(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 299 069 A1

(12) # EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
28.03.2018 Bulletin 2018/13

(21) Application number: **16796288.5**

(22) Date of filing: **28.04.2016**

(51) Int Cl.:
A63B 53/00 *(2015.01)* ***A63B 60/46*** *(2015.01)*
A63B 69/36 *(2006.01)*

(86) International application number:
PCT/JP2016/063390

(87) International publication number:
WO 2016/185894 (24.11.2016 Gazette 2016/47)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **20.05.2015 JP 2015102548**

(71) Applicant: **Mitsubishi Chemical Corporation**
Tokyo 100-8251 (JP)

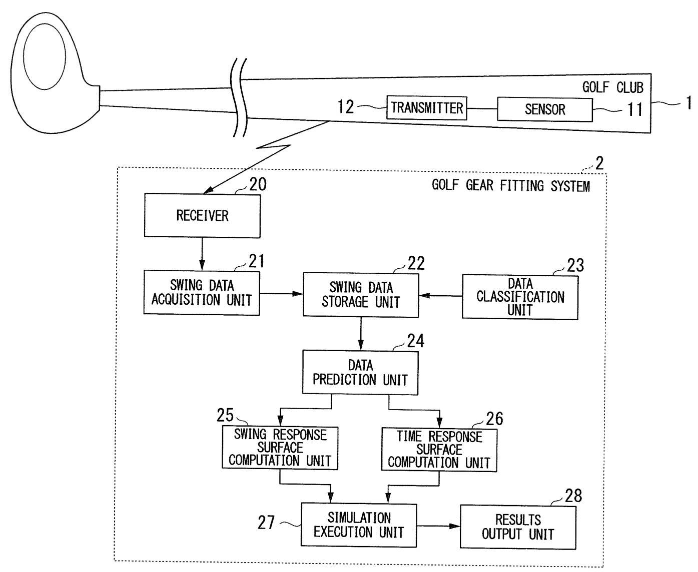
(72) Inventors:
- **SHIMONO Satoshi**
Toyohashi-shi
Aichi 440-8601 (JP)
- **SUZUKI Katsuyuki**
Kashiwa-shi
Chiba 277-8568 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) # GOLF GEAR FITTING SYSTEM, GOLF GEAR FITTING METHOD, GOLF GEAR FITTING PROGRAM, GOLF SWING CLASSIFICATION METHOD, GOLF SHAFT FITTING SYSTEM, GOLF SHAFT FITTING METHOD, AND GOLF SHAFT FITTING PROGRAM

(57) A golf gear fitting system (2) includes a swing data acquisition unit (21) to acquire swing data from a sensor (11) installed in a golf club (1), a swing data storage unit (22) to store the swing data acquired by the swing data acquisition unit (21), a data classification unit (23) to classify the swing data stored in the swing data storage unit (22), and a data prediction unit (24) to predict swing data of specifications not measured by the sensor (11) by referring to the swing data classified in the data classification unit (23).

FIG. 1



EP 3 299 069 A1

Description

Technical Field

[0001] The present invention relates to a golf gear fitting system, a golf gear fitting method, a golf gear fitting program, a golf swing classification method, a golf shaft fitting system, a golf shaft fitting method, and a golf shaft fitting program.
[0002] The present application is based upon and claims the benefit of priority to Japanese Application No. 2015-102548, filed May 20, 2015, the entire contents of which are incorporated herein by reference.

Background Art

[0003] In 2008, a regulation on the repulsive force of a golf club head was put into effect by the Rules of Golf, making it difficult to optimize ball carry by the club head alone. In response to the regulation, manufacturers switched their focus to the shaft, aiming to increase ball carry by optimizing the bending of a shaft. Accordingly, variations in shafts increased as of 2012, and combinations of shafts and club heads thereby brought about a further increase in variations of golf clubs. As an undesirable effect of such an increase, it is difficult for a player to select the most suitable golf gear, especially the most suitable shaft, at time of purchasing a golf club.
[0004] Fitting techniques are intended to be a solution for the aforementioned problem. The technique described in Patent Literature 1 is an example of a fitting technique focusing on the entire golf club. The head behavior at the moment of impact is photographed by a high-speed camera, and the behavior is converted into three-dimensional coordinates by a DLT (Direct Linear Transformation) method so as to quantify the position of the head. By so doing, the head position of each club at the moment of impact is determined, allowing the player to choose a suitable golf club. However, when such a technique is used, it is necessary for a player to test many golf clubs by actually hitting golf balls. Therefore, the player can only make a better choice, but it is still hard to make the best choice.
[0005] The technique described in Patent Literature 2 is intended to solve the above problem. In the technique, the swing is first measured, and the head behavior is simulated based on the swing data. When the technique is used, by performing one swing for measurement, the player obtains the results corresponding to test hitting with hundreds of clubs. However, when a player uses actual golf clubs each having a different rigidity and weight, the player hits a ball by changing the swing itself. Thus, when clubs and shafts with significantly different properties are simulated based on the data of one swing, the problem is that the simulation results do not correspond to actual solutions.
[0006] The technique described in Patent Literature 3 is intended to solve the above problem. By using a response surface methodology approach, the technique computes swings that vary as factors are changed in shaft properties (flex, kickpoint and torque). Based on the modified swing data, simulations closer to actual behaviors can be performed.
[0007] However, when the technique described in Patent Literature 3 is used, the issue is that it is difficult to simulate by changing, for example, the "weight" and "length" of members of a golf club. That is because when the weight and length are changed, even with the same player, swing time is significantly different from address (the position when the golf club is in contact with the ground) to top (the position when the golf club is at the top of backswing) and from top to impact (the moment the head hits a ball), making it difficult to obtain sufficiently accurate computations. Accordingly, specifications of golf clubs as variables used in the technique of Patent Literature 3 are limited to those excluding the weight, length and the like that significantly affect the swing time.
[0008] The technique described in Patent Literature 4 is intended to solve the above problem. By using a swing response surface and a time response surface, the technique is capable of accurately performing simulations even on such specifications that significantly affect swing time.

CITATION LIST

PATENT LITERATURE

[0009]

Patent Literature 1: JP2005-312734A
Patent Literature 2: JP4871218B
Patent Literature 3: JP2011-425A
Patent Literature 4: WO2014/132885

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010] However, to use the technique described in Patent Literature 4, it is necessary for the player to swing multiple golf clubs. Therefore, if the test hitter is a beginner whose swing is unstable, variations are observed among swings, and desired results may be difficult to obtain.

[0011] The present invention was carried out in consideration of the aforementioned issues. Its objective is to provide a golf gear fitting system, a golf gear fitting method, a golf gear fitting program, a golf shaft fitting system, a golf shaft fitting method, and a golf shaft fitting program, capable of determining suitable golf gear for the user by a small number of test hits.

SOLUTIONS TO THE PROBLEMS

[0012] The present invention has the following aspects.

[1] A golf gear fitting system, having: a swing data acquisition unit to acquire swing data from a sensor installed on multiple golf clubs with different specifications; a swing data storage unit to store the swing data acquired by the swing data acquisition unit; a data classification unit to classify the swing data stored in the swing data storage unit; and a data prediction unit to predict swing data of specifications not measured by the sensor by referring to the swing data classified by the data classification unit.

[2] A golf gear fitting method, including: a swing data acquisition step for acquiring swing data from a sensor installed on multiple golf clubs with different specifications; a swing data storing step for storing in a swing data storage unit the swing data acquired by the swing data acquisition step; a data classification step for classifying the swing data stored in the swing data storage unit; and a data prediction step for predicting swing data of specifications not measured by the sensor by referring to the swing data classified in the data classification step.

[3] A golf gear fitting program to be executed by a computer, including: a swing data acquisition process for acquiring swing data from a sensor installed on multiple golf clubs with different specifications; a swing data storing process for storing in a swing data storage unit the swing data acquired by the swing data acquisition process; a data classification process for classifying the swing data stored in the swing data storage unit; and a data prediction process for predicting swing data of specifications not measured by the sensor by referring to the swing data classified in the data classification process.

EFFECTS OF THE INVENTION

[0013] According to the present invention, suitable golf gear can be determined by a small number of test hits. Therefore, the present invention is also a preferable tool for a beginner with an unstable swing. Moreover, since the measurement time is reduced, more time is made available for listening to a golfer as the actual user as well as for test hitting the gear the golfer plans to purchase.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1 is a block diagram showing a golf gear fitting system according to a first embodiment;
FIG. 2A is a view showing an example of flexural rigidity (flex) of a shaft;
FIG. 2B is a view showing an example of the kickpoint of a shaft (flexural rigidity distribution L(x));
FIG. 3A is a view showing an example of torsional rigidity (torque) of a shaft and an example of specifications of a head;
FIG. 3B is a view showing an example of the depth of the center of gravity in the head;
FIG. 3C is a view showing an example of the height and distance of the center of gravity in the head;
FIG. 4 is a table showing specifications of nine golf clubs used for test hitting to obtain swing data;
FIG. 5A is a graph showing an example of swing data (acceleration);
FIG. 5B is a graph showing an example of swing data (angular velocity);
FIG. 6 is a view showing classification results of swing data;
FIG. 7 is a flowchart showing processes of a golf club fitting system;
FIG. 8 is a series of views illustrating a method for predicting swing data;
FIG. 9 is a graph showing swing data when the shaft weight is the same;
FIG. 10 is a graph showing swing data when the shaft weight is different;

FIG. 11 is a graph showing swing data computed using only a swing response surface;
FIG. 12 is a graph showing swing data computed using a swing response surface and a time response surface;
FIG. 13 is a graph showing simulation results;
FIG. 14 is a table showing examples of degree of impact;
FIG. 15 is a table used by the data classification unit in a second embodiment; and
FIG. 16 is a table used by the data prediction unit in the second embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0015] In the following, a golf gear fitting system, a golf gear fitting method, a golf gear fitting program, a golf swing classification method, a golf shaft fitting system, a golf shaft fitting method, and a golf shaft fitting program according to an embodiment of the present invention are described by referring to the attached drawings. Note that as an example of the specifications of golf gear, a golf shaft is described below, but that is not the only option in the present invention.

(First Embodiment)

[0016] FIG. 1 is a block diagram showing a golf gear fitting system according to a first embodiment. In the diagram, golf club 1 is prepared in advance by installing a golf shaft with known specifications. Golf club 1 is equipped with sensor 11 and transmitter 12 inside the shaft at the grip portion. Transmitter 12 transmits the output from sensor 11 to the outside via wireless communication.

[0017] Sensor 11 may be installed outside of a shaft. For example, sensor 11 may be installed on the outer side of a shaft beneath the grip portion. By so setting, sensor 11 is installed on golf club 1 owned by a player. Alternatively, sensor 11 may also be installed inside a shaft of golf club 1 at the grip edge. By so setting, even more accurate swing data are obtained. Sensor 11 and transmitter 12 are preferred to be integrated. When sensor 11 and transmitter 12 are not integrated, it is preferred that transmitter 12 and the battery or the like built into the transmitter be set to be attachable to an arm or the like of the golfer. Such a setting reduces the weight of a sensor main body to be installed in a club, thus preventing a change in specifications of the club caused by installation of sensor 11.

