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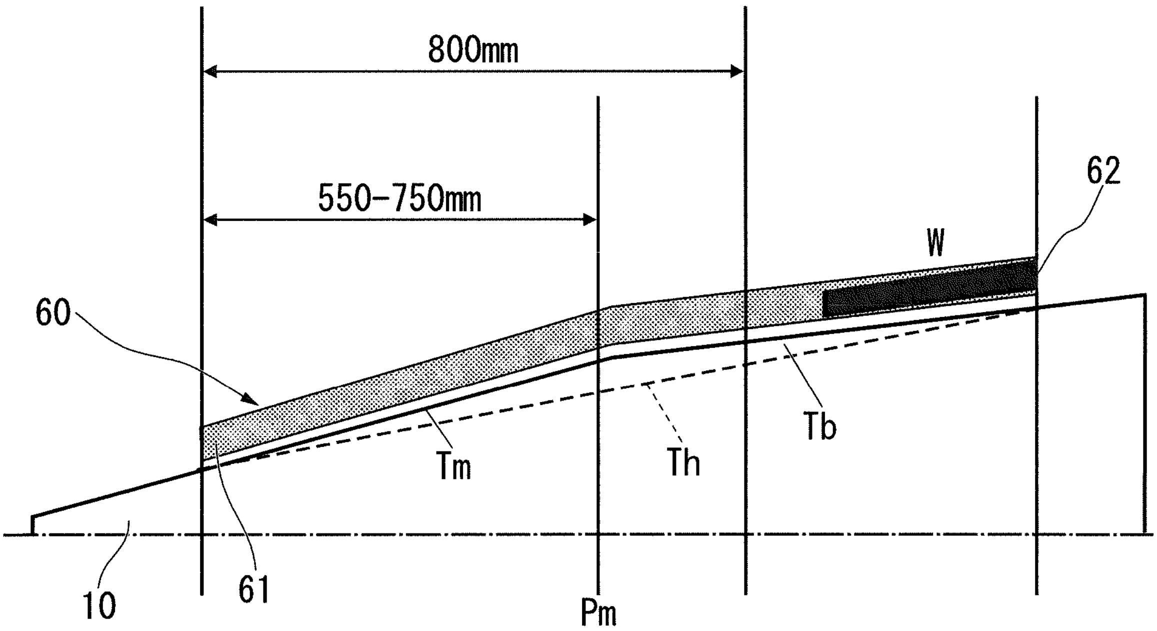
(54) GOLF CLUB SHAFT

(57) The present invention provides a high-balance-point shaft capable of increasing ball speed. A golf club shaft formed by laminating fiber-reinforced resin, wherein the balance point obtained by formula below is set to be 53% or higher; and the kickpoint obtained by formula below is set to be 44% or higher.

FIG. 2



EP 2 891 508 A1

Description

Field of the Invention

[0001] The present invention relates to a shaft used for a golf club.

[0002] The present application is based upon and claims the benefit of priority to Japanese Patent Application No. 2012-191090, filed August 31,2012. The entire contents of the application are incorporated herein by reference.

Background Art

[0003] Since restitution regulations on golf club heads were added to the rules, various methods have been attempted to compensate for lower restitution at the head. Designing heavier heads is one such attempt. That technology aims to extend carry distance by increasing the clubhead weight so as to increase the kinetic energy of the head during the swing motion.

[0004] However, if the clubhead weight is set greater, the moment of inertia of the club increases, resulting in a "heavy" feel during the swing motion. To solve the problem, golf shafts are also being improved, and a so-called high-balance-point shaft, in which the gravity center is shifted closer to the grip, is drawing attention. By so setting, even with a heavier head, the gravity center of the club is closer to the grip, preventing a "heavy" feel during the swing motion.

[0005] Patent publication 1 describes a shaft designed to increase the clubhead weight to the extent allowable by making the portion closer to the grip heavier so that even with the heavy head, a "heavy" feel during a swing motion is prevented. More specifically, patent publication 1 discloses a shaft where the balance point of the shaft, namely, the percentage of the distance from the tip end to the gravity center, is 56.5% or greater of the entire length of the shaft.

[0006] Patent publication 2 describes a specific method for manufacturing a so-called high-balance point shaft, where the portion closer to the grip is made heavier. The tip side of a high-balance point shaft is thinner. Thus, the publication discloses a technology so that strength is increased while the tip-side thickness is decreased to the extent allowable. Using the technology, the shaft is designed to have the gravity center positioned at a balance point of 53.0% or higher.

[0007] Theoretically, ball speed (carry distance) is expected to increase by a heavier head on a high-balance-point shaft as described in aforementioned publications. However, the problem is that ball speed does not always increase as theoretically predicted.

PRIOR ART PUBLICATION

PATENT PUBLICATION

[0008]

Patent publication 1: Specification of U.S. Patent Publication No. 2012/0071266
Patent publication 2: JP H09-239082A

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0009] In view of the aforementioned problems, the objective of the present invention is to provide a high-balance-point shaft capable of increasing ball speed.

SOLUTIONS TO THE PROBLEMS

[0010] The inventors of the present invention have carried out intensive studies and found that the above problems are solved by designing a shaft to have both a high balance point and a high kickpoint. Namely, the embodiments of the present invention are described in the following [1]~[11].

[0011]

[1] A golf club shaft formed by laminating fiber-reinforced resin in which the balance point obtained by formula (1) below is set at 53% or higher, and the kickpoint obtained by formula (2) below is set at 44% or higher.

$$\text{balance point (\%)} = (L_G/L_S)\times 100 \cdots \text{(formula 1)}$$

L_G: distance from the gravity center of a shaft to the tip end of the shaft
L_S: full length of the shaft

$$\text{kickpoint (\%)} = (L_K/L_B)\times 100 \cdots \text{(formula 2)}$$

L_K: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the shaft length, the distance from the tip end of the shaft to a point where a straight line connecting both ends intersects with a perpendicular line drawn from the apex of the curve.
L_B: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the shaft length, the linear distance between both ends of the shaft.

[2] The golf club shaft described in [1] above, in which the tip-side end of a weight layer (W) which weighs 10~30 wt.% of the shaft weight is positioned 800 mm or greater from the tip end of the shaft, and the flexural modulus of the weight layer (W) in a longitudinal direction of the shaft is 70 GPa or lower.

[3] The golf club shaft described in [1] or [2] above, in which the average thickness of the weight layer (W) is 0.5 mm or less.

[4] The golf club shaft described in any of [1]~[3] above, in which the mass of the shaft (M) [g] and its full length (L_S) [mm] satisfy the following formula.

$$30 \leq M\times(L_S/1168) \leq 80$$

[5] The golf club shaft described in any of [1]~[4] above, where the shaft is formed in a tube shape; the inner diameter of the shaft tapers, gradually increasing from the tip end toward the butt end; the inner-diameter taper has an inner-diameter taper bending point (Pm); the inner-diameter taper bending point (Pm) is positioned 550~750 mm from the tip end of the shaft; and when an inner-diameter tapering gradient is set as (Tm) to indicate the inner-diameter inclination between the tip end and the inner-diameter taper bending point (Pm), and when an inner-diameter tapering gradient is set as (Tb) to indicate the inner-diameter inclination between the inner-diameter taper bending point (Pm) and the butt end, Tm>Tb is satisfied.

[6] The golf club shaft described in [5], in which the inner-diameter taper has an inner-diameter taper bending point (Pt) positioned 40~140 mm from the tip end of the shaft, and when an inner-diameter tapering gradient is set as (Tt) to indicate the inner-diameter inclination between the tip end and the inner-diameter taper bending point (Pt), and when an inner-diameter tapering gradient is set as (Tm') to indicate the inner-diameter inclination between the inner-diameter taper bending point (Pt) and the inner-diameter taper bending point (Pm), the following are satisfied:

$Tt<Tm'$
$0.1/1000 \leq Tt \leq 5/1000$

[7] The golf club shaft described in [5] or [6] above, where (Tm) and (Tb) as defined above satisfy $1.5 \leq Tm/Tb \leq 5.5$.

[8] The golf club shaft described in any of [1]~[7] above, where the outer diameter at the tip end is 8.5 mm~9.3 mm, and the outer diameter at the butt end is 14.0 mm~16.5 mm.

[9] The golf club shaft described in any of [1]~[8] above, further including the following: an angle layer made of fiber-reinforced resin where the fiber orientation is set diagonally to the longitudinal direction of the shaft; the weight layer (W); a straight layer made of fiber-reinforced resin where the fiber orientation is set to be parallel to the longitudinal direction of the shaft; and a hoop layer where the fiber orientation is set to be perpendicular to the longitudinal direction of the shaft.

[10] The golf club shaft described in [9] above, further including a reinforcement layer made of fiber-reinforced resin; the reinforcement layer is disposed 400 mm or less from the tip end side of the shaft and has a fiber orientation set to be parallel to the longitudinal direction of the shaft.

[11] A golf club formed by using the golf club shaft described in any of [1]~[10] above.

EFFECTS OF THE INVENTION

[0012] A golf club shaft according to one aspect of the present invention and a golf club made of such a golf club shaft are capable of lowering the rate of reduction in head speed relative to a gain in head weight. As a result, when a gain in head weight causes the initial ball speed to increase, the effect is maximized, and carry distance of the ball increases.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1: a view showing the laminated structure of an embodiment of the present invention;
FIG. 2: a half sectional view of a shaft (including a mandrel) of an embodiment of the present invention;
FIG. 3: a half sectional view of a shaft (including a mandrel) of another embodiment of the present invention;
FIG. 4: a half sectional view of a shaft (including a mandrel) of yet another embodiment of the present invention;
FIG. 5: a view showing three examples of a hoop layer employable in each embodiment of the present invention;
FIG. 6: a graph illustrating the results showing the relationship between head weight and head speed in simulations conducted on an embodiment of the present invention;
FIG. 7: a view schematically illustrating the balance point in an embodiment of the present invention; and
FIG. 8 a view schematically illustrating the kickpoint in an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0014] In the following, examples of the embodiment of the present invention are described in detail. In the present application, the widest end of a shaft is referred to as the butt end, and the narrowest end as the tip end. In addition, depending on the situation, the butt-end side or the butt side may be referred to as the grip side, and the tip-end side or the tip side as the tip side.

[0015] A golf shaft according to an embodiment of the present invention is manufactured by a sheet wrapping method. In such a method, a fiber-reinforced resin layer, made by impregnating resin into a reinforcing fiber sheet having a unidirectional fiber orientation, is wrapped around a mandrel (core member) multiple times (usually 2~4 times, depending on the size of the resin layer), which is then thermoset to be shaped.

