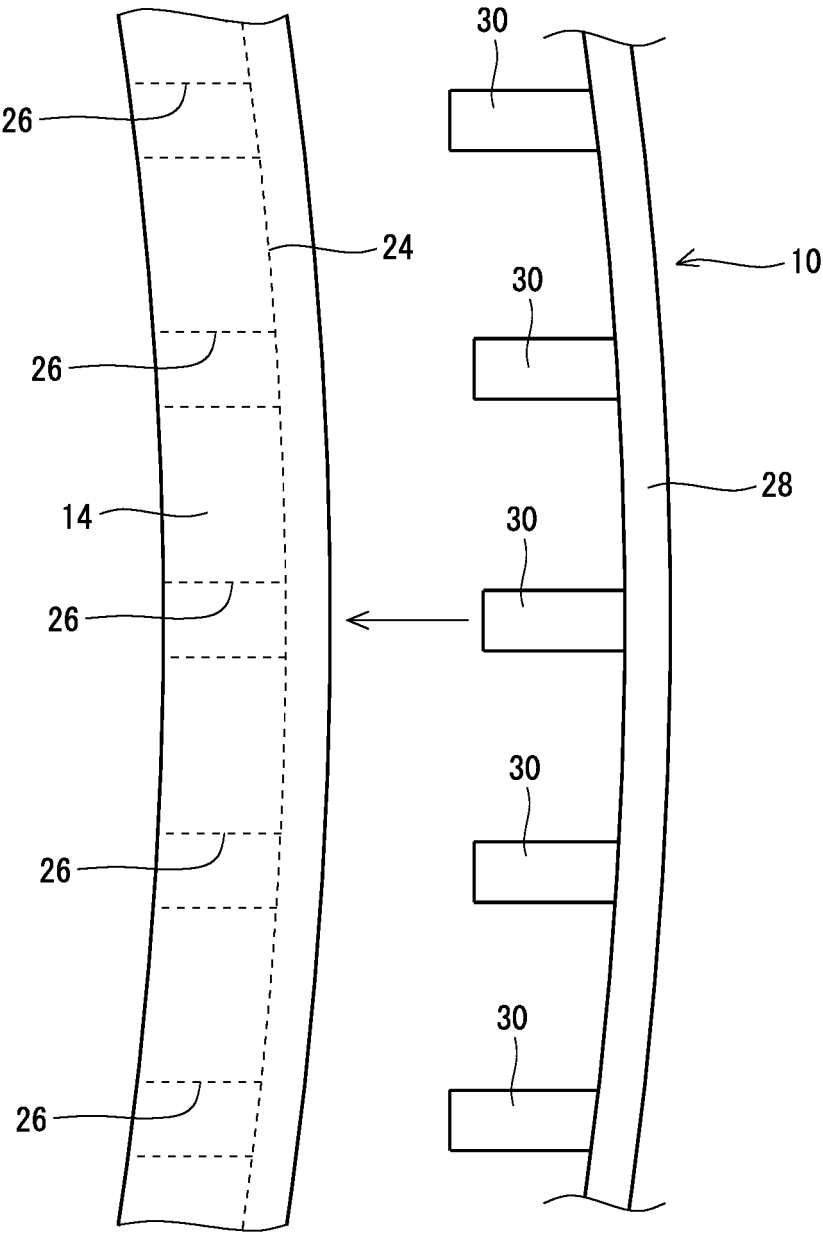


FIG. 3

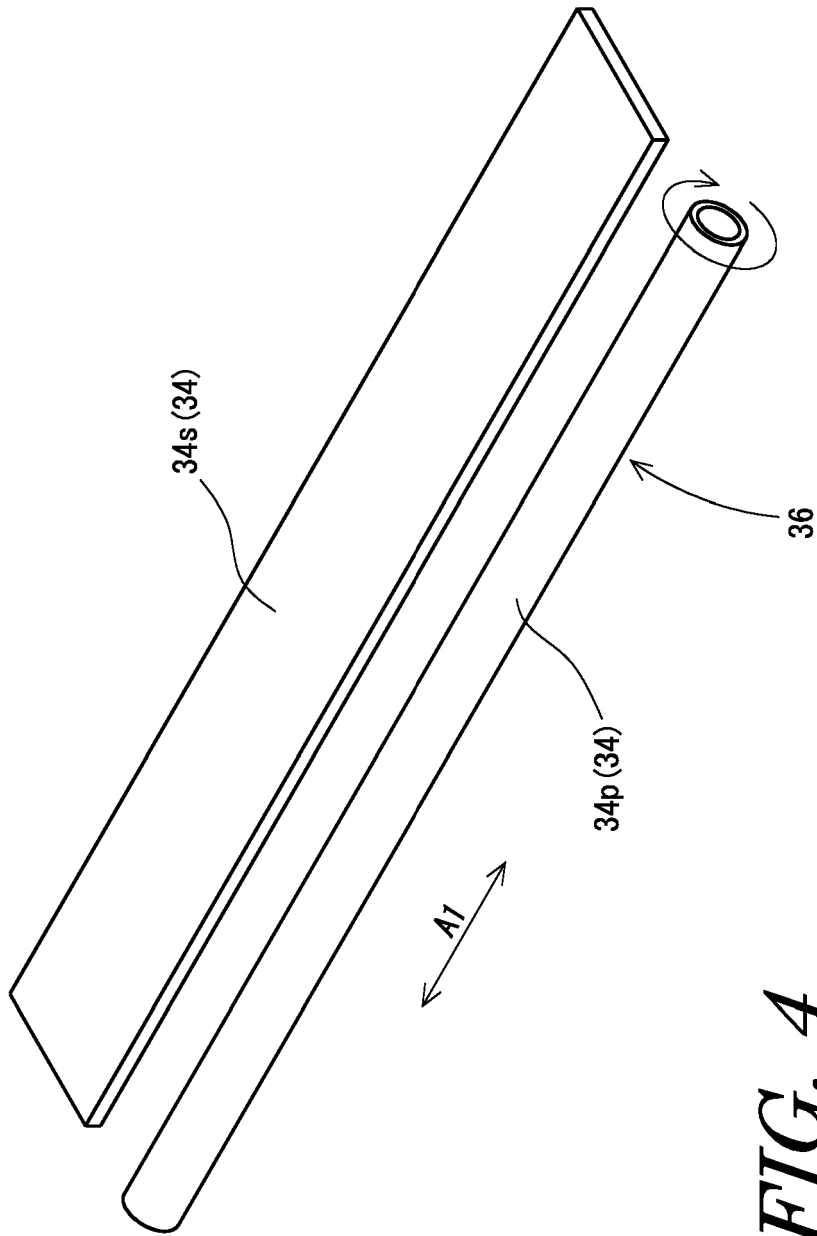


FIG. 4

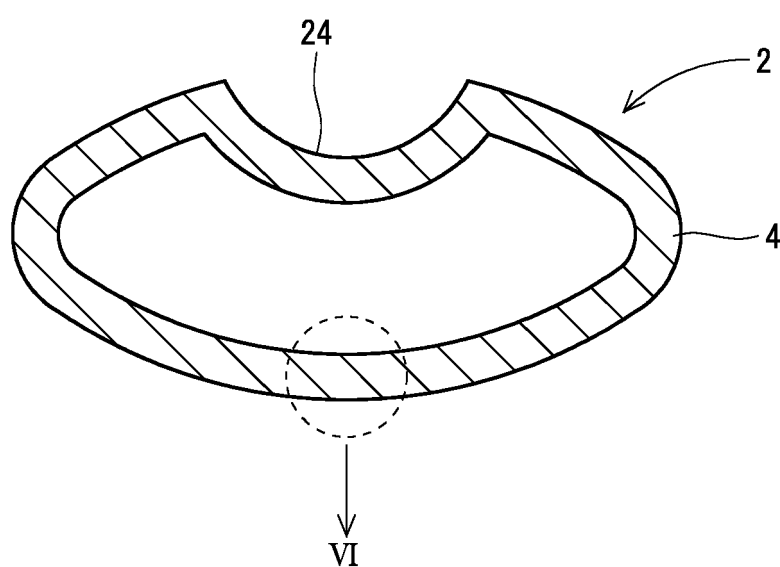