[0018] Sensor 11 is a six-axial sensor that detects and outputs acceleration in triaxial directions and angular velocity in triaxial directions. However, that is not the only option; for example, sensor 11 may be a nine-axial sensor that measures orientation in triaxial directions using geomagnetism in addition to acceleration in triaxial directions and angular velocity in triaxial directions. Also, sensor 11 may be formed with two sensors, having a six-axial sensor and a triaxial geomagnetometer, or with two accelerometers with different measuring ranges and one gyro sensor. In such a setting, a sensor with a narrow measuring range is used for slow motions such as backswing, and a sensor with a wide measuring range is used for quick motions such as downswing. By so setting, measuring accuracy is enhanced. The frequency of 200 Hz was used for the sensor here, but the preferred frequency is 500 Hz or higher, more preferably 1000 Hz or higher. The higher the frequency is, the greater is the detail in which slight changes in motion are captured

[0019] Golf gear fitting system 2 is a computer apparatus having a processor such as a CPU (Central Processing Unit) and a memory that stores a program for the processor to execute. Golf gear fitting system 2 includes receiver 20, swing data acquisition unit 21, swing data storage unit 22, data classification unit 23, data prediction unit 24, swing response surface computation unit 25, time response surface computation unit 26, simulation execution unit 27, and results output unit 28. Those functions are implemented when the CPU executes the program stored in the memory.

[0020] Receiver unit 20 receives output data (swing data) transmitted by transmitter 12 of the sensor. Swing data acquisition unit 21 acquires the swing data through receiver unit 20. In swing data storage unit 22, multiple swing data obtained when a large number of players swung multiple golf clubs are stored in advance. In addition, the data stored in swing data storage unit 22 are not limited to swing data. For example, swing data storage unit 22 may also store data on head behavior computed based on swing data.

[0021] Data classification unit 23 classifies swing data stored in swing data storage unit 22. Data classification unit 23 classifies swing data using a self-organizing map; a detailed description is provided later. The method for classification is not limited to using a self-organizing map. For example, data classification unit 23 may also use various clustering methods such as a neural network, support vector machines, Bayesian networks, hidden Markov models, k-means, cluster classification, principal component analysis, machine learning, and multivariate analysis. Moreover, classification may be conducted by golf experts based on their experience. Classification by data classification unit 23 is not limited to swing data, and may also include classification of head behavior.

[0022] Data prediction unit 24 refers to swing data storage unit 22 and extracts swing data similar to the swing data acquired by swing data acquisition unit 21. Then, based on the data of the player corresponding to the extracted swing data, data prediction unit 24 predicts swing data of a golf club that has not yet been swung by the player. Note that data predicted by data prediction unit 24 are not limited to swing data, and may include head behavior computed by the swing data.

[0023] Based on the swing data acquired by swing data acquisition unit 21, swing response surface computation unit 25 computes a swing response surface when golf club 1 is swung. Based on the swing data acquired by swing data acquisition unit 21, time response surface computation unit 26 computes a response surface of swing time when golf club 1 is swung. Simulation execution unit 27 performs a simulation through the FEM (Finite Element Method) using the swing response surface and time response surface. Results output unit 28 outputs the results of the simulation executed by simulation execution unit 27.

[0024] Next, golf club 1 used for obtaining swing data is described below. Swing data obtained by swinging golf club 1 are stored in swing data storage unit 22. Players swing golf club 1 according to its specifications (weight, flexural rigidity, torsional rigidity and the like of the shaft). Different specifications of golf club 1 produce a different swing by the player. Therefore, if a simulation is performed based on swing data obtained by using one golf club, it is difficult to achieve appropriate simulation results.

[0025] Therefore, the following describes an example of the method for selecting golf club 1 used for simulations. First, based on experimental design, three different specifications are selected from among numerous specifications of golf club 1. Then, a total of 27 golf clubs are prepared by setting three levels for each of the three specifications. Among them, 9 golf clubs 1 are selected based on an L9 orthogonal array. To obtain data on three levels for each of the three different specifications without using an experimental design, it is necessary to perform simulations on 3^3=27 golf clubs 1. Accordingly, using an experimental design reduces the load when acquiring swing data.

[0026] Here, an example of three specifications of golf club 1, namely, the weight of a shaft, the flexural rigidity of a shaft (hereinafter referred to as flex), and the flexural rigidity distribution of a shaft (hereinafter referred to as kickpoint), are used. As for golf clubs 1 to be used, three different levels are prepared for each of the three specifications, but such a setting is not the only option.

[0027] FIG. 2A is a view showing an example of the flexural rigidity (flex) of a shaft. In FIG. 2A, a point 920 mm from the tip end of a shaft is supported from below, a point 150 mm farther away toward the butt end (1070 mm from the tip end) is supported from above, and a load of 3.0 kgf is exerted on a point 10 mm from the tip end. The value of displacement of the tip end at that time is the flex of a shaft (flexural rigidity).

[0028] FIG. 2B is a view showing an example of the kickpoint of a shaft (flexural rigidity distribution L(x)). The kickpoint of a shaft is determined by coefficient (C) of function (P), showing the point of maximum bend of the shaft. In FIG. 2B, EI (i) indicates the flexural rigidity, and (x) shows the position on a shaft based on the tip end of the shaft. The kickpoint of a shaft is expressed by the formula below.

$$L(x)=C0\times P0(x)+ C1\times P1(x)+ C2\times P2(x)+ C3\times P3(x)$$

[0029] The kickpoint may also be defined as follows. When a shaft is curved, the point protruding the most in the shaft circumferential direction is set as the apex, and the distance (Lk) is measured from the apex to the tip end. The ratio of the distance (Lk) to the shaft length (Lb) when it is curved (linear distance between both ends of the shaft when it is curved) is the value of a kickpoint. Namely, the kickpoint is obtained by the formula below.

$$\text{kickpoint (\%)}=(Lk/Lb)\times 100$$

[0030] Kickpoint values in the present application are those obtained by a shaft kickpoint gauge "FG-105RM," made by Fourteen Co., Ltd. For example, shafts with a kickpoint lower than 44.0% are classified as low kickpoint shafts, shafts with a kickpoint of 44.0% or higher but lower than 45.0% are classified as middle kickpoint shafts, and shafts with a kickpoint of 45.0% or higher are classified as high kickpoint shafts.

[0031] Moreover, (Lk) and (Lb) are strictly defined as follows.

[0032] Lk: when a shaft is curved by a compression load applied on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the entire shaft length, (Lk) is the distance from the tip end of the shaft to the point where the straight line connecting both ends intersects a vertical line drawn from the apex of the curve.

[0033] Lb: when a shaft is curved by a compression load applied on both ends of the shaft so that the linear distance between both ends is 98.5~99.5% of the entire shaft length, (Lb) is the linear distance between both ends of the shaft.

[0034] The kickpoint of a shaft is classified as the point of maximum bend: when it is closer to the grip it is called a high kickpoint, when it is closer to the head it is called a low kickpoint, and when it is in the middle it is called a middle kickpoint. In addition, kickpoints are allotted to be any of high, low, and middle depending on the value determined by coefficient (C) of function (P). Swing data are acquired by using nine golf clubs 1 described above.

[0035] Other specifications that may be used are the torsional rigidity of a shaft (hereinafter referred to as the torque), torsional rigidity distribution of the shaft, weight distribution of the shaft, length of a golf club, weight of a head, club balance, depth, height and distance of the center of gravity in the head, grip weight, loft angle, lie angle and face angle.

[0036] FIG. 3A is an example showing the torsional rigidity (torque) of a shaft. As shown in FIG. 3A, the torque of a shaft is determined by the torsional angle of a shaft. In FIG. 3A, a position 1035 mm from the tip end of a shaft is fixed, and a torsional load is exerted on a position 45 mm from the tip of the shaft. In addition, a torsional load of 1.152 kgf is exerted on a position 120 mm from the shaft axis. That would be the same as exerting a torsional load of 1 ft·lb on the tip of the shaft. The torsional angle at the tip end of the shaft is defined as the torque of the shaft.

[0037] FIG. 3B is a view showing an example of the depth of the center of gravity in a club head. As shown in FIG. 3B, the depth of the center of gravity is the depth (distance) from the face surface to the center of gravity in the head. FIG. 3C is a view showing an example of the height and distance of the center of gravity in a club head. The height of the center of gravity is the length from the leading edge to the center of gravity on the face surface. The distance of the center of gravity is the length of a vertical line extending from the shaft axis toward the center of gravity on the face surface. The torsional rigidity distribution of a shaft and weight distribution of a shaft are described the same as the relationship of the flexural rigidity distribution and kickpoint.

[0038] The club balance (also called the swingweight) is how the head of a golf club feels when the golf club is swung. The swingweight of a head means the feel of weight of the head during a swing or waggle. Club balance is measured by using a club balance scale "Golf Club Scale" made by Kenneth Smith, Inc.

[0039] The stiffness of a club is specified by the frequency of golf club 1 when a grip and head are attached onto a shaft. The frequency is measured by using a "Golf Club Timing Harmonizer," made by Fujikura Rubber, Ltd. For example, a point 180 mm from the grip end is fixed and the club head is vibrated. The stiffness of the club is specified as the number of vibrations per minute obtained at a point 760 mm from the grip end.

[0040] FIG. 4 is a table showing specifications of nine golf clubs used for test hitting to obtain swing data. Specifications of nine golf clubs are determined by an L9 orthogonal table based on experimental design. The shaft weight shows a normalized value; a smaller value means a heavier shaft. In the present embodiment, when the shaft weight is rated as "0" it is 80 grams; when rated as "0.5" it is 70 grams; and when rated as "1" it is 60 grams.

[0041] Also, flex shows normalized values; a smaller value means a higher rigidity. In the present embodiment, when the flex is rated as "0" it is 130 mm; when rated as "0.5" it is 180 mm; and when rated as "1" it is 220 mm.

[0042] Moreover, the kickpoint is also normalized. When the shaft is rated as "0" it is a low kickpoint; when rated as "0.5" it is a middle kickpoint; and when rated as "1" it is a high kickpoint. The number of golf clubs to be used is not limited to nine, but may be any number that enables practical experiments.

[0043] The same type of head is attached to nine golf clubs 1 shown in FIG. 4. Each of nine golf clubs 1 has the same length and the same weight. As described, when using golf clubs 1 whose specifications are the same except for those that are subject to fitting, variations derived from other factors are eliminated.

[0044] Moreover, sensor 11, transmitter 12 and other devices necessary to operate them are inserted into each shaft of nine golf clubs 1. The total weight of sensor 11, transmitter 12 and other devices necessary to operate them is capped at 30 grams. Accordingly, the impact on swing derived from an increase in the weight of golf club 1 is suppressed. The total weight is preferred to be 20 grams or less. When those devices are installed, by choosing a generally available lightweight grip whose total weight is below 30 grams, measurement for data acquisition can be performed without changing the total weight or balance of the club.

[0045] Next, the method for classifying swing data is described. In the present embodiment, 126 players each swing nine golf clubs 1. A large volume of swing data is obtained accordingly. More specifically, since a six-axial sensor is used as sensor 11, 126 players $\times$ nine clubs $\times$ 6 axes=6804 pieces of data stored in swing data storage unit 22.