[0016] In the present embodiment, examples of the fiber used in a fiber-reinforced resin layer are glass fiber, carbon fiber, aramid fiber, silicon carbide fiber, alumina fiber, steel fiber and the like. Especially, a polyacrylonitrile-based carbon fiber is the most preferred, since it forms a fiber-reinforced plastic layer that exhibits excellent mechanical characteristics. Such reinforcing fibers may be used alone or in combination of two or more.

[0017] A matrix resin of a fiber-reinforced resin layer is not limited to any specific kind, but epoxy resin is generally used. Examples of epoxy resin are bisphenol-A epoxy resin, bisphenol-F epoxy resin, bisphenol-S epoxy resin, phenol novolac epoxy resin, cresol novolac epoxy resin, glycidylamine epoxy resin, isocyanate-modified epoxy resin, alicyclic epoxy resin and the like. Such epoxy resins may be liquid or solid, and in addition, may be used alone or in combination thereof. Also, a curing agent is often mixed into epoxy resin.

[0018] The fiber weight, resin content and the like in a fiber-reinforced resin layer are not limited specifically, and are determined properly from the thickness, wrap-around diameter and the like required for each layer.

[0019] A golf club shaft according to the present embodiment requires a balance point of 53% or higher and a kickpoint of 44% or higher. By so setting, when a ball is hit by a golf club made of such a shaft, the ball speed effectively increases. The details are described later. The effect on the increase in ball speed cannot be sufficiently achieved when the balance point and kickpoint are low.

[0020] As shown in FIG. 7, a balance point is defined as a percentage of distance (L_G) from tip end **61** to gravity center **70** of shaft **60** to the full length (L_S) of the shaft. Namely, a balance point is obtained by the following formula (1).

$$\text{balance point (\%)} = (L_G / L_S) \times 100 \cdots (1)$$

[0021] A balance point allows the position of the gravity center to be determined quantitatively. In the present embodiment, a shaft with a balance point lower than 50% is referred to as a low-balance shaft, a shaft with a balance point of 50% or higher but lower than 53% as a mid-balance shaft, and a shaft with a balance point of 53% or higher as a high-balance shaft. Generally speaking, when the tip end **61** side of shaft **60** is made thinner and the butt end **62** side of shaft **60** is made thicker, the value of the balance point increases; that is, a high-balance shaft is achieved.

[0022] As shown in FIG. 8, a kickpoint is defined as follows. Shaft **60** is curved by being compressed from both of its ends. At that time, compression load (P) exerted on both ends differs depending on the bending rigidity of the shaft; compression load (P) is exerted so that the linear distance between both ends is 98.5~99.5% of the shaft length prior to exerting compression load on shaft **60.** More specifically, both ends of shaft **60** are fixed by rotatable fixing jigs **81**, and the distance between both ends of the shaft is reduced to the above range by moving a fixing jig on one side so as to set fixing jigs **81** closer to each other. When the linear distance is within the above range, apex **80** of the curvature is found substantially at the same position. Length (L_D), which is the contraction amount of the length of shaft **60** when compression load (P) is exerted, is approximately 10 mm in an example shown in FIG. 8.)

[0023] In shaft **60C**, which is the curved shaft **60**, apex **80** is at the most protruding point in the peripheral direction of curved shaft **60C**. Then, distance (L_K) from apex **80** and tip end **61** is measured. The value of a kickpoint is determined as the percentage of distance (L_K) to shaft length (L_B) when it is curved as above (linear distance between both ends of the curved shaft), namely, the value is obtained by the following formula (2).

$$\text{kickpoint } (\%) = (L_K / L_B) \times 100 \cdots \text{(formula 2)}$$

[0024] In the present application, values are obtained by using a shaft kickpoint gauge "FG-105RM," made by Fourteen Corporation. For example, a shaft with a kickpoint of lower than 43.5% is classified as a low kickpoint shaft, a shaft with a kickpoint of 43.5% or higher but lower than 44.0% as a mid kickpoint shaft, and a shaft with a kickpoint of 44% or higher as a high kickpoint shaft. Generally speaking, when the tip end **61** side of shaft **60** is made harder and the butt end **62** side of shaft **60** is made softer, the value of the kickpoint increases. Namely, a high kickpoint shaft is achieved. In addition, (L_K) and (L_B) are defined precisely as follows.

L_K: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the shaft length, the distance from the tip end of the shaft to the point where the straight line connecting both ends of the shaft intersects with a perpendicular line drawn from the apex of the curve

L_B: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends of the shaft is 98.5~99.5% of the shaft length, the linear distance between both ends of the shaft

[0025] In the embodiment, to enhance the effect on the increase in ball speed by achieving both a high balance point and a high kickpoint, a balance point of 54% or higher and a kickpoint of 44.5% or higher are preferred; more preferably a balance point of 55% or higher and a kickpoint of 45% or higher, even more preferably a balance point of 56% or higher and a kickpoint of 45.5% or higher, and especially preferably a balance point of 57% or higher and a kickpoint of 46% or higher.

[0026] When a balance point is too high, the ratio of a weight layer (W) to the entire shaft **60** becomes too high, causing the tip end **61** side to be thinner and increasing the risk of breakage. Thus, the balance point is preferred to be 63% or lower, more preferably 61% or lower. In addition, if the kickpoint is too high, there may be a strange feel (feel while swinging a club). Thus, the kickpoint is preferred to be 48% or lower, more preferably 47.5% or lower.

[0027] A golf club shaft **60** of the present embodiment is preferred to include a weight layer (W) whose weight is 10~30% of the shaft weight. The material for forming a weight layer (W) may be selected from the above listed fiber-reinforced resins, but a weight layer needs to be designed in consideration of physical properties related to the design of the shaft **60**. If the weight layer (W) is too light, the weight on the grip side cannot be increased sufficiently, and a high balance point is not achieved. If the weight layer (W) is too heavy, the golf shaft will be too heavy, failing to satisfy the intended functions of the shaft **60**. The weight layer (W) is preferred to weigh 13% or greater but no greater than 27% of the entire shaft weight, more preferably 15% or greater but no greater than 25% of the entire shaft weight.

[0028] In addition, the average thickness of a weight layer (W) is preferred to be 0.5 mm or less. Here, the average thickness is defined precisely as follows: the entire longitudinal length of a weight layer (W) is divided by 5 and its circumference is divided by 4, the thickness at the middle point of each divided portion is measured, and their average value is calculated. If a weight layer (W) is too thick, it is hard to achieve a high kickpoint. That is because the outer diameter increases only where a weight layer (W) is disposed, and only the portion with a weight layer (W) disposed underneath will be emphasized because of the enlarged outer diameter due to the weight layer (W). As described earlier, a high kickpoint is likely to be achieved if the butt end **62** side is softer. Accordingly, a weight layer (W) is preferred to be thinner. It is preferred to be 0.4 mm or less, more preferably 0.3 mm or less, even more preferably 0.2 mm or less, especially preferably 0.1 mm or less. The lower limit of the average thickness of a weight layer (W) is preferred to be the smallest value allowable for a shaft design, but the targeted value is 0.02 mm. Namely, a weight layer (W) is preferred to be set at 0.02~0.5 mm, more preferably 0.02~0.3 mm, even more preferably 0.02~0.2 mm, and especially preferably 0.02~0.10 mm.

[0029] Furthermore, to position a weight layer (W) effectively, when shaft **60** is formed by wrapping multiple layers of fiber-reinforced resin into a tube shape, it is preferred to be disposed on the outer layer of the tube shape. In particular, a weight layer (W) is preferred to be disposed on the sixth layer from the outermost layer or closer. If a weight layer (W) is positioned closer to the center, it is hard to achieve a high kickpoint as described above. If a weight layer (W) is positioned on a layer even closer to the outermost layer, the weight layer (W) could be shaved off during a polishing process. Accordingly, a weight layer (W) is preferred to be positioned on the fourth layer from the outermost layer or closer, more preferably on the second layer or closer, counted from the outermost layer. If it is located on the first layer from the outermost layer or closer, the weight layer (W) is shaved off during a polishing process, causing the weight or shape of the weight layer (W) to be changed. Accordingly, the balance of the weight in the shaft is changed and the club may not perform well.

[0030] Here, physical properties of a shaft **60** in the present application are defined. In general production procedures, both ends of a golf club shaft are cut off after a wrapping process is done so as to minimize production errors during the wrapping process. The shaft length (L_S) is defined as a full length of the shaft after such cutting process. The shaft weight, the weight of a weight layer (W), a kickpoint, a balance point and the like are defined as their respective values obtained in a shaft as a product, namely, the values obtained in a shaft that is cut as above to avoid production errors. In addition, when assembled to form a golf club, the shaft is further cut. Regarding a shaft after it is assembled into a golf club (namely, a shaft that is further cut from the shaft having a full length (L_S)), such a shaft is also within a scope of the present invention as long as it is within the scope of patent claims. Furthermore, the position, length, orientation angle of fibers of each layer and the number of laminations are defined as follows. The fiber orientation angle including that in a later-described straight layer is set at approximately zero degrees to the shaft axis direction unless otherwise specified. The fiber orientation angles indicate those with respect to the shaft axis. The number of layers is one unless otherwise specified. There are three ways to measure the length of a reinforcement layer. In an example shown in FIG. 1, since a weight layer (W) is wrapped on a partial portion of the butt side, it is shaped to be trapezoidal, and the tip side end is cut off to be triangular so as to prevent the concentration of stress on its end portion (FIG. 1). The length of the trapezoidal layer does not include the cut-off portion. On the other hand, since a triangular reinforcement layer **50** (FIG. 1) does not include any cut-off portion, its length is measured from one end to the other. In addition, the length of a weight layer (W) is also measured from one end to the other.

[0031] Moreover, in the present embodiment, a weight layer (W) is preferred to be positioned at least 800 mm away from tip end **61** of shaft **60.** If a weight layer (W) is located too close to the tip end **61** side, gravity center **70** of shaft **60** is shifted to the tip end **61** side. As a result, a high balance point will not be achieved. A weight layer (W) is preferred to be located at least 850 mm from tip end **61**, more preferably at least 900 mm from tip end **61.** In the present embodiment, "a weight layer (W) is located at least 850 mm from tip end **61** of the shaft" means that a weight layer (W) is disposed in such a way that of both ends of the weight layer (W), one end on the tip end **61** side is located at least 800 mm from tip end **61.** The dimensions of a weight layer (W), namely, the dimensions in the longitudinal direction and radial direction of shaft **60** when the weight layer (W) is assembled into the shaft, are preferred to be 200~400 mm in the longitudinal direction and 0.02~0.5 mm in the radial direction, although they may vary depending on the weight of a weight layer (W) and the targeted balance in shaft **60**.