FIG. 5

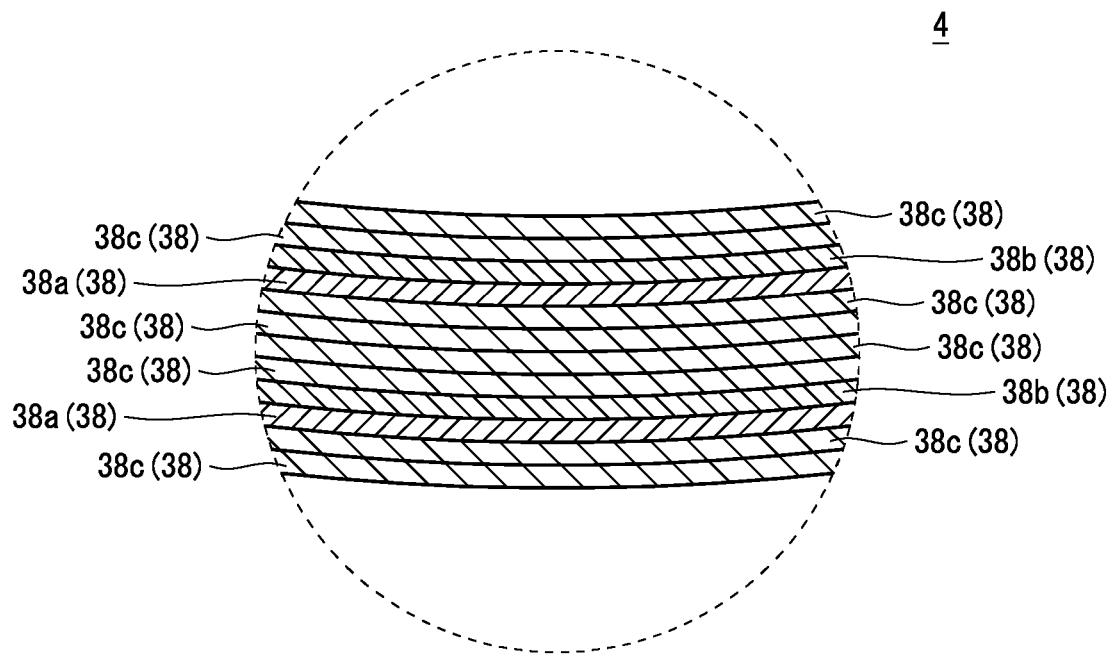


FIG. 6

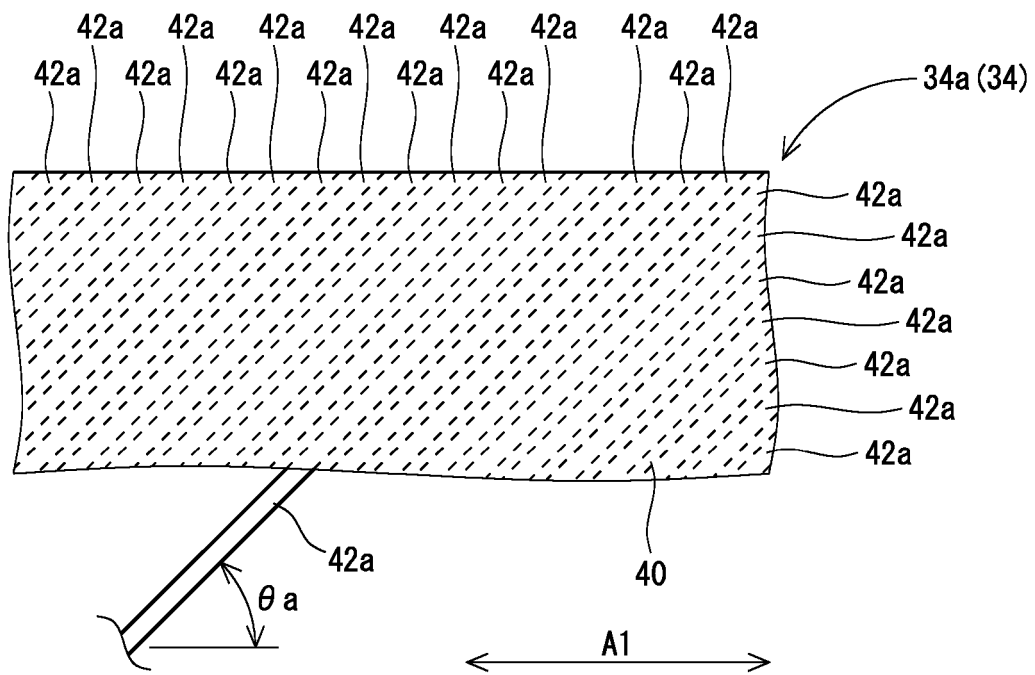


FIG. 7