[0046] FIG. 5A shows an example of swing data (acceleration). In FIG. 5A, the swing data (acceleration) of five players are shown; the solid lines show acceleration in the axis-x direction, broken lines show acceleration in the axis-y direction, and one-dot chain lines show acceleration in the axis-z direction. The vertical axis shows acceleration values normalized to have an absolute value of 1. The horizontal axis shows time from top (the position when the golf club is at the top of backswing) to impact (the moment the head hits the ball). The time from top to impact is divided into 40 sections.

[0047] FIG. 5B is a view showing an example of swing data (angular velocity). In FIG. 5B, swing data (angular velocity) of five players are shown; the solid lines show angular velocity around axis-x, broken lines show angular velocity around axis-y, and one-dot chain lines show angular velocity around axis-z. The vertical axis shows values of angular velocity normalized to have an absolute value of 1. The horizontal axis shows time from top to impact. The time from top to impact is divided into 40 sections.

[0048] As described above, swing data of 126 players are acquired in the present embodiment. When complex swing data of 126 players are stored, it is difficult to classify them by analysis through visual inspection by human beings. Therefore, data classification unit 23 classifies swing data using a self-organizing map in the present embodiment.

[0049] A self-organizing map (SOM) is an algorithm to conduct clustering through unsupervised learning, and is a data analysis tool for nonlinear mapping of high-dimensional data on a two-dimensional plane. A self-organizing map is a tool capable of clustering swing data by mapping high-dimensional complex data on a two-dimensional plane.

[0050] A self-organizing map has an input layer and an output layer. The input layer of the present embodiment is swing data. Among swing data of players, data classification unit 23 in the present embodiment uses the swing data of golf club 1 with club number "5" shown in FIG. 4. As described above, each set of swing data is divided timewise into 40 sections from top to impact. Moreover, each set of swing data is normalized to have an absolute value of 1.

[0051] The input vector (s) in formula (1) below shows the swing data of one player. Since the time from top to impact is divided into 40 sections, D=40 in the formula.

[math 1]

$$\vec{s} = (s_1, s_2, \cdots, s_D) \quad \cdots \text{formula (1)}$$

[0052] Moreover, swing data (S) of 126 players are represented by formula (2) below. Note that N=126.

[math 2]

$$S = \begin{pmatrix} s_{1,1} & s_{2,1} & \cdots & s_{D,1} \\ s_{1,2} & s_{2,2} & \cdots & s_{D,2} \\ \vdots & \vdots & \vdots & \vdots \\ s_{1,N} & s_{2,N} & \cdots & s_{D,N} \end{pmatrix} \quad \cdots \text{formula (2)}$$

[0053] Next, the output layer is described. Reference vector (m) is defined by formula (3) below using a neuron (u). Note that (i) is a positive integer.

[math 3]

$$\vec{m} = (u_{i,1}, u_{i,2}, \cdots, u_{i,D}) \quad \cdots \text{formula (3)}$$

[0054] Moreover, the matrix (M) is represented by formula (4) below. Note that (L) is the number of nodes in matrix (M).

[math 4]

$$M = \begin{pmatrix} \vec{m}_1 \\ \vec{m}_2 \\ \vdots \\ \vec{m}_L \end{pmatrix} \quad \cdots \text{formula (4)}$$

[0055] Data classification unit 23 allots a random value to each neuron (u). Data classification unit 23 provides the input layer with input vector (s). Data classification unit 23 determines the node of an output layer having a reference vector (m) that most closely matches the input vector (s) provided for the input layer. The node determined here is a winning node (c). Data classification unit 23 computes the winning node (c) based on the Euclidean distance between input vector (s) and reference vector (m) as shown in formula (5) below.

[math 5]

$$c = \arg\min \|\vec{m} - \vec{s}\| \quad \cdots \text{formula (5)}$$

[0056] When the winning node (c) is determined, data classification unit 23 updates the winning node (c) and nearby nodes via a learning process. More specifically, data classification unit 23 updates the winning node (c) in reference vector (m) and the nodes in its neighborhood to be closer to the input vector (s) according to formula (6) below.

[math 6]

$$\Delta \vec{m}_i = \frac{\vec{m}_i + h_{ci}\vec{s}}{\left\| \vec{m}_i + h_{ci}\vec{s} \right\|} \quad \cdots \text{formula (6)}$$

[0057] Here, according to formula (7) below, data classification unit 23 computes function (hci) that determines the size of learning. Coefficient (α) is a positive constant smaller than 1 and shows the rate of learning. In the present embodiment, (α) is set at 0.5 (α=0.5). Note that (ri) is a position on the output layer, (rc) is the coordinate of winning node (c), and (σ) is a positive constant, which corresponds to the standard deviation in the normalized distribution.
[math 7]

$$h_{ci} = \alpha \exp\left(-\frac{\left\| \vec{r}_i - \vec{r}_c \right\|^2}{2\sigma^2} \right) \quad \cdots \text{formula (7)}$$

[0058] Data classification unit 23 repeats the above learning process a predetermined number of times, and the swing data of 126 players are each separately classified into six data plots: acceleration on axes (x, y, z) and angular velocity on axes (x, y, z). In the present embodiment, data classification unit 23 repeated the learning process 10,000 times. Six separate sets of data may be connected in series to be one set of data.

[0059] FIG. 6 is a view showing classification results of monoaxial swing data (acceleration on axis-x) as an example. As shown in FIG. 6, data classification unit 23 mathematically classifies swing data in swing data storage unit 22 by using a self-organizing map. In FIG. 6, swing data are each classified into any of hexagonal blocks; however, that is not the only option. For example, regular polygonal (such as rectangular) blocks may be used. Moreover, an on-line SOM was used here, but a batch SOM may also be used. Since six different data groups, that is, acceleration data on axes (x, y, z) and angular velocity data on axes (x, y, z), are separately classified, six maps are actually created.

[0060] FIG. 7 is a flowchart showing processes of a golf gear fitting system. First, a player as a fitting target swings golf club 1 with the club number "5" among nine golf clubs 1. Sensor 11 outputs the detection results (swing data) obtained during the swing motion to transmitter 12. When swing data are outputted from sensor 11, transmitter 12 sends the swing data to receiver 20 by wireless transmission. Receiver 20 outputs the received swing data to swing data acquisition unit 21. Swing data acquisition unit 21 acquires the swing data outputted from receiver unit 20 (step S1).

[0061] Next, data prediction unit 24 refers to swing data in swing data storage unit 22, which are classified in advance by data classification unit 23 so as to predict swing data of eight other golf clubs 1 (club numbers "1~4, 6~9") (step S2).

[0062] The following describes the method for predicting swing data executed in step (S2). FIG. 8 is a view illustrating the prediction method of swing data. Swing data (SD1~SD9) correspond respectively to the swing data of club numbers "1~9". Difference data (DD1~DD4, DD6~DD9) respectively show the differences between swing data SD5 and swing data (SD1~SD4, SD6~SD9). Difference data (DD1~DD4, DD6~DD9) of multiple players are respectively stored in swing data storage unit 22.

[0063] From the classification of golf club 1 of club number "5", data prediction unit 24 predicts swing data of the other eight golf clubs 1. The process is conducted based on the assumption that a player with similar swings makes similar adjustments when swinging another shaft. Therefore, data prediction unit 24 computes eight sets of difference data (DD1~DD4, DD6~DD9) by subtracting data of club number "5" from each cluster with eight club numbers "1~4, 6~9".

[0064] When new data (ND) of golf club 1 of club number "5" are acquired by swing data acquisition unit 21, data prediction unit 24 determines where the new data (ND) are to be classified in the self-organizing map. More specifically, data prediction unit 24 searches all the swing data in swing data storage unit 22, and extracts the classification of swing data that lie most closely to the new data (ND), thereby identifying the swing data of a player with swings similar to those of the test hitter. Data classification unit 23 may perform a reclassification by adding new data (ND).

[0065] For example, to predict swing data of club number "1", data prediction unit 24 computes average values of all difference data (DD1) in the extracted classification. By adding the average values of computed difference data (DD1) to new data (ND), data prediction unit 24 computes the swing data of club number "1". Data prediction unit 24 also computes the swing data of other golf clubs 1 (club numbers "2~4, 6~9") in the same manner. Here, the average values of (DD1) of a classified group are added to (ND), but it is another option to add the (DD1) of a player with most similar swing data to (ND). Moreover, six sets of data obtained by a six-axial sensor are separately computed, but six sets of data may be connected in series and be processed as one set of data.

[0066] By the above process, data prediction unit 24 holds time-series swing data predicted as those when nine golf clubs 1 are used for one swing each. Data prediction unit 24 converts one acquired set of swing data (club number "5") and eight predicted sets of swing data (club numbers "1~4, 6~9") into grip motion velocity data and shaft axis rotation data of golf club 1. Such conversion is processed geometrically based on the installation position of sensor 11 inserted in golf club 1 and two positions of the grip in golf club 1 predetermined in advance.

[0067] In the above, data prediction unit 24 is set to convert only the swing data from top (the position when the golf club is at the top of backswing) to impact (the moment the head hits a ball) into motion velocity data and axis rotation data. However, that is not the only option. For example, data prediction unit 24 may also convert swing data from address (when golf club is in contact with the ground) to impact (moment golf club hits a ball) into motion velocity data and axis rotation data. As described, when data are predicted using a database obtained by swinging multiple golf clubs with different specifications, swing variations are identified for each specification. In addition, prediction values related to data of two or more different specifications (such as stiffness, kickpoint and weight) are obtained all at once. Accordingly, even easier fitting is made available, and interactions of specifications are also considered.

[0068] Next, swing response surface computation unit 25 reads out swing data of nine golf clubs held in data prediction unit 24 and computes a swing response surface by converting the skills and habits of a test hitter into a linear function (step S3). A swing response surface means a relational expression of the motion velocity data and axis rotation data obtained by test hitting nine golf clubs shown in FIG. 4 and three different specifications of golf club 1 (shaft weight, flex, kickpoint). A linear function is employed here, but higher-order functions such as a quadratic function may also be used.

[0069] The following describes a swing response surface computation process to be executed in step (S3). Swing data measured by test hitting multiple golf clubs 1 are expressed "f1~f9" as shown in formula (8) below. Time (t) is digitized as t={t1, ..., tn}. Note that swing data "f1~f9" are expressed since nine golf clubs 1 are used for test hitting in the present embodiment. However, the values differ by the number of golf clubs 1 used for test hitting. Moreover, "fj(ti)" indicates the measured value by golf club 1 of club number "j". More specifically, "fj(ti)" indicates acceleration in three directions {ax, ay, az} and angular velocity in three directions {ωx, ωy, ωz} respectively.

[0070] When three specifications (design variables) of each of nine golf clubs are set as {xj, yj, zj} (j=1, ..., 9), the relationships in formula (8) are obtained. Swing response computation unit 25 solves formula (8) for each (ti).