[0032] Moreover, when it is assembled into a shaft **60**, the flexural modulus of a weight layer (W) in the longitudinal direction of the shaft is preferred to be 70 GPa or lower in the present embodiment. If the flexural modulus of a weight layer (W) is too high, the butt end side hardens even if its aforementioned weight and position are satisfied. As a result, a high kickpoint will not be achieved. The flexural modulus of a weight layer (W) is preferred to be 50 GPa or lower, more preferably 20 GPa or lower. On the other hand, if the flexural modulus is too low, adhesiveness to prepreg decreases and the weight layer may be peeled off. Since the flexural modulus of a resin used for adhesion purposes is usually 3 GPa or higher, the flexural modulus of a weight layer (W) of the present embodiment is at least 3 GPa. In particular, the flexural modulus in one direction is set at 70 GPa or lower for a material to form a weight layer (W). In the present embodiment, the flexural modulus of a weight layer (W) in the longitudinal direction indicates a value measured according to JIS K7017; more specifically, a value obtained when a three-point bending test is conducted on a test piece of a predetermined size by setting the distance at 80 mm between supporting pins, and the size of a test piece is 100 mm long, 15 mm wide and 2 mm thick.

[0033] Examples of material having a flexural modulus of 70 GPa in a longitudinal direction are as follows: prepreg formed with low elastic pitch-based fibers laminated to have a fiber orientation of approximately zero degrees to the longitudinal direction of shaft **60**; prepreg made of glass fiber or prepreg with dispersed metal powder such as tungsten; prepreg formed with carbon fibers having a higher strength and a mid-range elasticity which are laminated to have a fiber orientation of approximately ±45 degrees to the longitudinal direction of a shaft **60**; prepreg formed with carbon fibers having a higher elasticity which are laminated to have a fiber orientation of approximately 90 degrees to the longitudinal direction of a shaft **60**; and the like. However, those are not the only options. Specific product names and properties are shown in Table 2.

[0034] A shaft of the present embodiment is formed to have a weight of 60 grams, frequency of 250 cpm and a full shaft length (L_S) of 1168 mm. Depending on the functions intended for the club, the weight, frequency and length of a shaft may be determined properly by the engineer who designs the club. A frequency measuring device made by Fujikura Ltd. is used to measure the frequency. The grip portion is located at 180 mm from the butt end, and the tip weight is set at 196 grams.

[0035] An example of a golf club shaft according to the present embodiment is described below with reference to FIG. 1.

[0036] Around mandrel **10,** fiber reinforced resin layers such as an angle layer **20,** a weight layer (W), a first straight layer **30,** a second straight layer **40,** and a tip reinforcement layer **50** are wrapped in that order. As a mandrel **10,** any conventional material for a golf club may be used. After the fiber reinforced resin layers wrapped around a mandrel **10** are thermoset, the mandrel **10** is pulled out. Then, sections 10 mm from the tip end **61** and 12 mm from the butt end **62** are respectively cut off and the remaining portion is polished. Accordingly, a tube-shaped shaft **60** is obtained. In the present embodiment, a shaft **60** for a wood is structured to have a full shaft length (L_S) of 1092-1220 mm, a narrow-end outer diameter of 7.50~9.00 mm, and a wide-end outer diameter of 15.0~15.8 mm. An example shown in FIG. 1 is a shaft **60** with a full shaft length (L_S) of 1168 mm, and a narrow-end outer diameter of 8.50 mm.

[0037] Here, the fiber orientation of the angle layer **20** is set diagonal to the longitudinal direction of a shaft **60**. A diagonal direction means that a fiber orientation is in any direction but excludes an orientation perpendicular or parallel to the longitudinal direction of a shaft **60**. In the example shown in FIG. 1, the angle layer **20** is made of fiber reinforced resin where a first fiber material **20A** and a second fiber material **20B** are adjacent to each other. The fiber orientation of the first fiber material is set at angle (D1), inclining counterclockwise at greater than zero but less than 90 degrees to the longitudinal direction of a shaft **60**. The fiber orientation of the second fiber material **20B** is set at angle (D2), inclining clockwise at greater than zero but less than 90 degrees to the longitudinal direction of a shaft **60**. The materials for an angle layer **20** are carbon fiber or the like, and may be selected properly from the above-listed materials for fiber reinforced resin layers that have a fiber orientation angle of 30~60 degrees. However, since angles (D1, D2) are preferred to be close to 45 degrees, those having a fiber orientation of 40~50 degrees are especially preferable. The most preferable material is one having an orientation angle of 45 degrees. In the example of FIG. 1, angle (D1) is approximately 45 degrees, and angle (D2) and angle (D1) are the same at approximately 45 degrees (in other words, fiber orientations are set at +45 degrees and -45 degrees respectively to the longitudinal direction of a shaft). The dimensions of an angle layer **20**, namely, dimensions corresponding to longitudinal and radial sizes when assembled into a shaft **60**, may vary depending on the weight of the angle layer **20** and on the targeted balances of a shaft **60**, and thus are selected according to the balances to be set in the shaft **60**.

[0038] A straight layer means a layer with a fiber orientation parallel to the longitudinal direction of a shaft **60**. In particular, fibers with a fiber orientation parallel to the longitudinal direction of a shaft **60** indicate that the fiber orientation is set at -5 to +5 degrees to the longitudinal direction of a shaft **60**. It is especially preferable if the fiber orientation is set at zero degrees in a measurable range to the longitudinal direction of a shaft **60**. The material for a straight layer may be carbon fiber or the like, and selected properly from the above-listed materials for fiber reinforced resin layers. It is an option to form multiple straight layers. It is especially preferable if there are two or three straight layers. In the example shown in FIG. 1, there are a first straight layer **30** and a second straight layer **40**. Dimensions of first and second straight layers **30** and **40** are determined properly in consideration of the balances set for a shaft **60**.

[0039] A tip reinforcement layer **50** is set to adjust the outer diameter and shape on the tip end side of a shaft **60.** The material for a tip reinforcement layer **50** may be carbon fiber or the like and may be selected properly from the above-listed materials for fiber reinforced resin layers. The shape and dimensions of a tip reinforcement layer **50** are described later.

[0040] In the present embodiment, the outer diameter of a tip end **61** is preferred to be 8.5 mm~9.3 mm. If the tip diameter is too small, it may cause insufficient strength, and if the tip diameter is too wide, it is difficult to achieve a high balance point. The outer diameter is more preferable if it is 8.5 mm~9.1 mm. Regarding a butt diameter, the outer diameter of a butt end is preferred to be 14.0 mm~16.5 mm. The grip may feel strange if the outer diameter of the butt end is too narrow or too wide. It is more preferable if the outer diameter is 14.5 mm~16.0 mm, even more preferable if it is 15.0 mm~15.5 mm.

[0041] To assemble a shaft **60** into a club, the butt end side of a shaft **60** is cut off. In the example shown in FIG. 1, 48 mm of the butt end side of a shaft 60 with a full shaft length (L_S) of 1168 mm is cut so that the full length of the assembled shaft is 1120 mm, which is the regular club size of 46 inches. Here, "R9" made by TaylorMade Golf Company, Inc. (Loft 9.5°) is used as a head. But that is not the only option.

[0042] As described above, the shaft length of a golf club shaft differs depending on purposes such as shafts for drivers, fairway woods, utilities, irons or the like. Examples of a club that requires a long carry distance, which is the objective of the present invention, are golf shafts for woods such drivers and fairway woods. The full shaft length (L_S) for such a club is usually set at 1092 mm~1220 mm as described above. However, when the full length (L_S) is made different, the weight of the shaft changes, making it difficult to define. Thus, to simplify descriptions in the present application, a shaft weight is defined as shown in the following formula by converting its full shaft length (L_S) to 1168 mm.

$$\text{shaft weight after conversion} = M \times (L_S / 1168)$$

M=shaft weight
L_S=full shaft length

[0043] Also, when a shaft is assembled into a club, the shaft is further cut as described above. The length to be cut differs depending on the type of a head, since the length inserted into the head is different. Since the exact weight at that time is also difficult to define, the same conversion as in the above formula is employed.

[0044] Based on the above formula, a shaft **60** in the present embodiment is preferred to have a shaft weight in the range of $30 \leq M \times (L_S / 1168) \leq 80$. If the shaft weight is too light, the feel may be strange during a swing motion and performance of the shaft decreases. Also, the risk of breakage may increase. If the shaft weight is too great, an intended increase in carry distance will not be achieved. A weight in the range of $35 \leq M \times (L_S / 1168) \leq 75$ is more preferable, and a weight in the range of $38 \leq M \times (L_S / 1168) \leq 70$ is even more preferable.

[0045] Furthermore, the golf shaft of the present embodiment is formed to have a balance point of 53% or higher and a kickpoint of 44% or higher.

[0046] The inventors of the present invention have found the following two issues from multiple test results.

(1) When a balance point is lower than 53%, it is difficult to sufficiently increase the head weight, and thus the ball speed cannot be increased.
(2) When a kickpoint is lower than 44%, the head speed decreases significantly even if the head weight is increased. Thus, the same as in (1) above, the ball speed cannot be increased.

[0047] When a high-balance point shaft is formed to have a balance point of 53% or higher, the tip side is usually thinner and the butt side is thicker as shown in patent publication 2. Thus, the butt side is stiffer relative to the soft tip side, resulting in a so-called low to mid kickpoint shaft having a kickpoint of lower than 44%. Namely, conventional technologies cannot produce a shaft having both a high balance point and high kickpoint.

[0048] As described above, setting a high balance in a shaft inevitably result in a low to mid kickpoint shaft when conventional technologies are employed. Accordingly, the aforementioned "theoretically expected increase in ball speed derived from a gain in head weight" is not achieved. To solve the problem, it is required to achieve both a high balance point and high kickpoint.

[0049] Therefore, as one of the solutions for such a problem, the inventors of the present invention have found that when a weight balance of a shaft is adjusted by a weight layer (W) described below, both a high balance point and high kickpoint are achieved.

- the weight of a weight layer (W) is at least 10% but no greater than 30% of the entire shaft weight.
- the weight layer (W) is disposed at a location at least 800 mm away from the tip side.
- the flexural modulus of the weight layer (W) in the longitudinal direction of a shaft is 70 GPa or lower.

[0050] To form a high kickpoint shaft, a large reinforcement member needs to be disposed on the tip side. Thus, the weight of the reinforcement member causes the balance to be shifted to the tip side. Accordingly, the method shown in FIG. 2 is preferred for forming a shaft.

[0051] FIG. 2 is a half-sectional view of a shaft **60** and a mandrel **10**. As described above, a shaft **60** is obtained when predetermined materials are wrapped around a mandrel **10** and then the mandrel **10** is pulled out toward the butt end (butt end **62** side). As a result, the shaft **60** has a shaft inner diameter equal to the outer diameter of the mandrel. To specify the shape of a shaft using the outer diameter of a mandrel, the description would be complex. Thus, the shape of the shaft will be described using the inner diameter of the shaft.