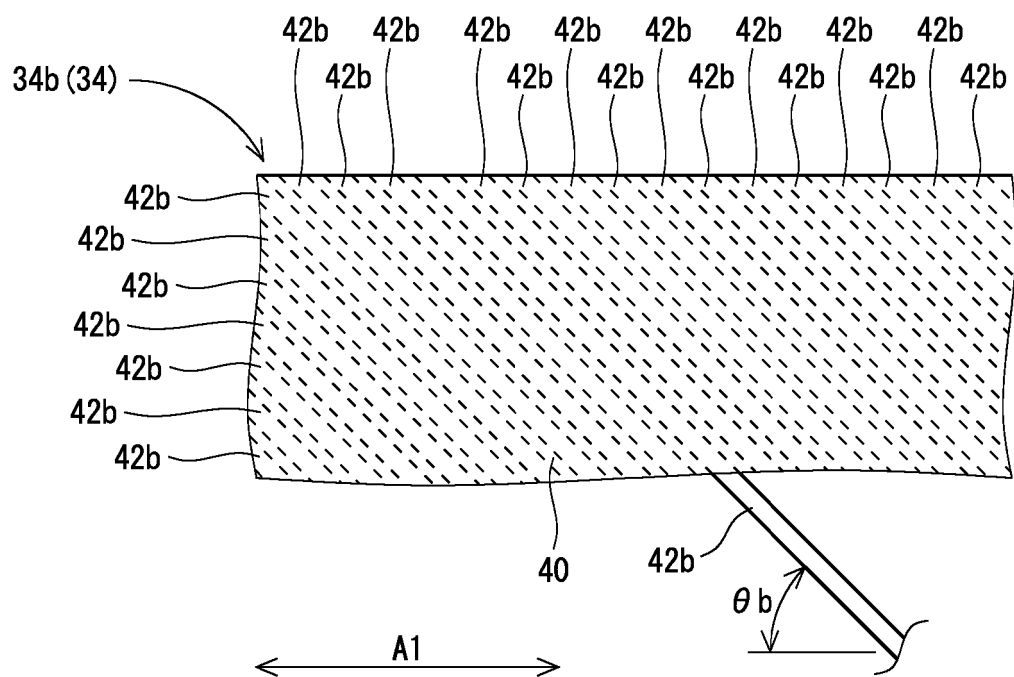


FIG. 8

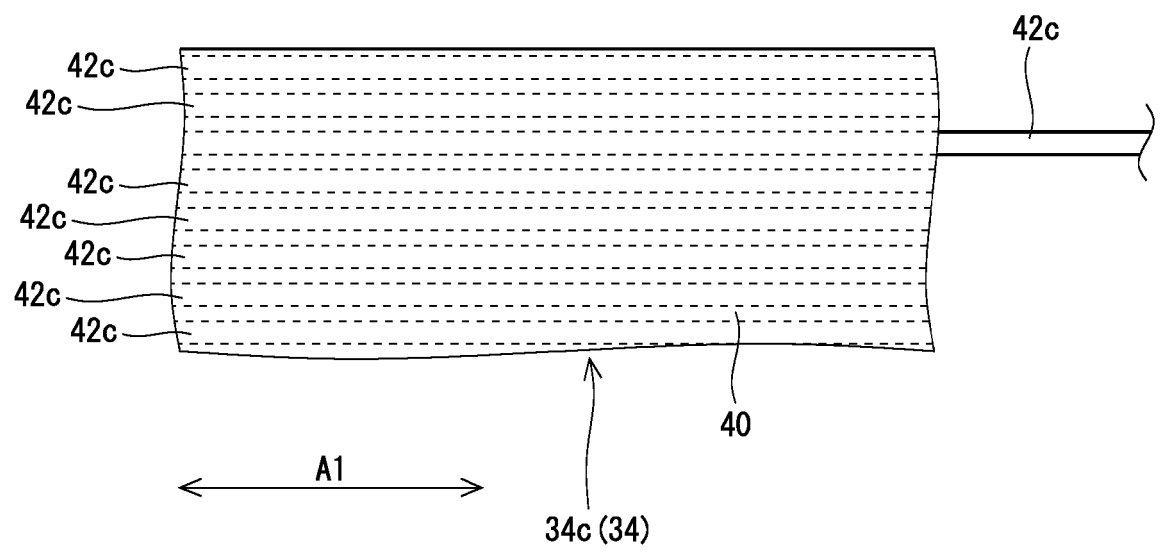


FIG. 9

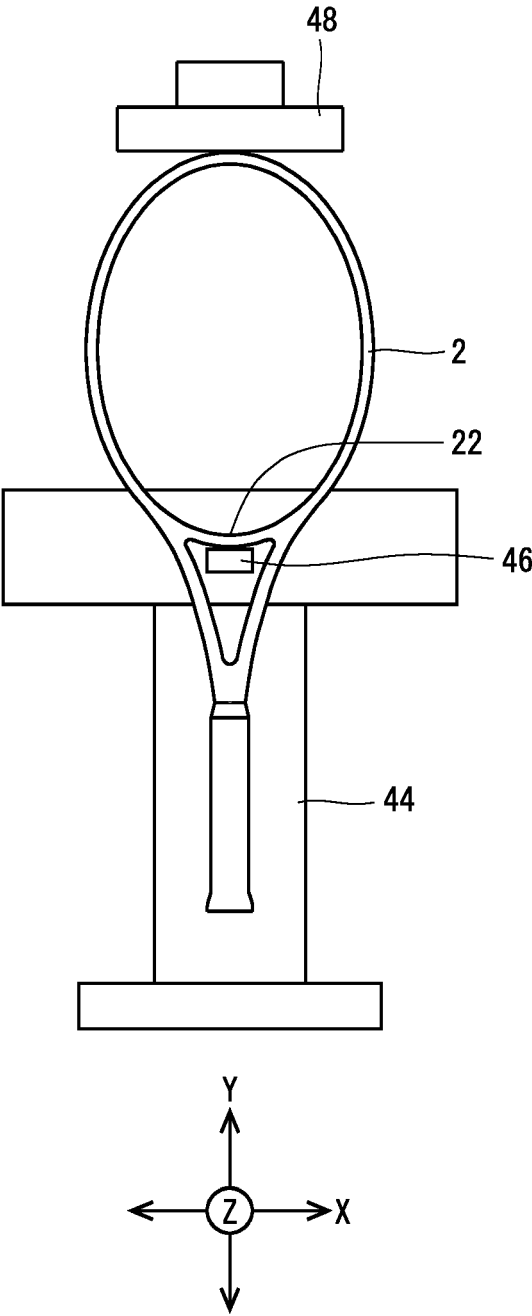