[0071] Here, (x, y, z) are design variables respectively; "x" is a first specification (shaft weight), "y" is a second specification (flex) and "z" is a third specification (kickpoint). Numbers (1~n) in (x1~xn, y1~yn, z1~zn) respectively correspond to the club numbers. Any value convenient for analysis is given to bar "x", bar "y" and bar "z". For example, middle values of design variables may be respectively assigned to bar "x", bar "y" and bar "z".

[math 8]

$$\begin{Bmatrix} f_1(t_i) \\ f_2(t_i) \\ \\ f_9(t_i) \end{Bmatrix} = \begin{bmatrix} 1 & (x_1-\bar{x}) & (y_1-\bar{y}) & (z_1-\bar{z}) \\ 1 & (x_2-\bar{x}) & (y_2-\bar{y}) & (z_2-\bar{z}) \\ & & & \\ 1 & (x_9-\bar{x}) & (y_9-\bar{y}) & (z_9-\bar{z}) \end{bmatrix} \begin{Bmatrix} a_1(t_i) \\ a_2(t_i) \\ a_3(t_i) \\ a_4(t_i) \end{Bmatrix} \quad \cdots \text{formula (8)}$$

[0072] By solving formula (8), swing response surface computation unit 25 computes coefficients (a1~a4) of a response surface as shown in formula (9). When n=5 or greater, formula (8) is in over-conditions, and no exact solution exists. Thus, swing response surface computation unit 25 uses a generalized inverse matrix A^+ (also called a Moore-Penrose inverse matrix, or pseudoinverse matrix). The approach is a tool for computing approximation when there is no exact solution. Namely, the approach is for computing a solution to minimize an error |Ax-b| 2. The tool is a generally used mathematical method; a detailed description is omitted here. To solve formula (8), a mathematical computing software "MALTAB" made by The MathWorks, Inc. was used.

[math 9]

$$\begin{Bmatrix} a_1(t_i) \\ a_2(t_i) \\ a_3(t_i) \\ a_4(t_i) \end{Bmatrix} = A^+ \begin{Bmatrix} f_1(t_i) \\ f_2(t_i) \\ \\ f_9(t_i) \end{Bmatrix} \quad \cdots \text{formula (9)}$$

[0073] Coefficients (a1~a4) obtained in formula (9) are values corresponding to the skills and swing habits of a test hitter. According to formula (10), swing response surface computation unit 25 computes swing data (f) of specifications that are not actually measured. In other words, swing response surface computation unit 25 computes according to formula (10) the approximate values of acceleration in triaxial directions and angular velocity in triaxial directions relative

to any specifications (x, y, z).
[math 10]

$$f(t_i) = a_1(t_i) + a_2(t_i)(x - \bar{x}) + a_3(t_i)(y - \bar{y}) + a_4(t_i)(z - \bar{z}) \quad \cdots \text{formula (10)}$$

[0074] Then, swing response surface computation unit 25 computes according to formula (11) the swing data of golf club 1 of club number (m) that are not actually measured. In formula (11), "fm(t)" represents a swing response surface.
[math 11]

$$f_m(t) = a_1(t) + a_2(t)(x_m - \bar{x}) + a_3(t)(y_m - \bar{y}) + a_4(t)(z_m - \bar{z}) \cdots \text{formula (11)}$$

[0075] Next, time response surface computation unit 26 reads out the swing data of nine clubs held in data prediction unit 24. Then, time response surface computation unit 26 computes a time response surface for specifying the swing time of a player (step S4).

[0076] The following describes the computation process of a time response surface to be executed in step (S4). When swing time varies depending on golf club 1 and when the number of clubs of golf club 1 is set as "k" (k=1, ..., 9), sampling times are normalized as formula (12); "tk" is the swing time of each golf club 1.
[math 12]

$$t_i = \frac{i}{n} t_k \quad \cdots \text{formula (12)}$$

[0077] When there is no significant difference in swing time, to save time in the normalization process, time response surface computation unit 26 may cut off the computation process at the shortest swing time "tmin" among nine golf clubs.

[0078] A time response surface is a relational expression of each swing time of nine different golf clubs 1 shown in FIG. 4 and three specifications of golf club 1 (shaft weight, flex, kickpoint). Time response surface computation unit 26 computes a time response surface according to formulas (13)~(15).

[0079] In formula (13), "g1~g9" are swing times of nine golf clubs 1. Time response surface computation unit 26 computes coefficients (b1~b4) according to formula (14). Coefficients (b1~b4) are values each corresponding to the swing time of a player. By such a process, time response surface computation unit 26 computes the difference in swing time that depends on differences in the weight of golf club 1.
[math 13]

$$\begin{Bmatrix} g_1 \\ g_2 \\ \\ g_9 \end{Bmatrix} = \begin{bmatrix} 1 & (x_1 - \bar{x}) & (y_1 - \bar{y}) & (z_1 - \bar{z}) \\ 1 & (x_2 - \bar{x}) & (y_2 - \bar{y}) & (z_2 - \bar{z}) \\ & & & \\ 1 & (x_9 - \bar{x}) & (y_9 - \bar{y}) & (z_9 - \bar{z}) \end{bmatrix} \begin{Bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{Bmatrix} \cdots \text{formula (13)}$$

[math 14]

$$\begin{Bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{Bmatrix} = \mathrm{B}^{+} \begin{Bmatrix} g_1 \\ g_2 \\ \\ g_9 \end{Bmatrix} \cdots \text{formula (14)}$$

[0080] Next, time response surface computation unit 26 computes "gm" according to formula (15). In formula (15),

"gm" represents a time response surface.
[math 15]

$$g_m = b_1 + b_2(x_m - \bar{x}) + b_3(y_m - \bar{y}) + b_4(z_m - \bar{z}) \quad \cdots \text{formula (15)}$$

[0081] As shown in formula (16), swing data "fm'(t)" is computed. Swing data "fm'(t)" are those newly computed data obtained based on the swing data response surface and time response surface.
[math 16]

$$f_m'(t) = f_m\left(\frac{g_m}{t_i n} t\right) \quad \cdots \text{formula (16)}$$

[0082] Using swing response surface "fm" computed by swing response surface computation unit 25 and time response surface "gm" computed by time response surface unit 26, simulation execution unit 27 computes swing data "fm'(t)" of golf club 1 that are not used for measurement. Then, based on the computed swing data "fm'(t)", simulation execution unit 27 simulates the motion of the head of golf club 1 through dynamic finite element analysis (step S5).

[0083] The simulation results obtained by the above analysis showing the motion of golf club 1 represent the club speed at impact, face angle and impact loft (loft angle at impact). The club speed affects the ball carry, face angle affects the ball flight patterns, and impact loft affects the trajectory height. The simulation results computed by simulation execution unit 27 are not limited to the club speed, face angle and impact loft. For example, simulation execution unit 27 may also compute simulation results of the club path, attack angle, ball speed, and ball carry.

[0084] For analysis using a dynamic finite element method, since a known tool (such as a commercially available dynamic finite element software) is used, a detailed description of the process is omitted here. Using a swing response surface obtained by converting the skills and habits of a test hitter into a linear function, and a time response surface obtained by formulating the swing time of a player, simulation execution unit 27 analyzes the motion of a golf clubhead. Accordingly, simulation execution unit 27 is capable of simulating the motion of golf club 1 by considering the skills, habits and swing time (variation of swing time depending on the specifications of golf club 1) of a player.

[0085] As described above, swing time is significantly affected by the weight and length of a club. FIG. 9 is a view showing swing data when shaft weights are the same. FIG. 10 is a view showing swing data when shaft weights are different. FIGs. 9 and 10 show angular velocity (ωx) around axis-x as an example of swing data. When the shaft weights are the same, fewer variations are observed in swing time as shown in FIG. 9. By contrast, when shaft weights are different such as 40g, 60g and 80g, significant variations are observed in swing time as shown in FIG. 10.

[0086] In the above case, to solve formula (9) above using a generalized inverse matrix, it is necessary to set (t) to be constant. As shown in FIG. 9, if there is no significant difference observed in swing time, no significantly greater error will result by any method taken to set swing time to be constant. However, if swing times differ significantly as shown in FIG. 10, a much greater difference will be derived from artificially setting the (t) to be constant. Therefore, time response surface computation unit 26 computes a time response surface after each (t) is normalized. Simulation execution unit 27 computes swing data that reflect proper swing time by converting (t) again according to the time response surface.

[0087] As described above, even when specifications of golf club 1 are changed, swing data that reflect proper swing time are obtained. Accordingly, in the event of changing specifications (weight, length) that significantly affect swing time, accurate simulation results are obtained. Strictly speaking, swing times vary even with a slight change in specifications that have less impact on swing time. When simulation execution unit 27 computes swing data by using a swing response surface and time response surface, computation accuracy is enhanced even when specifications are changed that have less impact on swing time.

[0088] FIG. 11 is a graph showing swing data computed using only a swing response surface. FIG. 12 is a graph showing swing data computed using a swing response surface and time response surface. As is clear from those graphs, even further accurate simulation results are obtained when simulation execution unit 27 performs simulations by using a swing response surface and time response surface.

[0089] The following provides descriptions of a resultant data generation process conducted by results output unit 28. In the present embodiment, the level of shaft weight (number of divided levels "i" of the first specification) was 3, the level of flex (number of levels "j" of the second specification) was 5, and the level of kickpoint (number of levels "k" of third specification) was 5. The number of divided levels is set to have any selected number of levels for the specifications of nine clubs actually used for test hitting.

[0090] Specifically, the shaft weight has three levels (60g, 70g, 80g), flex has five levels (X, S, R, A, L listed in the order from hardest), and kickpoint has five levels (zero (low kickpoint), 0.25 (mid-low kickpoint), 0.5 (middle kickpoint), 0.75 (mid-high kickpoint), 1 (high kickpoint)).

[0091] By so setting, simulation execution unit 27 obtains simulation results of the motions of golf clubs 1 each having $3\times5\times5$=75 types of shafts. Results output unit 28 displays simulation results by plotting, for example, club speeds on the vertical axis and simulation results numbers on the horizontal axis.

[0092] FIG. 13 is a graph showing simulation results. FIG. 13 indicates that the greater the value of club speed, the faster the speed (longer ball carry), and the smaller the value of club speed, the slower the speed (shorter ball carry). As shown in FIG. 13, to maximize the club speed, golf club 1 that has a shaft weight of "60 g", a flex of "X" and a kickpoint of "mid-high" is selected. Selection of golf club 1 is performed by simulation execution unit 27. Alternatively, a user may confirm simulation results and select a golf club 1 having optimal specifications accordingly. Moreover, other than the club speed, the face angle, impact loft and the like may also be expressed by the same method.

[0093] Furthermore, results output unit 28 may display the tendency of specifications by using a natural language. Namely, when results output unit 28 displays results of a simulation performed by simulation execution unit 27, the results are converted into a natural language in association with the corresponding absolute value and inclination for each result. For example, if the purpose of fitting is to increase club speed, results output unit 28 displays "club speed will increase if the flex is stiffer," "club speed will increase if the shaft is lightweight," "increase in club speed is maximum when the kickpoint is high," "the impact from the shaft weight is greatest," and the like. If the purpose of fitting is to increase the impact loft (higher ball flight), results output unit 28 displays "the ball flight is higher if the flex is stiffer," "the ball flight is higher if the shaft is lightweight," "the ball flight is maximum if the kickpoint is low," "the impact of the flex is greatest" and the like. Accordingly, it makes it easier for a user of golf gear fitting system 2 to grasp the tendency of specifications in natural language and to select golf equipment more easily.