[0052] As shown in FIG. 2, the inner surface of tube-shaped shaft **60** is set so that the inner diameter of the tube-shaped shaft tapers, increasing from the tip end **61** of the shaft toward the butt end **62.** On the inner surface of shaft **60**, an inner-diameter taper bending point (Pm) is formed so that the tapering degree of the inner diameter reduces on the butt end **62** side. Here, the inner-diameter taper bending point (Pm) is set to be positioned 550 mm~750 mm from the tip end **61**. When the position of a point (Pm) is closer to the tip side, the kickpoint is shifted to the tip side, making it difficult to achieve a high kickpoint. When the position of a point (Pm) is closer to the butt side, the kickpoint is also shifted to the tip side, making it difficult to achieve a high kickpoint. Positioning a point (Pm) at 600 mm~700 mm from the tip end **61** is preferred. When an inner-diameter tapering gradient is set as (Tm) to indicate the inner-diameter inclination between the tip end **61** and the inner-diameter taper bending point (Pm), and when an inner-diameter tapering gradient is set as (Tb) to indicate the inner-diameter inclination between the inner-diameter taper bending point (Pm) and the butt end **62**, the tapering gradient is adjusted to satisfy $Tm>Tb$. By so setting, the kickpoint is moved toward the grip side, resulting in an even higher kickpoint.

[0053] In addition, the shaft is formed so that the inner diameter increases from the tip end **61** toward the butt end **62**. Namely, in the shaft, the inner diameter increases from the tip so as to flare out toward the butt, and at the point (Pm) the diameter further enlarges toward the periphery with respect to a virtual line (Th) that connects the tip and the butt end (namely, a shaft is formed to satisfy $Tm>Tb$). By so setting, without using a reinforcement member on the tip side as described above, a high kickpoint shaft is more likely to be achieved.

[0054] Also, when $Tm>Tb$ is satisfied, there is an advantage that even with a weight layer (W) disposed on the butt side, the outer diameter is unlikely to be enlarged. When the outer diameter on the butt side is enlarged, the butt side is inevitably made stiff and a high kickpoint is hard to achieve. However, when the inner diameter is set as in the present embodiment, the space for a weight layer (W) is secured, making it easier to achieve a high kickpoint.

[0055] To make it even easier to achieve a high kickpoint, $1.5 \leq Tm/Tb \leq 5.5$ is preferred. When the value of Tm/Tb is too small, the effect of moving a kickpoint toward the grip side is reduced, making it harder to achieve a high kickpoint. When Tm/Tb is too great, the kickpoint is shifted toward the tip side, making it harder to achieve a high kickpoint. The range is more preferred to be $2.5 \leq Tm/Tb \leq 3.5$.

[0056] As described in patent publication 2, it is necessary to reduce the tip side thickness in a high balance point shaft. In addition, as described above, on the tip side of a high kickpoint shaft, a reinforcement member is necessary, namely, the tip side thickness is required to be increased. There are two methods to make it easier to achieve a high kickpoint without increasing the tip side thickness. One is to form the aforementioned inner-diameter taper bending point (Pm). The other is to use a material containing fiber with a higher elastic modulus for the tip side. However, material with a higher elastic modulus is fragile and easy to snap. Since the tip side of a high balance shaft is thinner, using a material with a higher elastic modulus in the tip side means a higher risk of breakage.

[0057] Therefore, it is preferred to employ a third method as follows. FIG. 3 shows an example with such a third method employed therein.

- an inner-diameter taper bending point (Pt) is positioned at 40~140 mm from the tip side.
- when the inner-diameter tapering gradient is set as (Tt) to indicate the inclination between the inner diameter at the tip end and the inner diameter at the inner-diameter taper bending point (Pt), and when the inner-diameter tapering gradient is set as (Tm’) to indicate the inclination between the inner diameter at the inner-diameter taper bending point (Pt) and the inner-diameter taper bending point (Pm), the following is satisfied:

$$Tt<Tm'$$
$$0.1/1000 \leq Tt \leq 5/1000$$

A shaft 60A according to the third structure is formed to be thicker only where the greatest load is exerted when hitting a ball, and thus is capable of preventing breakage from occurring when a ball is hit.

[0058] The portion 40~140 mm from the tip side is said to sustain the greatest deformation when striking a ball and thus is the portion most likely to break. By setting $Tt<Tm'$, the position of a point (Pt), namely, any portion located 40~140 mm from the tip side, is locally made thicker, and breakage is thus prevented. Moreover, by employing the present structure, the thickness of the portion on the tip side of a point (Pt) is maintained. Thus, both a high balance point and a high kickpoint are more likely to be achieved.

[0059] When the position of a point (Pt) is shifted much closer to the tip side, the effect of preventing breakage is low in the manufacturing process and use of shaft **60**. Also, when the position of a point (Pt) is shifted much closer to the butt side, the balance point is shifted to the tip side, making it harder to achieve a high balance point. The position of a point (Pt) is more preferred to be 70~110 mm from the tip side.

[0060] When the value (Tt) is too small, tapering is closer to being parallel. Thus, friction increases when the mandrel is pulled out during the manufacturing process of a shaft **60**, and the tip side of the shaft may crack. When the value (Tt) is too great, since the portion closer to the tip side from a point (Pt) is too thick, it is harder to achieve a high balance point. The value (Tt) is more preferred to be $1/1000 \leq Tt \leq 4/1000$, even more preferred to be $2/1000 \leq Tt \leq 3/1000$.

[0061] For producing a high balance and high kickpoint shaft, the above structure is preferred to be employed from the viewpoint of preventing breakage during actual use.

[0062] Next, by referring to FIG. 4, (Pm), (Pt), (Tb) and (Tt) are each defined in further detail. A shaft **60A** of the present embodiment may have multiple inner-diameter taper bending points. In such a case, inner-diameter taper bending points are arranged from the tip side in the order of P1, P2, ··· Pn (n is a whole number). Among the inner-diameter taper bending points located 550~750 mm from the tip side, the point closer to the 550 mm side is set as a point (Pm) (P4 in FIG. 4), and among the inner-diameter taper bending points located 40~140 mm from the tip side, the point closer to the 40 mm side is set as a point (Pt) (P1 in FIG. 4).

[0063] Also, (Tb) is set as the inner-diameter tapering gradient made when a point (Pm) and the butt end are connected; (Tm) is set as the inner-diameter tapering gradient made when the tip end and a point (Pm) are connected; (Tt) is set as the inner-diameter tapering gradient made when the tip end and a point (Pt) are connected; and (Tm') is set as the inner-diameter tapering gradient made when (Tt) and (Pm) are connected.

[0064] In addition, a shaft **60A** of the present embodiment has a tip reinforcement layer **50** (FIG. 1) which is also used for adjusting the outer diameter. One end of the tip reinforcement layer **50** is preferred to be positioned at the tip end, and the other is preferred to be positioned 50~400 mm away from the tip end **61** toward the butt end **62**. When a tip reinforcement layer is present from the tip end **61** to a point less than 50 mm away from the tip end, reinforcement of the tip is insufficient, and the risk of breakage increases when striking a ball. When a tip reinforcement layer is present from the tip end to a point further than 400 mm away from the tip end, the weight concentrates on the tip end **61** side, making it harder to achieve a high balance point.

[0065] Moreover, a shaft **60A** may have a hoop layer **90** laminated with a fiber orientation angle set to be perpendicular to the longitudinal direction of a shaft **60**. Here, "set to be perpendicular" means a fiber orientation of approximately 90 degrees to the longitudinal direction of a shaft **60**. It may be approximately 85~95 degrees, but it is preferred to be 90 degrees in a measurable range. The arrangement of a hoop layer 90 may be patterns A-C shown in FIG. 5, for example. Patterns A~C are defined as follows.

A: at least one hoop layer **90** is arranged on the entire length of a shaft **60**.

B: a hoop layer **90** is arranged in such a way that one end of a hoop layer **90** is positioned at least 300 mm away from the tip end **61** and on the tip end **61** side of the center of the shaft **60**, while the other end is positioned at the butt end **62**.

C: a hoop layer **90** is arranged in such a way that one end of a hoop layer **90** is positioned at least 300 mm away from the tip end **61** and on the tip end **61** side of the center of the shaft **60**, while the other end is positioned at least 700 mm away from the tip end 61.

[0066] The size and position of the hoop layer **90** are preferred to be A, B or C, since the risk of breakage is reduced when actually striking a ball. The effects of reducing breakage by the hoop layer **90** are high on the butt end side of the 300-mm point, but low on the tip end side of the 300-mm point. Accordingly, from the viewpoint of achieving both breakage reduction and a high balance, a structure where one end of a hoop layer **90** is positioned at least 300 mm away from the tip end **61** and on the tip end **61** side of the center of the shaft **60**, while the other end is positioned at the butt end **62**, namely, the structure of B, is most preferred. Such a structure is especially effective to be employed on a shaft **60** with a weight of 60 grams or lower. Such a structure may also be employed in a shaft **60A** as well.

EXAMPLES

[0067] In the following, examples of the present embodiment are described in detail. However, the present invention is not limited to such examples. As for fiber-reinforced resin layers, carbon prepregs (made by Mitsubishi Rayon Co., Ltd.) shown in Table 1, for example, may be used. As for a weight layer (W), combinations of a prepreg and a lamination angle shown in Table 2, for example, may be used (combinations in which the flexural modulus of a weight layer (W) is 70 GPa or lower in a direction corresponding to the longitudinal direction of a shaft **60** when the weight layer (W) is assembled in the **shaft 60).**

[0068] Flexural moduli in Table 2 are measured according to JIS K7107 as described above. When the fiber orientation angle is changed, the orientation angle is required to be changed when a test piece is formed so that the relationship of the fiber orientation angle in the fiber-reinforced resin to the longitudinal direction of a shaft **60** corresponds to that described above. However, measuring methods and the size of test pieces are the same. Generally speaking, when the orientation angle is closer to zero degrees, the flexural modulus is higher, whereas when the orientation angle is closer to 90 degrees, the flexural modulus is lower.