FIG. 10A

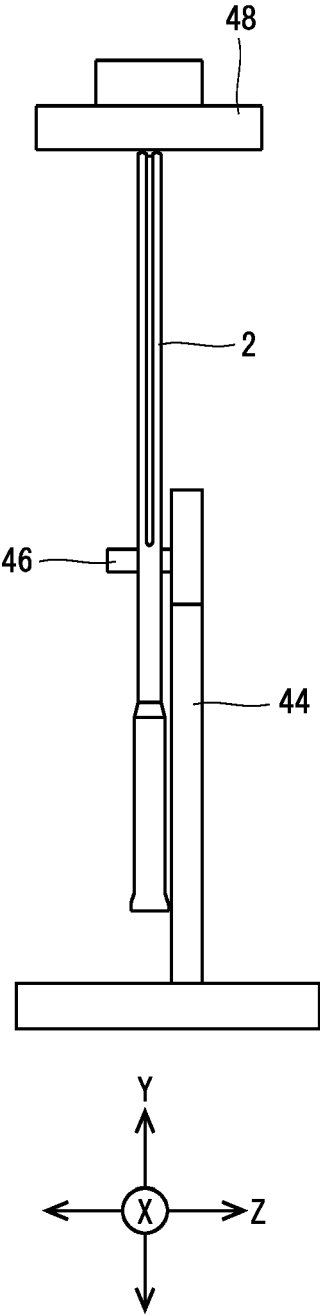


FIG. 10B

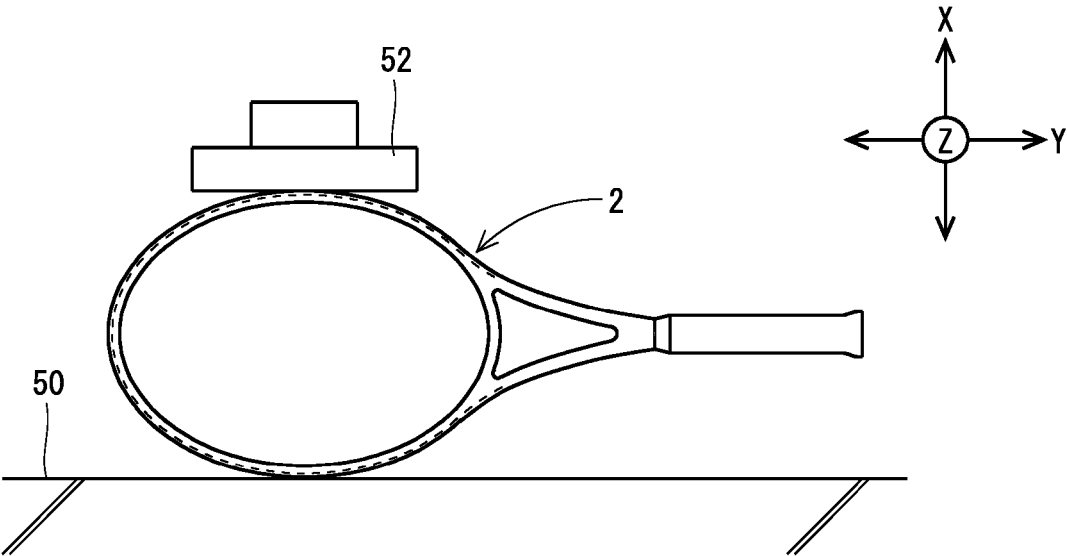


FIG. 11