[0094] As described, results output unit 28 outputs simulation results by associating the purpose of fitting with specifications, thereby enabling a user to understand the association with specifications at a glance. In addition, results output unit 28 is set not only to output the specification of a shaft that exhibits the maximum club speed but also to output all the available specifications. Accordingly, the user can identify such specifications that allow the user to achieve a moderate carry, a moderate trajectory height, and a moderate trajectory curve. Therefore, the user can select specifications of golf club 1 according to preference. That is especially effective when face angles are computed. If a user chooses a shaft that exhibits a maximum bend because the user intends to produce a trajectory curve, the user may face an issue of excessive trajectory curve. Therefore, it is preferable for users to have a selection of shafts that exhibit a moderate trajectory curve.

[0095] FIG. 13 shows examples where results output unit 28 displays information using characters associated with specifications. However, related specifications may also be displayed in different colors. To make the display easier to grasp, results output unit 28 may devise a plotting method, or may use a bar chart or a three-dimensional graph for displaying results. Moreover, results output unit 28 may output the results by changing the color density of the lines or the like so that reviewing the results is even easier and those including the best values will stand out.

[0096] In the above descriptions, the shaft weight (3 levels) is set as a first specification, the flex (5 levels) is set as a second specification, and the kickpoint (5 levels) is set as a third specification. However, other specifications may be used. For example, it is an option to set the torque (5 levels) as a first specification, the flex (5 levels) as a second specification, and the kickpoint (5 levels) as a third specification. Alternatively, it is another option to set the flex (5 levels) as a first specification, the torque (5 levels) as a second specification, and the weight (3 levels) as a third specification.

[0097] The present embodiment is described as an example by employing specifications of a shaft. However, simulation execution unit 27 may also perform the simulation of the present embodiment by using specifications of a club, specifications of a head, specifications of a grip and the like.

[0098] Next, procedures are described to output complex conditions such as club speed and trajectory height, or club speed and trajectory curve, as the results of fitting. Generally, a player expects golf club 1 to exhibit not a single performance but complex performances; for example, preventing slice, while maximizing club speed and simultaneously increasing trajectory height, or the like. The trajectory of a ball is determined by the height and direction of the trajectory. In the present embodiment, trajectory height is sorted into three levels, "High" (high trajectory), "Mid" (medium trajectory) and "Low" (low trajectory), and the trajectory direction is sorted into three levels, "Fade," "Straight" and "Draw." Among nine combinations of trajectory height and trajectory direction, one trajectory is selected based on the request of the player.

[0099] Here, "Fade" means the trajectory curves to the right when a user is right-handed, and "Draw" means the trajectory curves to the left when a user is right-handed. Then, results output unit 28 outputs conditions that satisfy the selected trajectory while the club speed is maximized. To output complex conditions, specifications that maximize an objective function (F) are selected. Objective function (F) is expressed by the formula below.

$$F=\alpha\times f1+\beta\times f2+\gamma\times f3$$

[0100] In the above formula, "f1" represents first result data (club speed, for example), "f2" represents second result data (face angle, for example), "f3" represents third result data (impact loft, for example), and "α, β, γ" are weighting factors. Here, "α, β, γ" are selected properly according to the request of a player. Generally, "α" is preferred to be 1~3 times the value of (β+γ.) That is because club speed is most important for a golfer.

[0101] Results output unit 28 may display the specifications that show the maximum simulation results (club speed, impact loft, face angle and the like) by converting the results into actual product names of golf gear. By so doing, the golf gear fitting system 2 is put into more practical use.

[0102] As described, results output unit 28 is capable of displaying whether or not the golf gear is suitable to achieve the trajectory selected according to the request of a player. Accordingly, the user of golf gear fitting system 2 can easily select a golf gear suitable to achieve desired trajectory. Namely, golf gear fitting is conducted by the aforementioned golf gear fitting system 2. The system is capable of performing measurement, analysis and results display in a short period of time, thus enabling users to visually determine specifications of the most suitable golf gear.

[0103] In the example above, the shaft weight, flex and kickpoint are selected. However, that is not the only option. Also, the number of specifications is not limited to 3. Specifications to be used for simulation are preferred to be those that tend to affect swing time. Other specifications to be selected are any of the following: flexural rigidity, torsional rigidity, weight, flexural rigidity distribution, torsional rigidity distribution and weight distribution of a shaft, length of a golf club, head weight, club balance, depth, height and distance of the center of gravity in the head, grip weight, loft angle, lie angle and face angle.

[0104] Moreover, time response surface computation unit 26 may compute a time response surface by stretching each piece of swing data to correspond to the longest swing time so that all the swing times are set equal. In such a case, computation time is shortened.

[0105] FIG. 14 shows degrees of impact. An impact degree means the degree of impact on head behavior when certain specifications are changed. When multiple different specifications are selected for simulations, it is preferred to select a combination of those having similar impact degrees. The reasons are as follows.

[0106] For example, when simulation execution unit 27 performs simulations based on three different specifications consisting of head weight (impact degree: 5), torsional rigidity distribution of a shaft (impact degree: 1), and height of the center of gravity in the head (impact degree: 1), the obtained data are mostly affected by the specifications with a greater degree of impact (head weight), and the results of the rest with a smaller degree of impact (torsional rigidity distribution of a shaft and height of the center of gravity in the head) are hardly recognizable. Thus, it is preferred to select specifications having degrees of impact within a certain range (in the present embodiment, within 2). Also, the degrees of impact of three different specifications are more preferred to be the same.

[0107] When simulations are performed by selecting three specifications, it is most preferred to use shaft weight, flexural rigidity (flex) and flexural rigidity distribution (kickpoint). Optimal shaft fitting is achieved using such a combination.

[0108] In addition, it is an option to employ a combination of flexural rigidity (flex), torsional rigidity (torque) and shaft weight. Yet other options are a combination of flexural rigidity (flex), torsional rigidity (torque) and flexural rigidity distribution (kickpoint); and a combination of flexural rigidity (flex), shaft weight and shaft weight distribution. By employing such combinations, the results of the present embodiment are applicable for shaft design.

[0109] Furthermore, a combination of flexural rigidity (flex), length of a club, and head weight may be used. Club fittings are preferably conducted using such a combination.

[0110] Also, a combination of the height, depth and distance of the center of gravity in the head may be used. In such a combination, the results are preferably used for head fittings. Yet furthermore, a combination of the loft angle, lie angle and face angle of a head may also be available. In such a combination as well, the results are preferably used for head fittings.

[0111] It is yet another option to employ a combination of the hardness, length and total weight of a club along with club balance. As described, examples of preferable combinations are listed above. However, the present embodiment is not limited to such combinations.

(Second Embodiment)

[0112] Next, a second embodiment is described by referring to FIG. 1. In the first embodiment, head behavior is computed through the process of swing data acquisition unit 21, swing data storage unit 22, data classification unit 23, data prediction unit 24, swing response surface computation unit 25, time response surface computation unit 26 and simulation execution unit 27. Simulation execution unit 27 is set to compute the head behavior from the posture of the head and the coordinates of its position by simply assuming that the shaft is rigid. In the first embodiment, a high-performance computer is required as simulation execution unit 27. Therefore, a computer to operate as simulation execution unit 27 is preferred to be set at a server or the like, separately from swing data acquisition unit 21.

[0113] By contrast, in the second embodiment, head behavior is computed without using simulation execution unit 27. More specifically, swing data acquisition unit 21 is set to directly measure head behavior by using a camera, acoustic waves and the like. Swing data storage unit 22 stores the head behavior measured by swing data acquisition unit 21. In the second embodiment, a high-performance computer is not necessary; for example, a smartphone or the like may also be used.

[0114] Data classification unit 23 classifies the head behavior stored in swing data storage unit 22 based on the table shown in FIG. 15. Data classification unit 23 determines which group the newly obtained data of head behavior belongs to among groups 1-45 classified in advance as shown in FIG. 15. In the present embodiment, data classification unit 23 classifies data focusing on three categories -- club speed, club path and attack angle.

[0115] For example, when the measured data are a club speed of 33 [m/s], a club path of 1.2 [deg], and an attack angle of -2.0 [deg], data classification unit 23 determines that the measured head behavior belongs to group 14.

[0116] Based on the table shown in FIG. 16, data prediction unit 24 predicts the specifications of a most suitable shaft. In the present embodiment, the weight and flex are predicted from the club speed, the level of flex is predicted from the club path, and the kickpoint is predicted from the attack angle.

[0117] For example, when data classification unit 23 determines that the measured head behavior belongs to group 14, data prediction unit 24 predicts that the most suitable specification (a weight of 40~50 [g], flex of "A", and kickpoint of "middle").

[0118] Results output unit 28 outputs recommended golf club 1 based on the specifications of a shaft predicted by data prediction unit 24. In the present embodiment, swing response surface computation unit 25, time response surface computation unit 26 and simulation execution unit 27 can be omitted from golf gear fitting system 2.

[0119] Data classification unit 23 is not limited to the table in FIG. 15, and is capable of classifying a head behavior stored in swing data storage unit 22 based on various other classification methods. In addition, data prediction unit 24 is not limited to the table in FIG. 16 and is capable of predicting specifications of golf club 1 based on various other prediction methods.

[0120] As described above, golf gear fitting system 2 of the present embodiment is formed to include swing data acquisition unit 21 to acquire swing data from sensor 11 installed on golf clubs 1; swing data storage unit 22 to store the swing data acquired by swing data acquisition unit 21; data classification unit 23 to classify the swing data stored in swing data storage unit 22; and data prediction unit 24 to predict specifications for swing data not measured by sensor 11 by referring to the swing data classified by data classification unit 23. By so setting, appropriate golf gear is selected through a smaller number of test hits.

[0121] The program to execute functions of the golf equipment fitting system 2 may be recorded on a computer readable recording medium, and a computer system may read out the stored program on the medium and execute it to perform the above process at each unit. Here, "a computer system reads out the stored program on a recording medium and executes the program" includes installing the program in a computer system. Here, a "computer system" includes the OS and hardware such as peripheral devices. Also, a "computer system" may include multiple computer devices connected through the Internet, WAN, LAN and networks that include exclusive communication lines. "Computer readable recording media" means portable media such as flexible disks, magneto-optical disks, ROM and CD-ROM, and memory devices such as hard discs built into a computer system. The recording medium to store the program may be a non-transitory recording medium such as a CD-ROM. Also, a recording medium includes a recording medium installed internally or externally to be accessible for a distribution server to distribute the program. The program code stored in the recording medium of the distribution server may be different from the code that allows the terminal device to execute the program. Namely, the memory code to be stored in a distribution server is not limited specifically as long as it allows the terminal device to download and install the program from the distribution server in executable code. Moreover, the program may be divided into multiple sections and integrated back in a terminal device after the sections are downloaded at different times, or distribution servers for each divided section may be different. Furthermore, "computer readable recording media" includes a medium for retaining the program for a certain duration such as volatile memory (RAM) inside a computer system that becomes a server or a client when the program is transmitted through networks. In addition, the above program may be intended to implement part of the functions described above. Alternatively, the above program may be a so-called difference file (difference program) for implementing the above functions in combination with another program already installed in the computer system.