Table 1

prepreg	product number	fiber: tensile elasticity [GPa]	laminate: flexural modulus JIS K7017 [GPa]	weight [g/m^2]	resin content [mass%]	thickness [mm]
A	TR350C075S	235	176	75	25	0.062
B	TR350C100S	235	176	100	25	0.083
C	TR350C125S	235	176	125	25	0.103
D	TR350C150S	235	176	150	25	0.124
E	TR350C175S	235	176	175	25	0.145

(continued)

prepreg	product number	fiber: tensile elasticity [GPa]	laminate: flexural modulus JIS K7017 [GPa]	weight [g/m^2]	resin content [mass%]	thickness [mm]
F	TR350J050	235	147	54	37.5	0.058
G	TR350E100R	235	165	100	30	0.091
H	TR350E125S	235	165	125	30	0.113
I	TR350E150S	235	165	150	30	0.136
J	MR350C050S	295	221	58	25	0.05
K	MRX350C075R	295	221	75	25	0.063
L	MRX350C100R	295	221	100	25	0.085
M	MRX350C125R	295	221	125	25	0.106
N	MRX350C150R	295	221	150	25	0.127
O	MRX350K020S	295	177	23	40	0.026
P	MRX350J050S	295	184	54	37.5	0.058
Q	HRX350C050S	390	293	58	25	0.048
R	HRX350C075S	390	293	69	25	0.057
S	HRX350C100S	390	293	92	25	0.076
T	HRX350C125S	390	293	116	25	0.096
U	HSX350C050S	450	338	58	25	0.047
V	HSX350C075S	450	338	69	25	0.056
X	HSX350C100S	450	338	92	25	0.075
Y	HSX350C125S	450	338	116	25	0.095

Table 2

prepreg	product number	fiber: tensile elasticity [GPa]	0° laminate: flexural modulus JIS K7017 [GPa]	±45° laminate: flexural modulus JIS K7017 [GPa]	90° laminate: flexural modulus JIS K7017 [GPa]	weight [g/m^2]	resin content [mass%]	thickness [mm]
W1	E1026C-10N	98	66	16	5	149	33	0.099
W2	GE352G135S	76	53	13	4	200	30	0.111
W3	TP013GE3417	-	5	5	5	700	-	0.090
W4	E0526A-12N	45	30	8	2	198	33	0.136
W5	TR350C100S	235	176	44	13	100	25	0.083
W6	MRX350C100F	295	221	55	17	100	25	0.085
W7	HRX350C100S	390	293	73	22	92	25	0.076
W8	HSX350C100S	450	338	84	25	92	25	0.075

(Example 1)

[0069] Example 1 of the present invention is described with reference to FIG. 1. Around the mandrel 10 of FIG. 1 (diameter at the tip end=6.0 mm, diameter at the butt end=13.3 mm), the following layers were wrapped in that order: an angle layer **20** (prepreg K: two sheets of prepreg K were laminated with fiber orientation angles of ±45 degrees to the longitudinal direction of a shaft), a weight layer (W) (prepreg W1: laminated with a fiber orientation angle of zero degrees to the longitudinal direction of a shaft), a first straight layer **30** (prepreg D), a second straight layer 40 (prepreg D), and a tip reinforcement layer **50** (prepreg H: wrapped from the tip end to a point 250 mm upward). After thermosetting the resin, the mandrel 10 was pulled out. Next, a section 10 mm from the tip end and a section 12 mm from the butt end were cut off and the remaining portion was polished. Accordingly, a shaft was obtained to have a full length (L_S) of 1168 mm, a narrow-end outer diameter of 8.50 mm, and a wide-end outer diameter of 15.1~15.3 mm. The weight of the shaft was 60 grams and the frequency was 250 cpm.

[0070] Here, regarding "a weight layer (W) (prepreg W1: laminated with a fiber orientation angle of zero degrees to the longitudinal direction of a shaft)" as described above, the flexural modulus of the weight layer (W) in the longitudinal direction of a shaft is "0° laminate: flexural modulus" in Table 2. In the examples below, a suitable orientation angle is selected from Table 2, and the value in the column is set as "the flexural modulus of a weight layer (W) in the longitudinal direction of a shaft."

[0071] A weight layer (W) was disposed to be positioned 800 mm from the tip end of the shaft to the butt end. Also, the number of wrappings in the weight layer (W) was adjusted so that its weight is 10% of the total weight of the shaft.

(Example 2)

[0072] The shaft was produced the same as in Example 1 except that the number of wrappings in the angle layer was changed and the following modification was made to adjust the total weight of the shaft. The number of wrappings in the angle layer was adjusted not only in the present example but in each example. However, that description is omitted.

[0073] The weight percentage of the weight layer (W) was set at 13.5%.

(Example 3)

[0074] The shaft was produced the same as in Example 1 except for the following change.

[0075] The weight percentage of the weight layer (W) was set at 17.0%.

(Example 4)

[0076] The shaft was produced the same as in Example 3 except for the following change.

[0077] As a weight layer (W), two sheets of prepreg (W5) were laminated to have fiber orientation angles of ±45 degrees to the longitudinal direction of the shaft.

(Example 5)

[0078] The shaft was produced the same as in Example 3 except for the following change.

[0079] The weight layer (W) was switched to prepreg (W3).

(Example 6)

[0080] The shaft was produced the same as in Example 1 except for the following change.

[0081] The weight layer (W) is disposed to be positioned 900 mm from the tip end of the shaft to the butt end.

(Comparative Example 1)

[0082] The shaft was produced the same as in Example 1 except for the following change.

[0083] As a weight layer (W), two sheets of prepreg (W8) were laminated to have fiber orientation angles of ±45 degrees to the longitudinal direction of the shaft.

(Comparative Example 2)

[0084] The shaft was produced the same as in Example 1 except for the following change.

[0085] Prepreg (W5) was laminated as the weight layer (W).

(Comparative Example 3)

[0086] The shaft was produced the same as in Example 1 except for the following change.
[0087] The weight percentage of the weight layer (W) was set at 6.5%.

(Comparative Example 4)

[0088] The shaft was produced the same as in Example 1 except for the following change.
[0089] The weight percentage of the weight layer (W) was set at 3.0%.

(Comparative Example 5)

[0090] The shaft was produced the same as in Example 1 except for the following change.
[0091] The weight layer (W) is disposed to be positioned 700 mm from the tip end of the shaft to the butt end.

<Evaluation of Test>

[0092] Clubs were assembled using the shafts produced in the examples and comparative examples above, and robot testing was conducted under the following conditions.

(Assembly of Club)

[0093] As described earlier, the club length was set at 46 inches, and the club balance was set at D0. As a head, "R9 Loft: 9.5°" made by TaylorMade was used.

(Club Balance)

[0094] When a golf club is assembled, club balance is measured. By measuring club balance, the moment of inertia in the direction of swing can be estimated by approximation. Since the moment of inertia in the direction of swinging the club is "weight" that is felt during a swing motion, the weight felt during a swing motion is the same if the club balance is the same. In the present test, the head weight was adjusted to have a club balance of D1. Club balance was measured using the "Golf Club Scale," a swing weight scale made by the Kenneth Smith Golf Company.

(Robot Testing)

[0095] For robot testing, a swing robot "ROVO IV" made by Miyamae Co., Ltd., was used. Five balls were test hit for each shaft. To track the trajectory of a ball, "TrackMan," a trajectory tracking device made by TrackMan, was used.
[0096] Average values obtained by the test are shown in Table 3.

Table 3

		example 1	example 2	example 3	example 4	example 5	example 6	comp. example 1	comp. examples 2	comp. example 3	comp. example 4	comp. example 5
shaft: total weight	g	60	60	60	60	60	60	60	60	60	60	60
shaft: frequency	cpm	250	250	250	250	250	250	250	250	250	250	250
shaft: full length L_S	mm	1168	1168	1168	1168	1168	1168	1168	1168	1168	1168	1168
grip weight	g	50	50	50	50	50	50	50	50	50	50	50
club balance	Pt	D0	D0	D0	D0	D0	D0	D0	D0	D0	D0	D0
head weight	g	203	205	207	207	207	205	203	203	201	199	201
balance point	%	53.0	54.0	55.0	55.0	55.0	54.0	53.0	53.0	52.0	51.0	52.0
kickpoint	%	44.0	44.0	44.0	44.5	45.0	44.0	43.5	42.5	44.0	44.0	43.5
weight layer W: weight	%	10.0	13.5	17.0	17.0	17.0	13.5	10.0	10.0	6.5	3.0	10.0
weight layer W: elastic modulus	GPa	66	66	66	44	5	66	84	176	70	70	70
weight layer W: position	mm	800	800	800	800	800	900	800	800	800	800	700
head speed	m/s	40.3	40.0	39.9	40.0	40.1	40.0	39.7	39.5	39.9	40.3	39.8
ball speed	m/s	62.0	62.1	62.6	62.7	62.9	62.1	61.1	60.7	60.8	60.8	60.6
ball carry distance	yrd	222.8	223.4	225.0	225.5	226.1	223.4	219.5	218.4	218.5	218.4	217.9

[0097] Compared with the comparative examples, the ball speed is increased significantly in the examples as shown in Table 3 (t-test: $P<0.05$). As a result, carry distance of the ball is significantly extended. That is based on the following principles.

[0098] Head weight is increased when it is a high balance shaft; however, in mid-kickpoint and low-kickpoint shafts as seen in Comparative Examples 1 and 2, head speed is significantly reduced and ball speed cannot be increased. In the same manner, in the case of mid-balance point shafts as seen in Comparative Examples 3 and 4, even when they are set to have a high kickpoint, head weight is not increased sufficiently. Thus, the ball speed cannot be increased.

[0099] By contrast, as seen in Examples, when a shaft has both a high balance point and a high kickpoint, the rate of reduction in head speed is lowered. Thus, a significantly extended carry distance is achieved from an increase in impulse caused by a gain in head weight.

(Confirming the Effects by Simulations)

[0100] To confirm more clearly the aforementioned effects (principles), simulations were conducted using FEM. A general-purpose "ABAQUS" analysis software made by SIMULIA Corp. was used. The results are shown in Table 4 and FIG. 6. In the simulations, gravity centers of a low kickpoint (kickpoint=42%) and high kickpoint (kickpoint=44%) were changed every 1% from 500%~59%, and the head weight was changed corresponding to each gravity center.

Table 4

Low Kickpoint											
simulation number		1	2	3	4	5	6	7	8	9	10
head weight	g	195	197	199	201	203	205	207	209	211	213
balance point	%	50.0	51.0	52.0	53.0	54.0	55.0	56.0	57.0	58.0	59.0
kickpoint	%	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0
head speed	m/s	41.38	41.21	41.12	40.85	40.67	40.43	40.34	40.14	39.88	39.67
High Kickpoint											
simulation number		1	2	3	4	5	6	7	8	9	10
head weight	g	195	197	199	201	203	205	207	209	211	213
balance point	%	50.0	51.0	52.0	53.0	54.0	55.0	56.0	57.0	58.0	59.0
kickpoint	%	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
head speed	m/s	41.42	41.39	41.22	41.18	41.11	40.80	40.75	40.71	40.62	40.50

[0101] As shown in the simulation results, when head weight is increased, the head speed is significantly reduced in a low-kickpoint shaft, whereas the rate of reduction in head speed is low in a high-kickpoint shaft. Namely, the simulation results confirmed the test results obtained above.