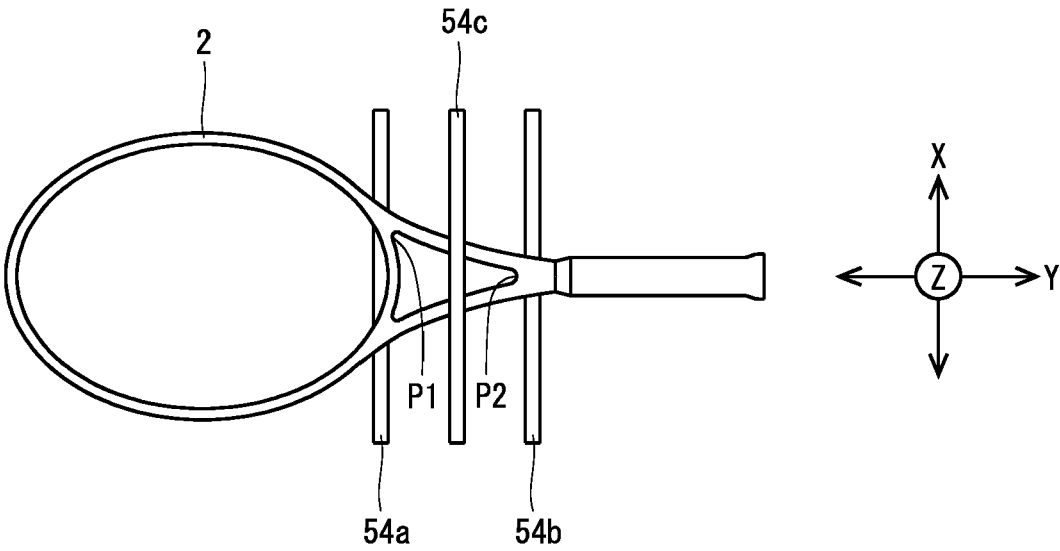


FIG. 12A

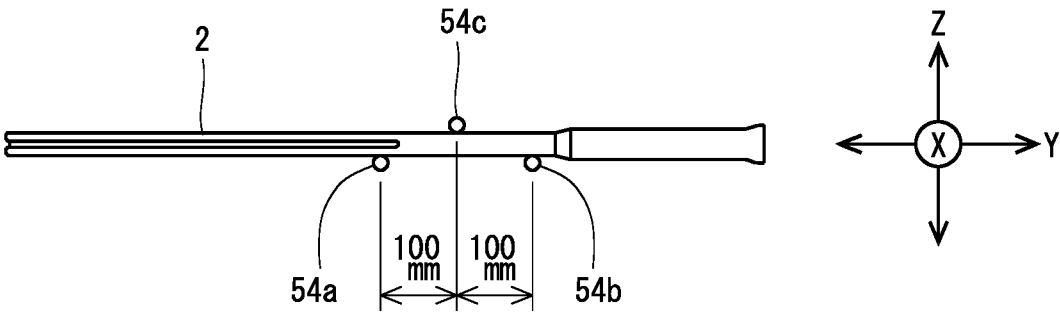


FIG. 12B

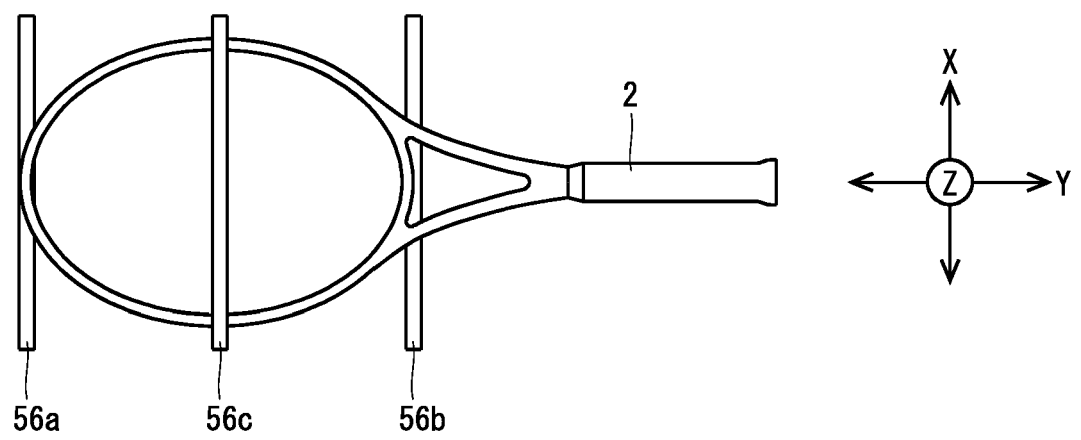