[0122] Also, some or all of the above functions may be implemented as an integrated circuit such as an LSI (large scale integration). The functions may be set individually in separate processors. Some or all of the above functions may be integrated and set in a processor. To integrate the functions, LSIs, or exclusive or generic processors may be used. Also, when new integration technology is made available to replace LSIs through the development of semiconductor technology, integrated circuits by such technology may also be applied.

[0123] So far, embodiments of the present invention have been described. However, those embodiments are described as examples, and are not intended to limit the scope of the present invention. Various modifications are possible when practicing those embodiments. Various omissions, replacements, changes and the like may be made within a scope that does not deviate from the gist of the present invention. It should be understood that those embodiments and modifications thereof are included in the scope and gist of the present invention, while also being included in the present invention specified by the scope of patent claims and in any equivalent thereof.

DESCRIPTION OF NUMERICAL REFERENCES

[0124]

1	golf club
2	golf gear fitting system
11	sensor
20	receiver
21	swing data acquisition unit
22	swing data storage unit
23	data classification unit
24	data prediction unit
25	swing response surface computation unit
26	time response surface computation unit
27	simulation execution unit
28	results output unit

Claims

1. A golf gear fitting system, comprising:

a swing data acquisition unit to acquire swing data from a sensor installed in a plurality of golf clubs with different specifications;
a swing data storage unit to store the swing data acquired by the swing data acquisition unit;
a data classification unit to classify the swing data stored in the swing data storage unit; and
a data prediction unit to predict swing data of specifications not measured by the sensor by referring to the swing data classified in the data classification unit.

2. The golf gear fitting system according to claim 1, further comprising:

a swing response surface computation unit to compute a swing response surface by a response surface methodology using the swing data predicted by the data prediction unit;
a time response surface computation unit to compute a time response surface by a response surface methodology using the swing data predicted by the data prediction unit; and
a simulation execution unit to compute swing data of a specification not measured by the sensor by using the swing response surface and time response surface, and to perform simulation on the swing of a golf club based on the computed swing data.

3. The golf gear fitting system according to claim 2, wherein the simulation execution unit computes the head behavior at impact using the finite element method and the swing data predicted by the data prediction unit.

4. The golf gear fitting system according to claim 2, further comprising a results output unit to output the results of a simulation executed by the simulation execution unit.

5. The golf gear fitting system according to claim 4, wherein the results output unit converts into a natural language the results of the simulation executed by the simulation execution unit, and outputs the language accordingly.

6. The golf gear fitting system according to claim 2, wherein the difference in the degree of impact is set within a predetermined level among the specifications of a plurality of golf clubs used for the simulation.

7. The golf gear fitting system according to any of claims 1 to 6, wherein the data classification unit classifies the swing data stored in the swing data storage unit by using an unsupervised learning method.

8. The golf gear fitting system according to claim 7, wherein the data classification unit classifies the swing data stored in the swing data storage unit by using a self-organizing map as an unsupervised learning method.

9. The golf gear fitting system according to any of claims 1 to 8, wherein the swing data storage unit stores difference data, which are the difference between the swing data of a specific golf club and the swing data of another golf club, for each of the plurality of players; and
when the swing data of the specific golf club are newly acquired by the swing data acquisition unit, the data prediction unit reads out from the swing data storage unit the difference data of swing data that belong to the same classification of the newly acquired swing data, and predicts swing data of the other golf club using the readout difference data.

10. The golf gear fitting system according to claim 1, wherein the swing data acquisition unit measures the head behavior of the golf club,
the data classification unit determines which group the head behavior acquired by the swing data acquisition unit belongs to among a plurality of groups classified in advance,and
the data prediction unit predicts the most suitable specifications of the golf club based on the group determined by the data classification unit.

11. The golf gear fitting system according to any of claims 1 to 10, wherein the sensor is a six-axial sensor to detect acceleration in triaxial directions and angular velocity in triaxial directions.

12. The golf gear fitting system according to any of claims 1 to 11, wherein the sensor is a nine-axial sensor to detect acceleration in triaxial directions, angular velocity in triaxial directions, and orientation in triaxial directions.

13. The golf gear fitting system according to any of claims 1 to 10, wherein the sensor is formed to include a six-axial sensor to detect acceleration in triaxial directions and angular velocity in triaxial directions and a geo-magnetometer to detect orientation in triaxial directions.

14. The golf gear fitting system according to any of claims 1 to 13, wherein the sensor is attached to the grip of the golf club.

15. The golf gear fitting system according to any of claims 1 to 14, wherein the swing data storage unit is a database that stores swing data of a plurality of players.

16. The golf gear fitting system according to any of claims 1 to 15, wherein the plurality of golf clubs with different specifications are selected based on an L4 orthogonal array specified by experimental design.

17. A golf gear fitting method, comprising:

a swing data acquisition step for acquiring swing data from a sensor installed on a plurality of golf clubs with different specifications;
a swing data storing step for storing in a swing data storage unit the swing data acquired by the swing data acquisition step;
a data classification step for classifying the swing data stored in the swing data storage unit; and
a data prediction step for predicting swing data of specifications not measured by the sensor by referring to the swing data classified in the data classification step.

18. A golf gear fitting program to be executed by a computer, comprising:

a swing data acquisition process for acquiring swing data from a sensor installed on a plurality of golf clubs with different specifications;
a swing data storing process for storing in a swing data storage unit the swing data acquired by the swing data acquisition process;
a data classification process for classifying the swing data stored in the swing data storage unit; and
a data prediction process for predicting swing data of specifications not measured by the sensor by referring to the swing data classified in the data classification process.

19. A golf swing classification method for classifying swing data by using a self-organizing map when swing data are acquired from a sensor installed on a golf club.

20. A golf shaft fitting system using the golf gear fitting system according to any of claims 1 to 16.

21. A golf shaft fitting method using the golf gear fitting method according to claim 17.

22. A golf shaft fitting program using the golf gear fitting program according to claim 18.

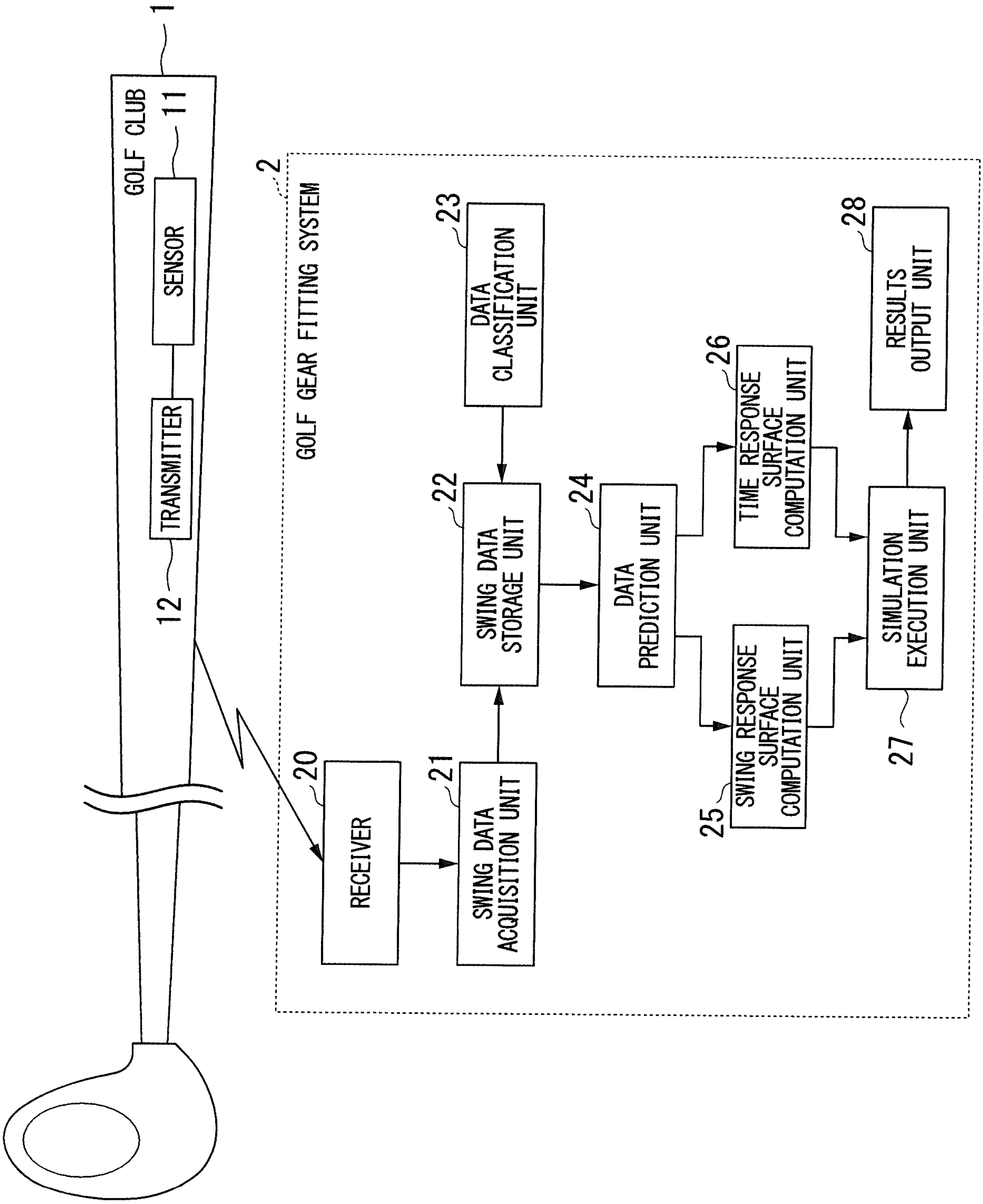

GOLF CLUB
1
SENSOR
11
TRANSMITTER
12
GOLF GEAR FITTING SYSTEM
2
RECEIVER
20
SWING DATA ACQUISITION UNIT
21
SWING DATA STORAGE UNIT
22
DATA CLASSIFICATION UNIT
23
DATA PREDICTION UNIT
24
SWING RESPONSE SURFACE COMPUTATION UNIT
25
TIME RESPONSE SURFACE COMPUTATION UNIT
26
SIMULATION EXECUTION UNIT
27
RESULTS OUTPUT UNIT
28

FIG. 1

FIG. 2A

FLEXURAL RIGIDITY (FLEX)