[0102] Other examples are described below.

(Example 7)

[0103] In Example 7, a mandrel shown in FIG. 2 was used (tip-end diameter=4.2 mm, diameter at point (Pm)=11.0 mm, butt-end diameter=13.1 mm). In Example 7, the inner-diameter taper bending point (Pm) was set at 650 mm from the tip side. Also, Tb=4.0/1000 and Tm=10.5/1000 were set. The rest of the structure was the same as in Example 1. The structure is shown in Table 5, but the same components as those in Example 1 were omitted.

(Example 8)

[0104] The shaft in Example 8 was prepared the same as in Example 7 except that the position of the inner-diameter taper bending point (Pm) was set at 550 mm from the tip side.

(Example 9)

[0105] The shaft in Example 9 was prepared the same as in Example 7 except that the position of the inner-diameter taper bending point (Pm) was set at 750 mm from the tip side.

(Example 10)

[0106] The shaft in Example 10 was prepared the same as in Example 7 except that Tm/Tb was set at 1.5.

(Example 11)

[0107] The shaft in Example 11 was prepared the same as in Example 7 except that Tm/Tb was set at 5.5.

(Example 12)

[0108] The shaft in Example 12 was prepared the same as in Example 7 except that a mandrel shown in FIG. 3 was used (tip-end diameter=5.1 mm, diameter at point (Pt)=5.3 mm, diameter at point (Pm)=11.0 mm, butt-end diameter=13.1 mm), the inner-diameter taper bending point (Pt) was set at 90 mm from the tip side, and Tt=2.5/1000, Tm'=12.0/1000 and Tt<Tm' were set.

(Example 13)

[0109] The shaft in Example 13 was prepared the same as in Example 12 except that the position of (Pt) was set at 40 mm.

(Example 14)

[0110] The shaft in Example 14 was prepared the same as in Example 12 except that the position of (Pt) was set at 140 mm.

(Example 15)

[0111] The shaft in Example 15 was prepared the same as in Example 12 except that Tt=0.1/1000.

(Example 16)

[0112] The shaft in Example 16 was prepared the same as in Example 12 except that Tt=5/1000.

(Example 17)

[0113] The shaft in Example 17 was prepared the same as in Example 12 except that a hoop layer (prepreg P) was added along the entire length. By so setting, the breakage risk factor is reduced.

(Example 18)

[0114] The shaft in Example 18 was prepared the same as in Example 12 except that a tip reinforcement layer was formed from the tip end to a point 400 mm upward. By so setting, the breakage risk factor is reduced.

(Example 19)

[0115] The shaft in Example 19 was prepared the same as in Example 1 except that prepreg (W1) was used for the weight layer (W) and its average thickness was set at 0.45 mm. The balance point was 53.2% and the kickpoint was 44.2%.

(Example 20)

[0116] The shaft in Example 20 was prepared the same as in Example 1 except that prepreg (W2) was used for the weight layer (W) and its average thickness was set at 0.25 mm. The balance point was 53.2% and the kickpoint was 44.6%.

(Example 21)

[0117] The shaft in Example 21 was prepared the same as in Example 1 except that prepreg (W3) was used for the weight layer (W) and its average thickness was set at 0.15 mm. The balance point was 53.2% and the kickpoint was 45.0%.

(Comparative Example 6)

[0118] The shaft in Comparative Example 6 was prepared the same as in Example 1 except that prepreg (W5) was used for the weight layer (W) and its average thickness was set at 0.55 mm. The balance point was 53.2% and the kickpoint was 43.8%.

[0119] In Table 5, a list of production conditions for Examples 7-16 is shown. By so setting, both high balance point and high kickpoint are more likely to be achieved. In addition, in Examples 19~21, both high balance point and high kickpoint are more likely to be achieved, although they are not shown in the table.

Table 5

		example 7	example 8	example 9	example 10	example 11	example 12	example 13	example 14	example 15	example 16
balance point	%	53.2	53.2	53.2	53.2	53.2	53.2	53.2	53.1	53.2	53.1
kickpoint	%	44.2	44.2	44.2	44.1	44.1	44.1	44.1	44.1	44.1	44.1
position of Pm	mm	650	550	750	650	650	650	650	650	650	650
Tb	1/1000	4.0	4.0	4.0	7.0	1.9	4.0	4.0	4.0	4.0	4.0
Tm	1/1000	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Tm/Tb	-	2.6	2.6	2.6	1.5	5.5	2.6	2.6	2.6	2.6	2.6
position of Pt	mm	-	-	-	-	-	90	40	140	90	90
Tt	1/1000	-	-	-	-	-	2.5	2.5	2.5	0.1	5.0
Tm'	1/1000	-	-	-	-	-	12.0	12.0	12.0	12.0	12.0

INDUSTRIAL APPLICABILITY

[0120] The golf shaft related to the present invention is capable of lowering the rate of reduction in head speed when head weight is gained. As a result, the effect on the increase in ball speed derived from a gain in head weight is maximized, and carry distance of the ball increases.

[DESCRIPTION OF NUMERICAL REFERENCES]

[0121]

10	mandrel
20	angle layer
20A	first fiber material
20B	second fiber material
30	first straight layer
40	second straight layer
50	tip reinforcement layer
60, 60A, 60C:	shaft
61	tip end
62	butt end
63	compressed shaft
70	gravity center of shaft
80	kickpoint position
81	fixing jig
90	hoop layer
Ls	full length of shaft
L_G, L_K, L_B, L_D	length
P	load
W	weight layer

Claims

1. A golf club shaft formed by laminating fiber-reinforced resin,
wherein the balance point obtained by formula (1) below is set to be 53% or higher; and
the kickpoint obtained by formula (2) below is set to be 44% or higher.

$$\text{balance point (\%)} = (L_G/L_S)\times 100 \cdots \text{(formula 1)}$$

L_G: distance from the gravity center of a shaft to the tip end of the shaft
L_S: full length of the shaft

$$\text{kickpoint (\%)} = (L_K/L_B)\times 100 \cdots \text{(formula 2)}$$

L_K: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the shaft length, the distance from the tip end of the shaft to a point where a straight line connecting both ends intersects with a perpendicular line drawn from the apex of the curve.
L_B: when a shaft is curved by a compression load exerted on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the shaft length, the linear distance between both ends of the shaft.

2. The golf club shaft according to Claim 1, wherein the tip-side end of a weight layer (W) that weights 10~30% of the shaft weight is positioned at 800 mm or greater from the tip end of the shaft, and the flexural modulus of the weight layer (W) in a longitudinal direction of the shaft is 70 GPa or lower.

3. The golf club shaft according to Claim 1 or 2, wherein the average thickness of the weight layer (W) is set at 0.5

mm or less.

4. The golf club shaft according to any of Claims 1~3, wherein the mass of the shaft M [g] and the full shaft length (L_S) [mm] satisfy the following formula.

$$30 \leq M \times (L_S/1168) \leq 80$$

5. The golf club shaft according to any of Claims 1~4, wherein the shaft is formed in a tube shape; the inner diameter of the shaft tapers, gradually increasing from the tip end toward the butt end; the inner-diameter taper has an inner-diameter taper bending point (Pm); the inner-diameter taper bending point (Pm) is positioned at 550~750 mm from the tip end of the shaft; and when an inner-diameter tapering gradient is set as (Tm) to indicate the inner-diameter inclination between the tip end and the inner-diameter taper bending point (Pm), and when an inner-diameter tapering gradient is set as (Tb) to indicate the inner-diameter inclination between the inner-diameter taper bending point (Pm) and the butt end, Tm>Tb is satisfied.

6. The golf club shaft according to Claim 5, wherein the inner-diameter taper has an inner-diameter taper bending point (Pt) positioned 40~140 mm from the tip end of the shaft; and when an inner-diameter tapering gradient is set as (Tt) to indicate the inner-diameter inclination between the tip end and the inner-diameter taper bending point (Pt), and when an inner-diameter tapering gradient is set as (Tm') to indicate the inner-diameter inclination between the inner-diameter taper bending point (Pt) and the inner-diameter taper bending point (Pm), the following are satisfied:

$$Tt < Tm'$$
$$0.1/1000 \leq Tt \leq 5/1000$$

7. The golf club shaft according to Claim 5 or 6, wherein the (Tm) and the (Tb) satisfy $1.5 \leq Tm/Tb \leq 5.5$.

8. The golf club shaft according to any of Claims 1~7, wherein the outer diameter at the tip end is set to be 8.5 mm~9.3 mm, and the outer diameter at the butt end is set to be 14.0 mm~16.5 mm.

9. The golf club shaft according to any of Claims 1~8, further comprising an angle layer made of fiber-reinforced resin where the fiber orientation is set diagonally to the longitudinal direction of the shaft; the weight layer (W); a straight layer made of fiber-reinforced resin where the fiber orientation is set to be parallel to the longitudinal direction of the shaft; and a hoop layer where the fiber orientation is set to be perpendicular to the longitudinal direction of the shaft.

10. The golf club shaft according to Claim 9, further comprising a reinforcement layer made of fiber-reinforced resin, wherein the reinforcement layer is disposed 400 mm or less from the tip end side of the shaft, and its fiber orientation is set to be parallel to the longitudinal direction of the shaft.