FIG. 13A

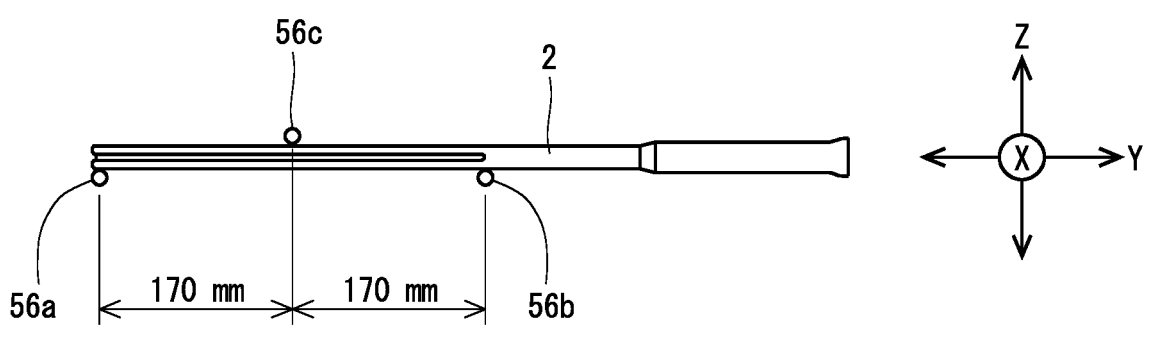


FIG. 13B

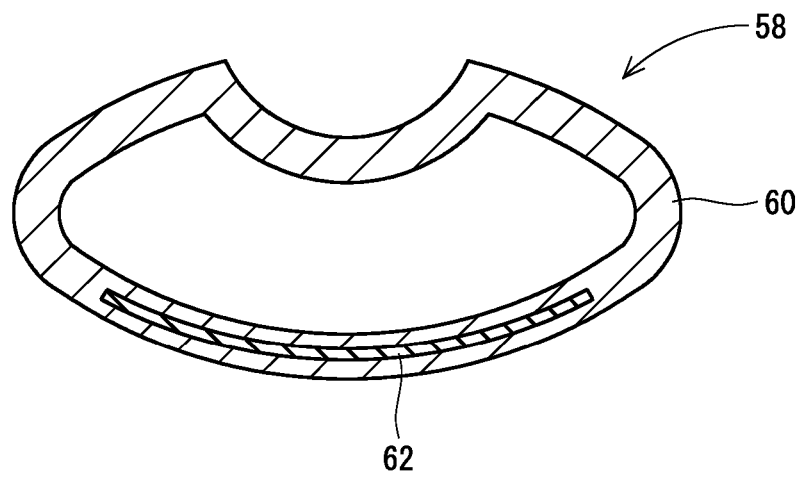


FIG. 14