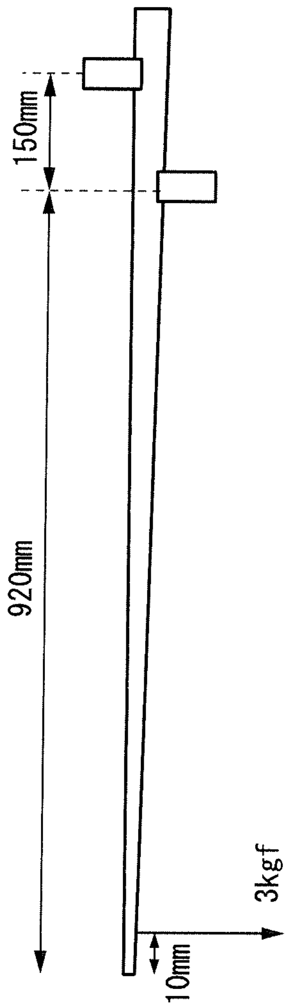


FIG. 2B

FLEXURAL RIGIDITY DISTRIBUTION (KICKPOINT) : REGULATED BY COEFFICIENT (C) OF FUNCTION (P)

$$L(x) = C0 \times P0(x) + C1 \times P1(x) + C2 \times P2(x) + C3 \times P3(x)$$

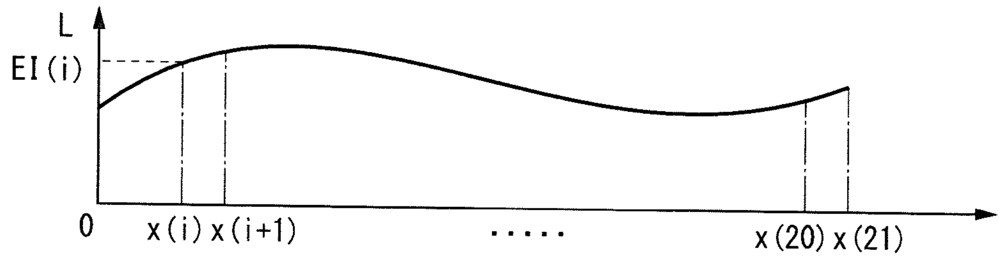


FIG. 3A

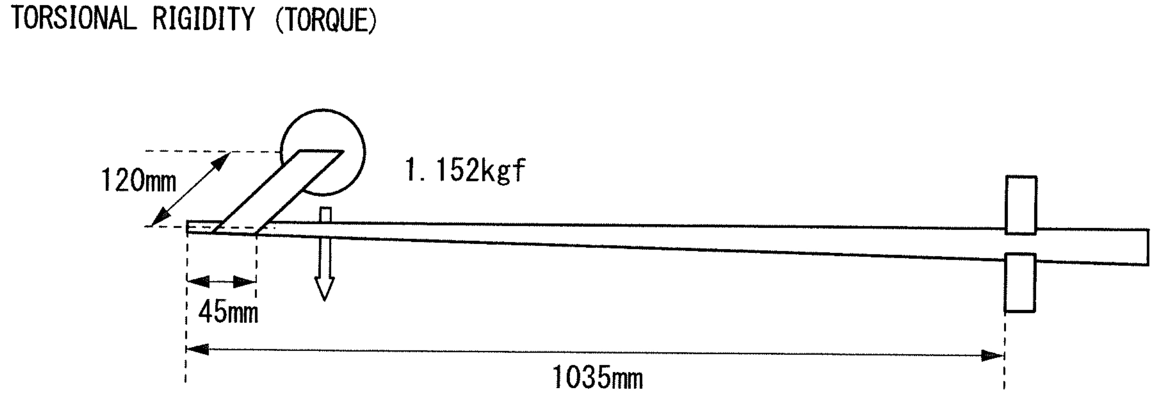


FIG. 3B

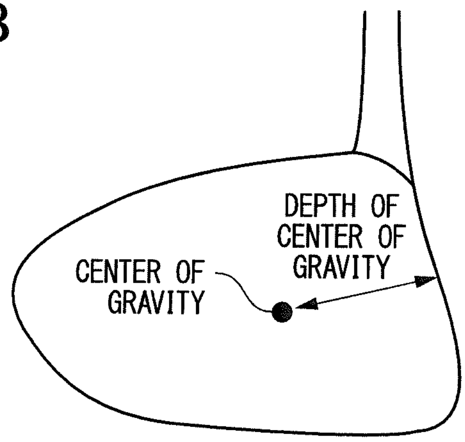


FIG. 3C

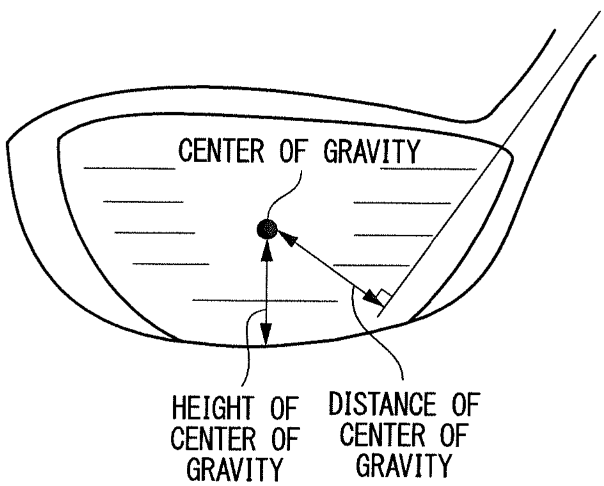


FIG. 4

CLUB NUMBER	SHAFT WEIGHT	FLEX	KICKPOINT
1	0	0	0
2	0	0.5	0.5
3	0	1	1
4	0.5	0	0.5
5	0.5	0.5	1
6	0.5	1	0
7	1	0	1
8	1	0.5	0
9	1	1	0.5

FIG. 5A

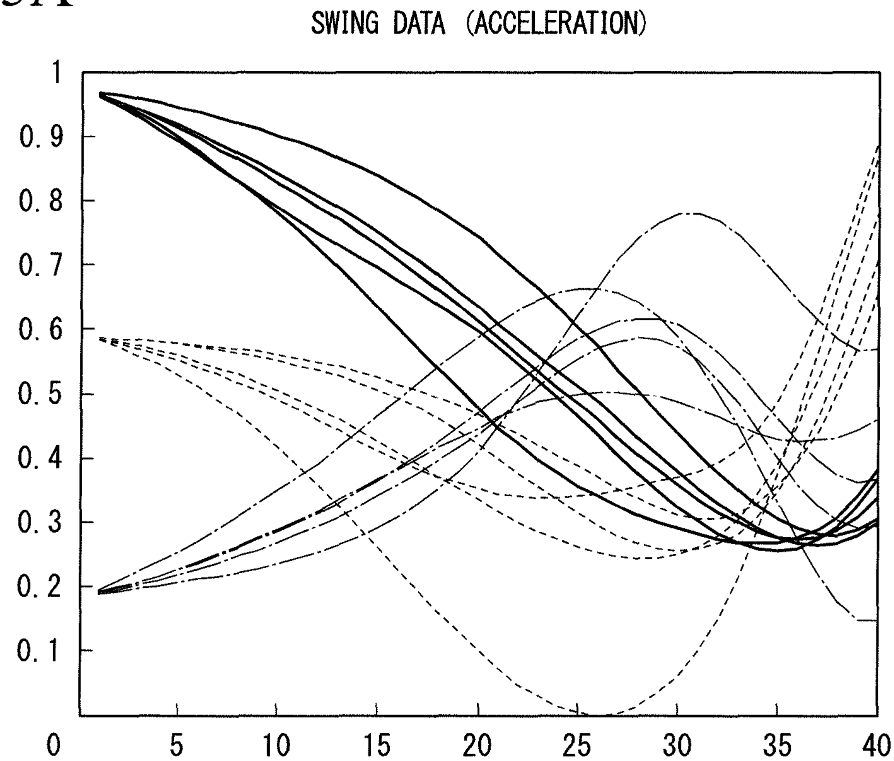

SWING DATA (ACCELERATION)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
35
40

FIG. 5B

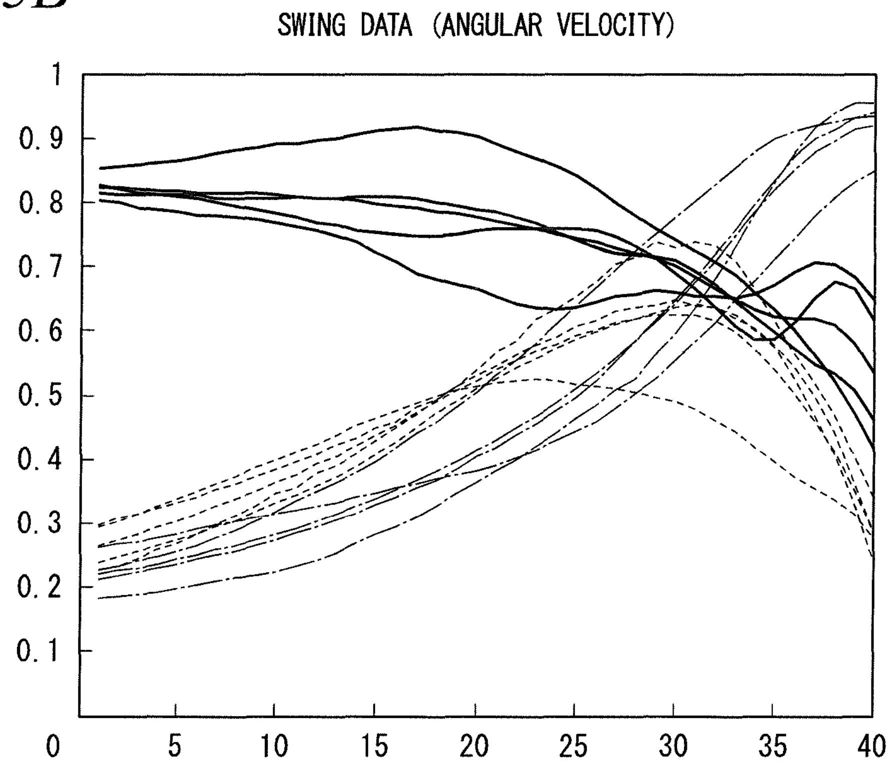

SWING DATA (ANGULAR VELOCITY)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
35
40