11. A golf club comprising the golf club shaft according to any of Claims 1~10.

FIG. 1

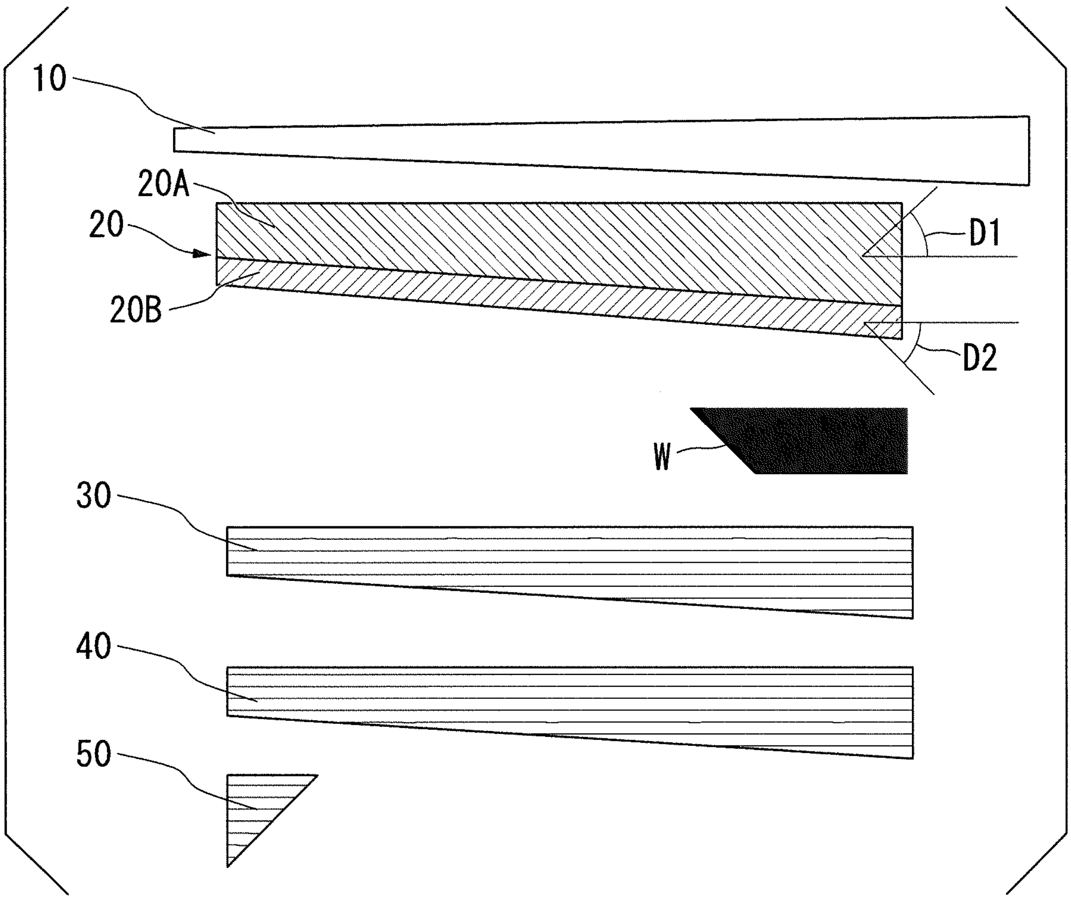

10
20A
20
20B
D1
D2
W
30
40
50

FIG. 2

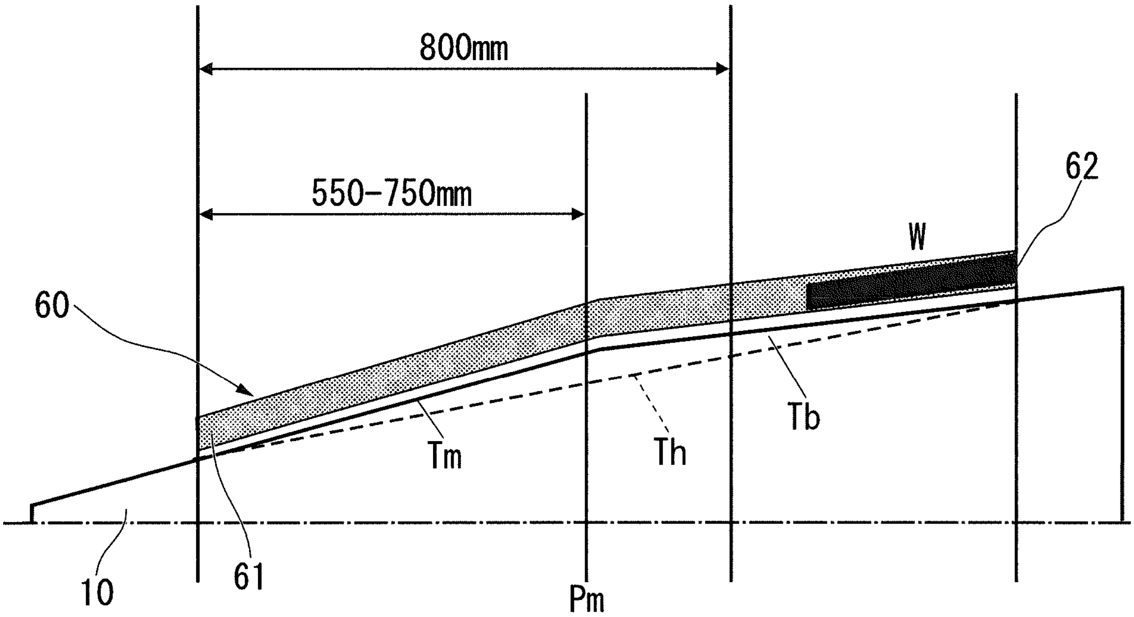
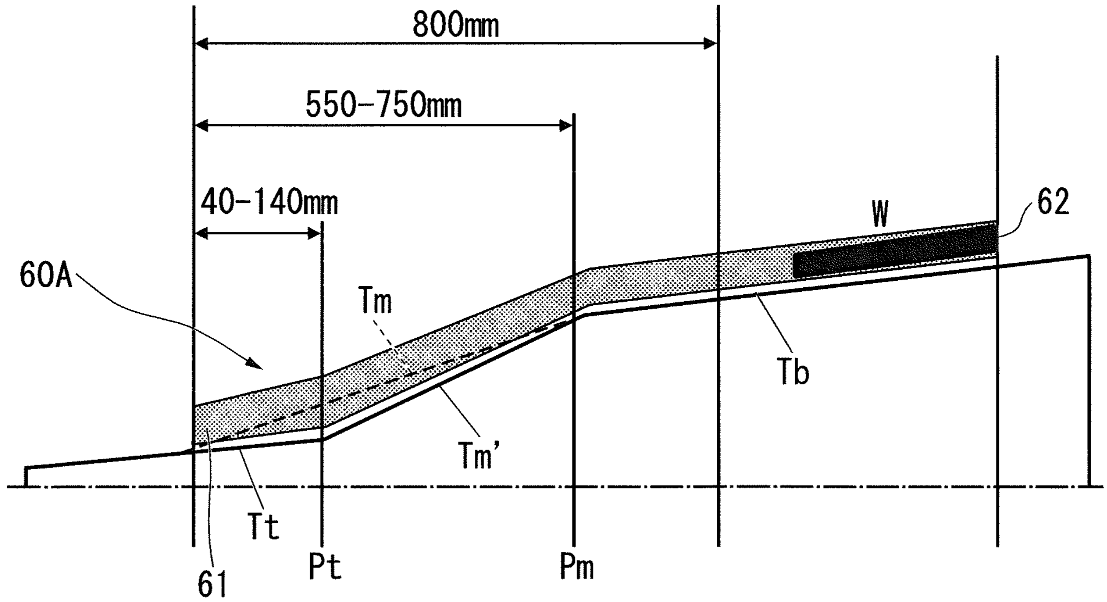
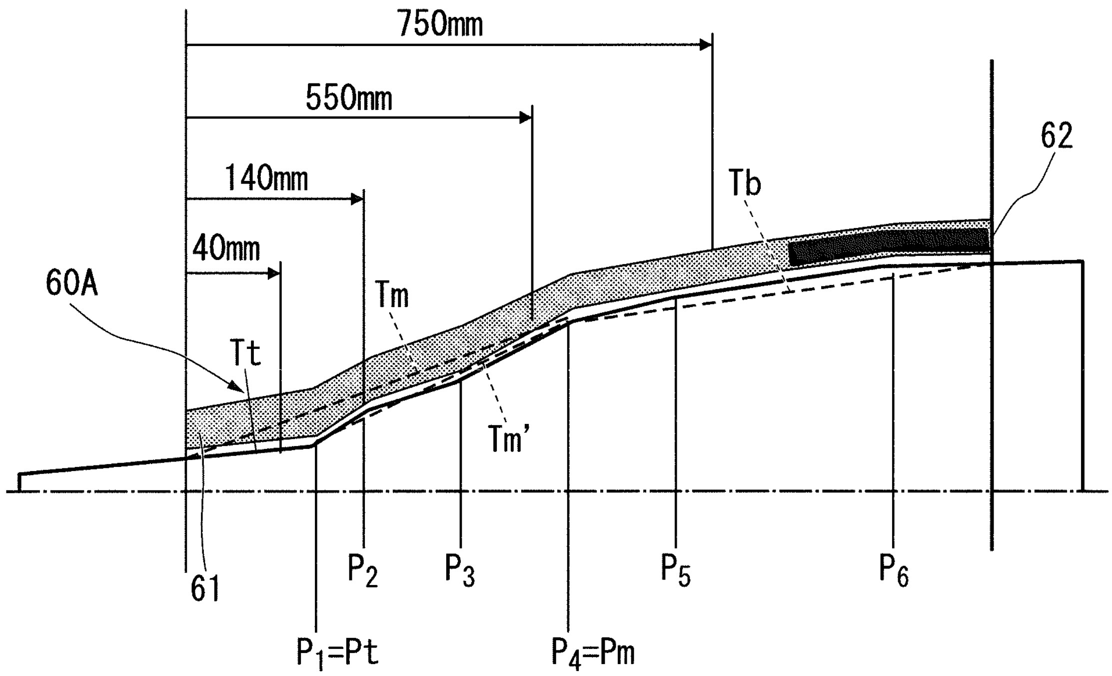

800mm
550-750mm
62
W
60
Tb
Tm
Th
10
61
Pm

FIG. 3



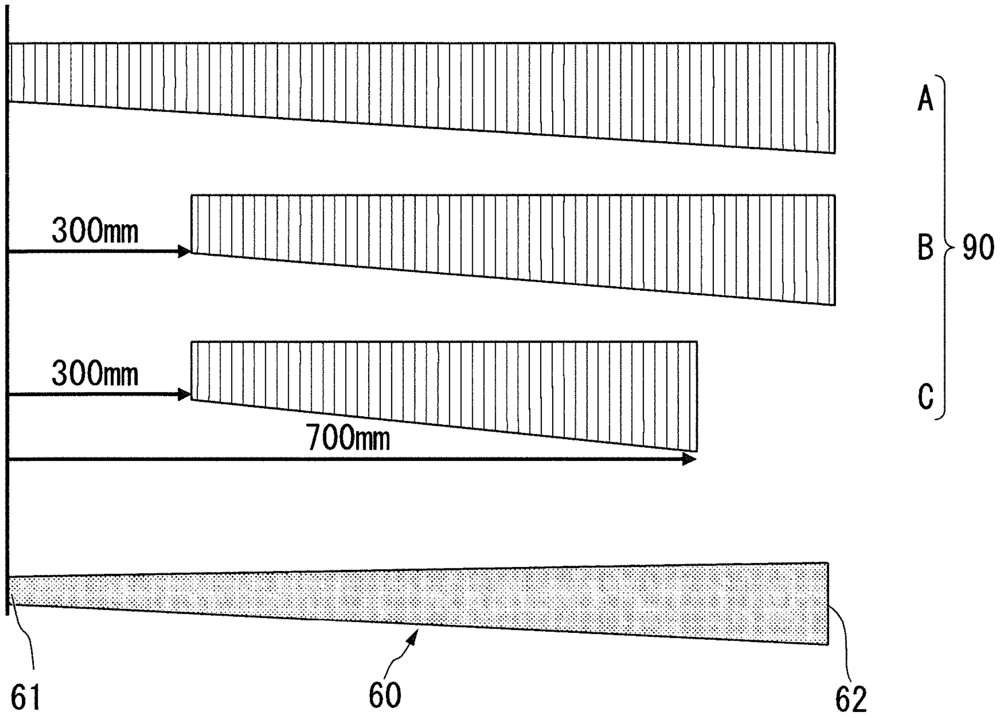
800mm
550-750mm
40-140mm
W
62
60A
Tm
Tb
Tm'
Tt
61
Pt
Pm