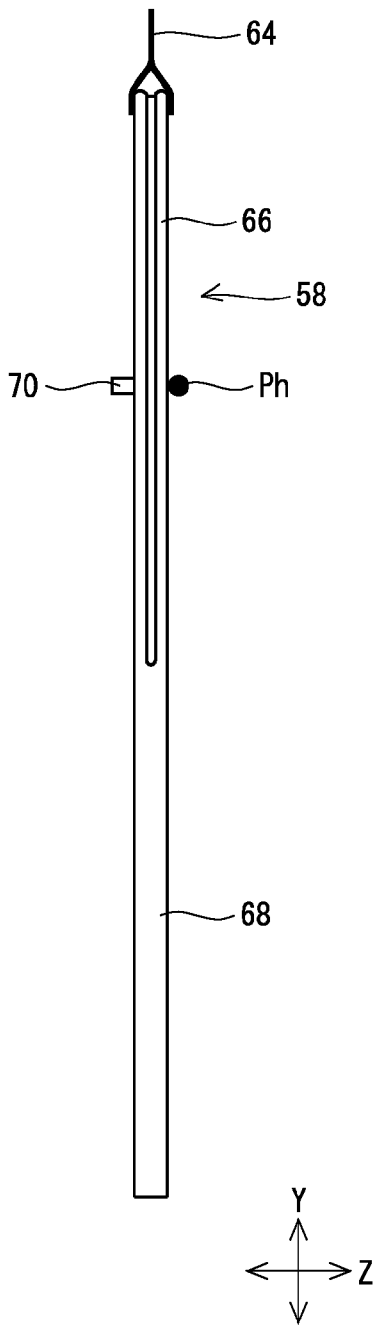


FIG. 15A

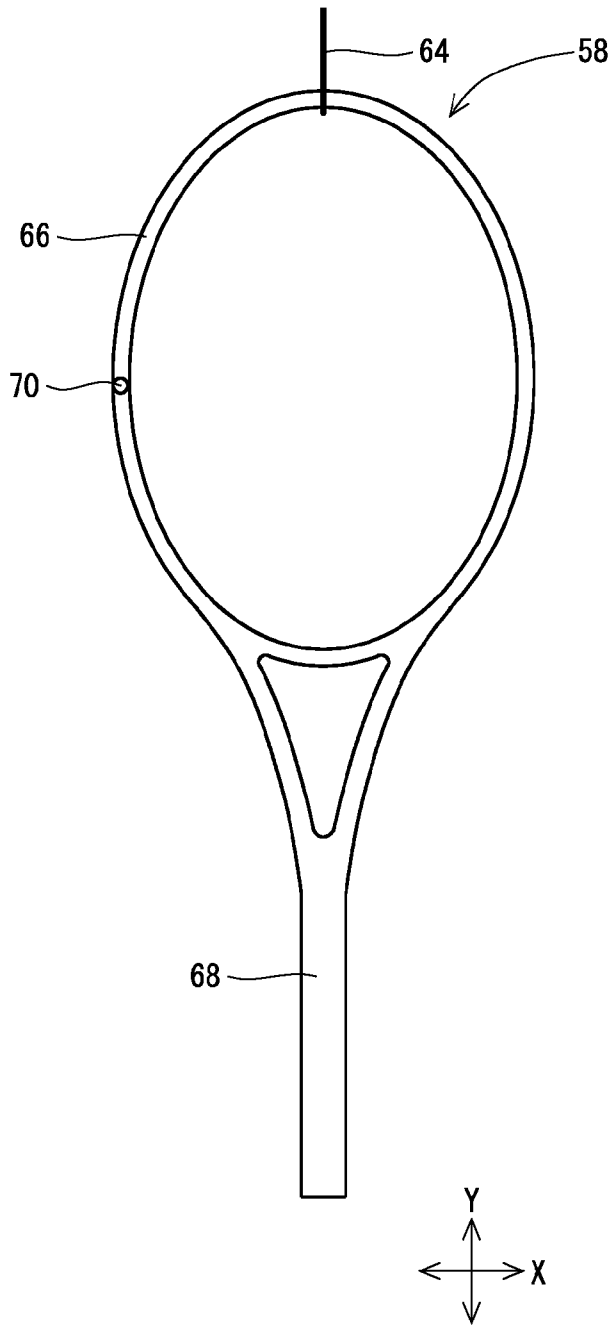
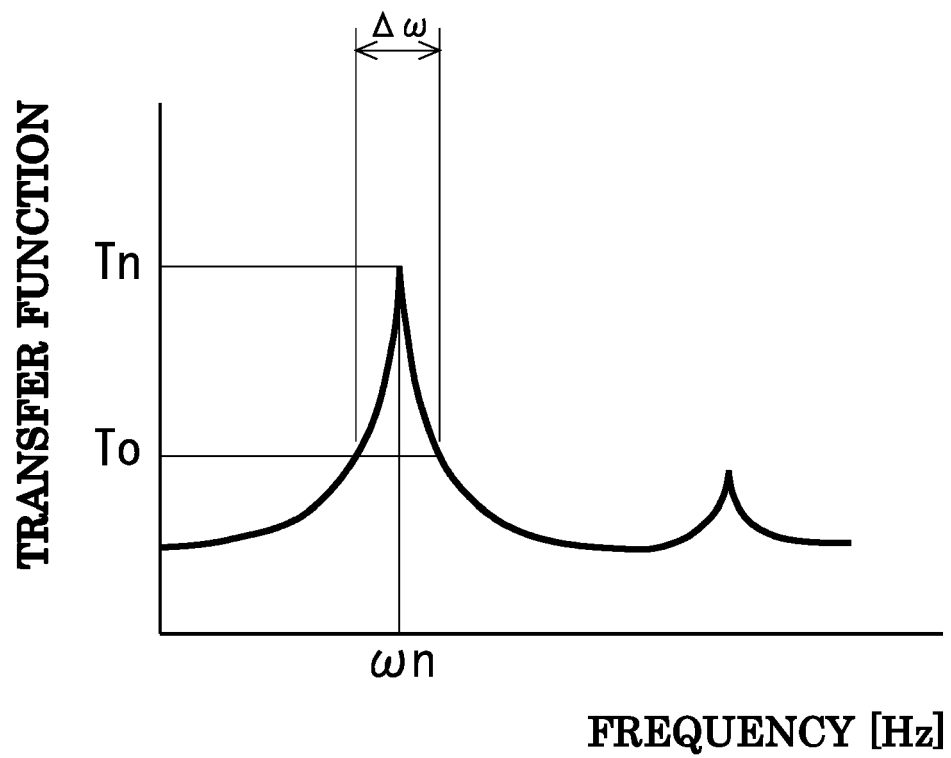


FIG. 15B

*FIG. 16*



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Application Number

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