FIG. 4



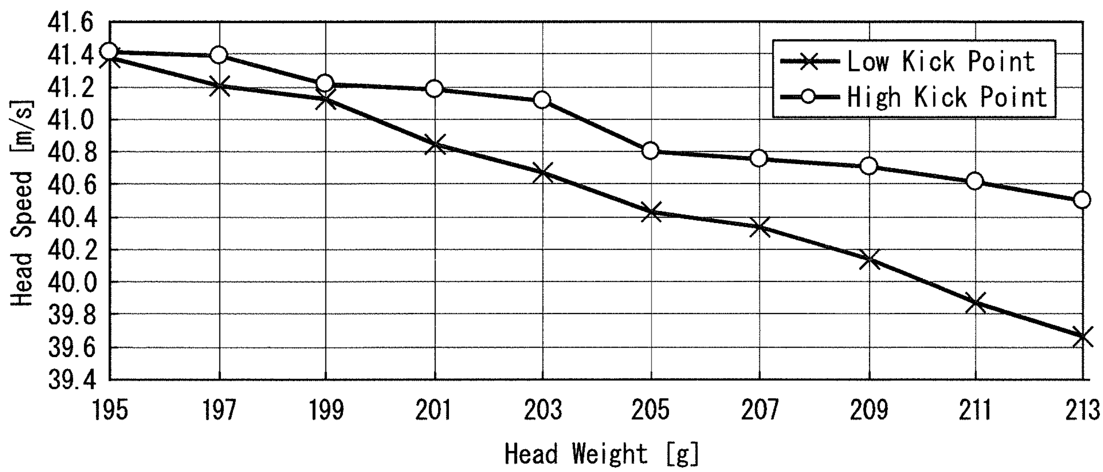
750mm
550mm
140mm
40mm
62
Tb
60A
Tm
Tt
Tm'
61
P2
P3
P5
P6
P1=Pt
P4=Pm

FIG. 5



A
300mm
B
90
300mm
C
700mm
61
60
62

FIG. 6



Low Kick Point
High Kick Point
Head Speed [m/s]
41.6
41.4
41.2
41.0
40.8
40.6
40.4
40.2
40.0
39.8
39.6
39.4
195
197
199
201
203
205
207
209
211
213
Head Weight [g]

FIG. 7

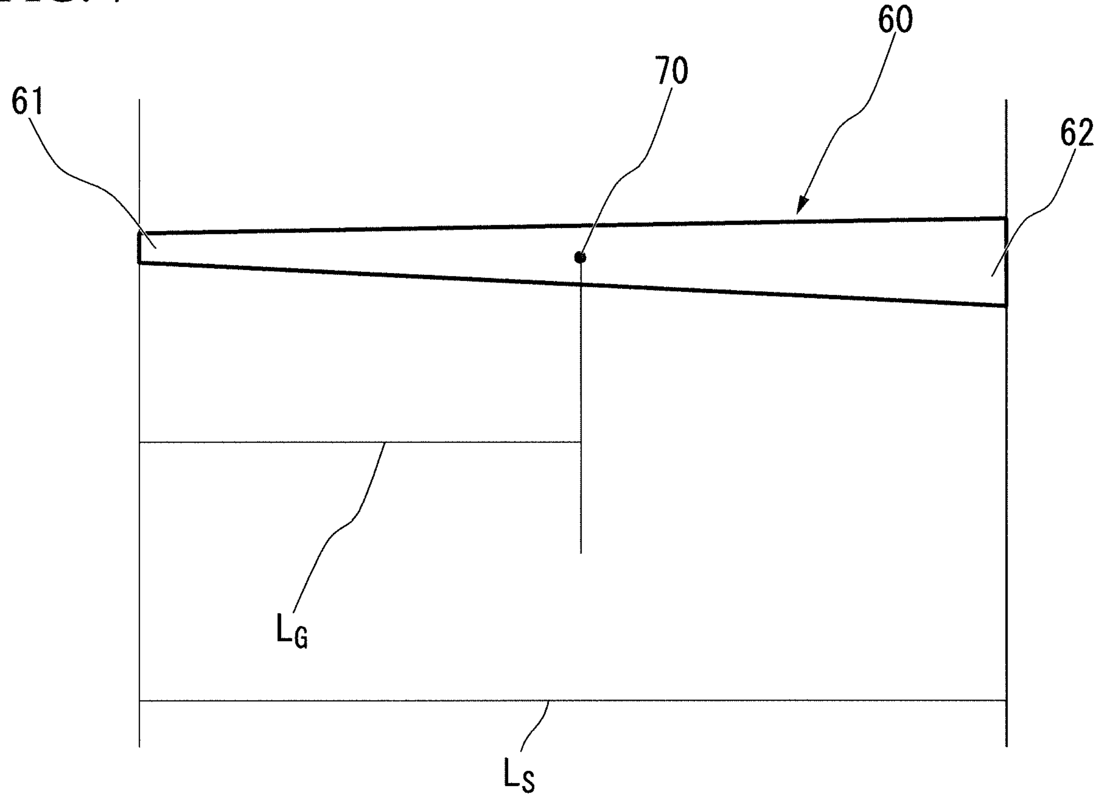
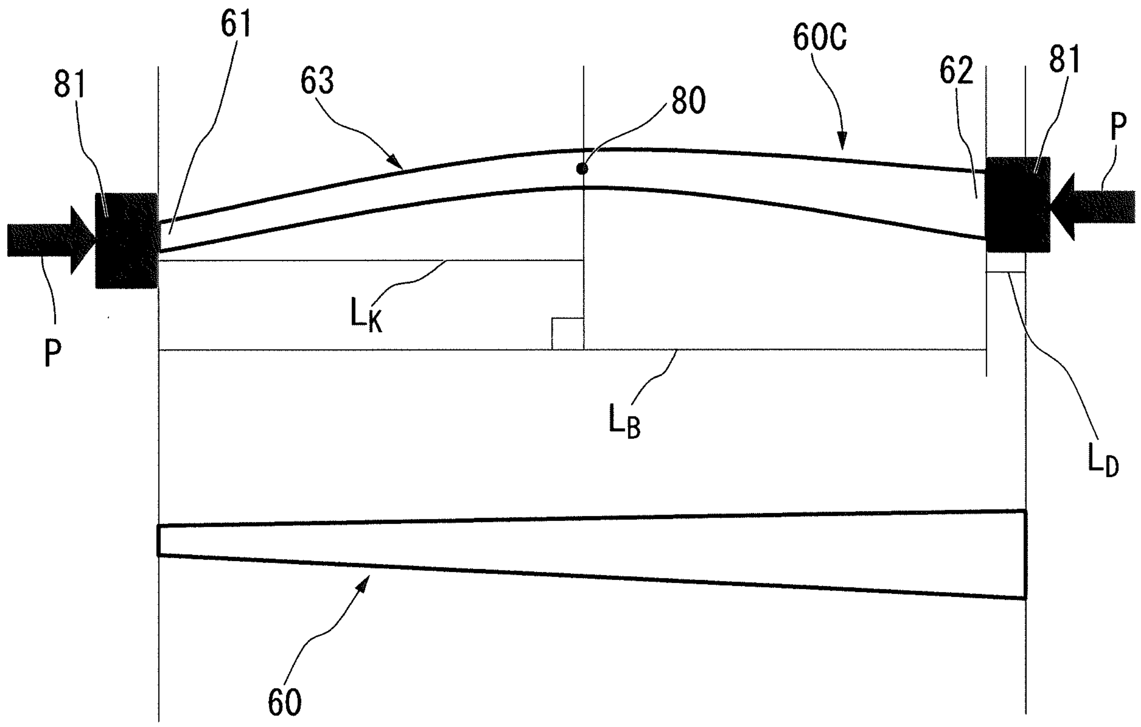


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/073212

A. CLASSIFICATION OF SUBJECT MATTER
A63B53/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A63B53/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2001-346925 A (Daiwa Seiko Inc.), 18 December 2001 (18.12.2001), paragraphs [0018] to [0020] (Family: none)	2
Y	JP 2005-131838 A (Sumitomo Rubber Industries, Ltd.), 26 May 2005 (26.05.2005), paragraph [0030]; fig. 1 (Family: none)	3

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

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Date of the actual completion of the international search	Date of mailing of the international search report
12 September, 2013 (12.09.13)	15 October, 2013 (15.10.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/073212

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X Y A	JP 2001-137404 A (Honma Golf Co., Ltd.), 22 May 2001 (22.05.2001), paragraphs [0005], [0017] to [0021], [0028]; fig. 1 (Family: none)	1,4,5,7,11 6,8 2,3,9,10
Y A	JP 11-216206 A (Mitsubishi Rayon Co., Ltd.), 10 August 1999 (10.08.1999), paragraphs [0007] to [0009], [0015]; fig. 1, 2, 10 & US 2001/14626 A1 paragraphs [0017] to [0019], [0047]; fig. 1, 2, 10 & JP 2008-173517 A	6 5,7
P,X P,A	JP 2012-239574 A (Dunlop Sports Co., Ltd.), 10 December 2012 (10.12.2012), paragraphs [0024] to [0031], [0074], [0087], [0090], [0092], [0105], [0112], [0113]; table 5; fig. 1, 2, 6 & US 2012/295734 A1 paragraphs [0033] to [0040], [0082], [0094], [0106], [0108], [0121], [0128], [0130]; table 5; fig. 1, 2, 6 & CN 102784464 A	1-4,8-11 5-7
A	JP 2009-219652 A (Daiwa Seiko Inc.), 01 October 2009 (01.10.2009), paragraphs [0010], [0019], [0020], [0030], [0031]; fig. 1, 4 (Family: none)	1-11
A	JP 2001-161872 A (Mitsubishi Rayon Co., Ltd.), 19 June 2001 (19.06.2001), table 2 (Family: none)	1-11
A	JP 11-319170 A (The Fujikura Rubber Ltd.), 24 November 1999 (24.11.1999), fig. 4 (Family: none)	5-7

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REFERENCES CITED IN THE DESCRIPTION

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