FIG. 6

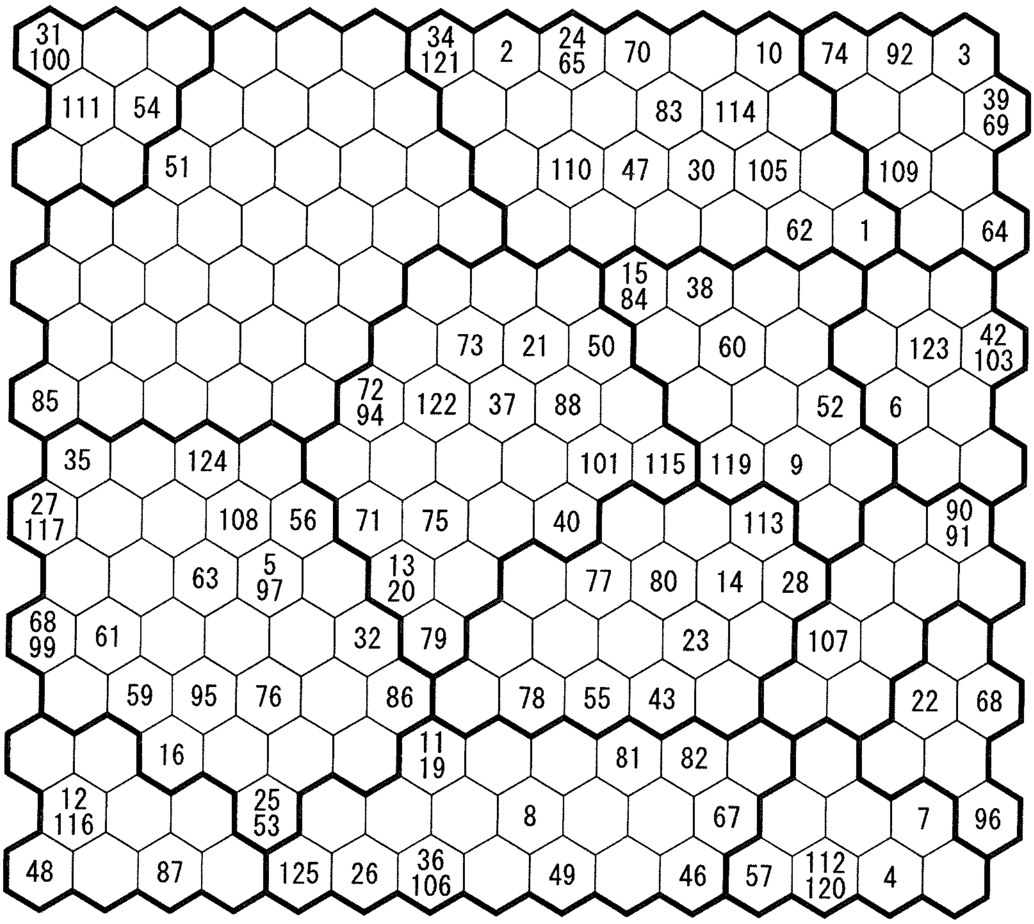
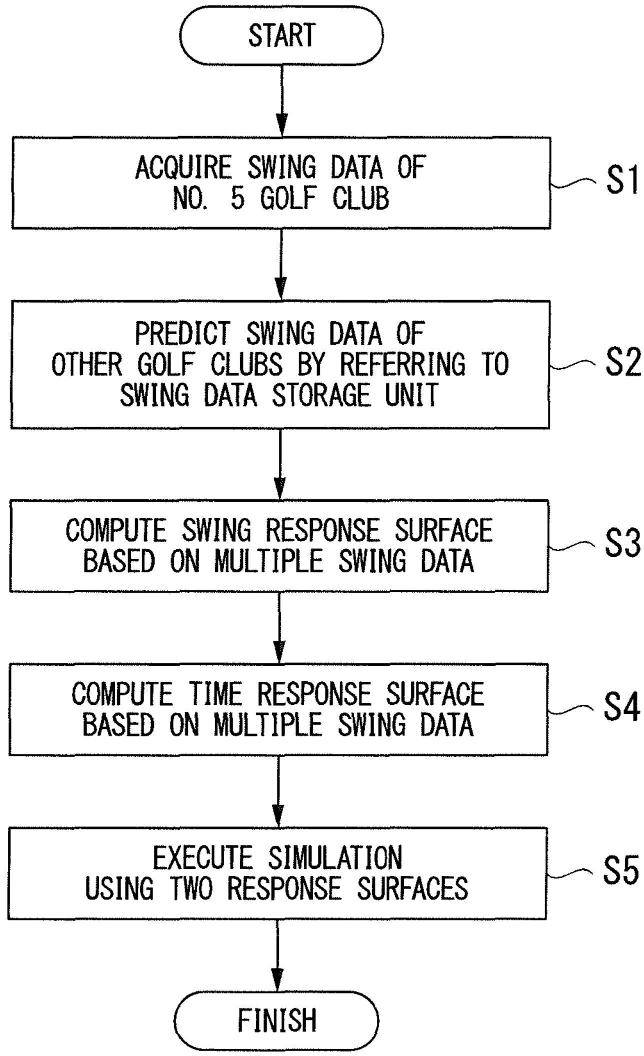

31
100
34
121
2
24
65
70
10
74
92
3
111
54
83
114
39
69
51
110
47
30
105
109
62
1
64
15
84
38
73
21
50
60
123
42
103
85
72
94
122
37
88
52
6
35
124
101
115
119
9
27
117
108
56
71
75
40
113
90
91
63
5
97
13
20
77
80
14
28
68
99
61
32
79
23
107
59
95
76
86
78
55
43
22
68
16
11
19
81
82
12
116
25
53
8
67
7
96
48
87
125
26
36
106
49
46
57
112
120
4

FIG. 7


START
ACQUIRE SWING DATA OF NO. 5 GOLF CLUB
S1
PREDICT SWING DATA OF OTHER GOLF CLUBS BY REFERRING TO SWING DATA STORAGE UNIT
S2
COMPUTE SWING RESPONSE SURFACE BASED ON MULTIPLE SWING DATA
S3
COMPUTE TIME RESPONSE SURFACE BASED ON MULTIPLE SWING DATA
S4
EXECUTE SIMULATION USING TWO RESPONSE SURFACES
S5
FINISH

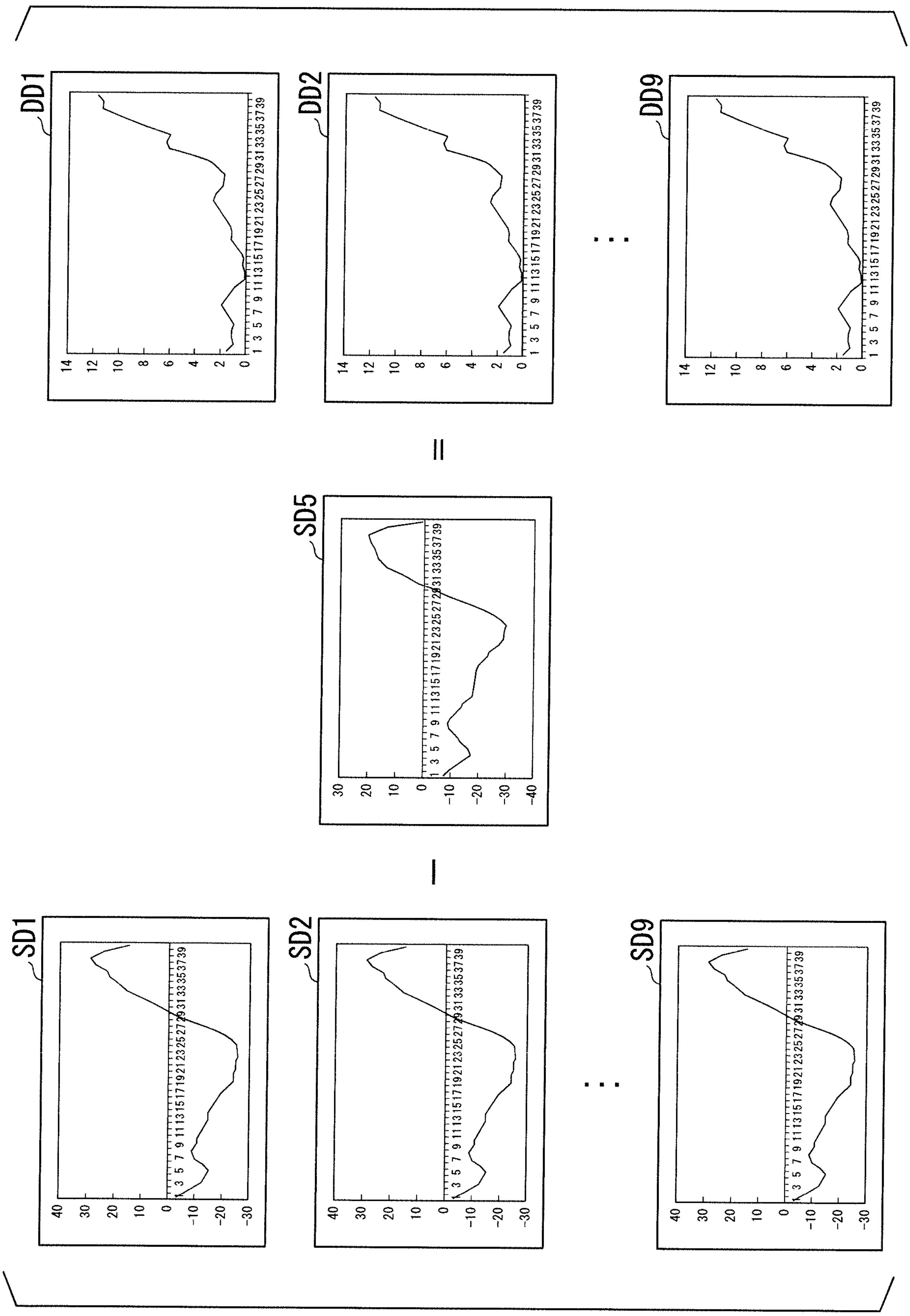
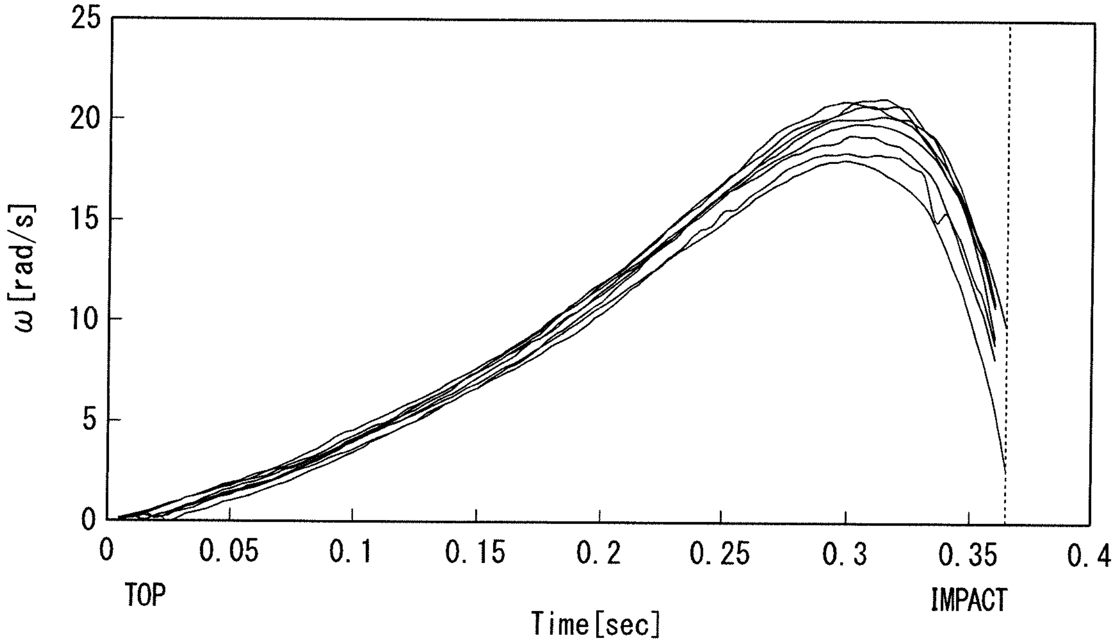


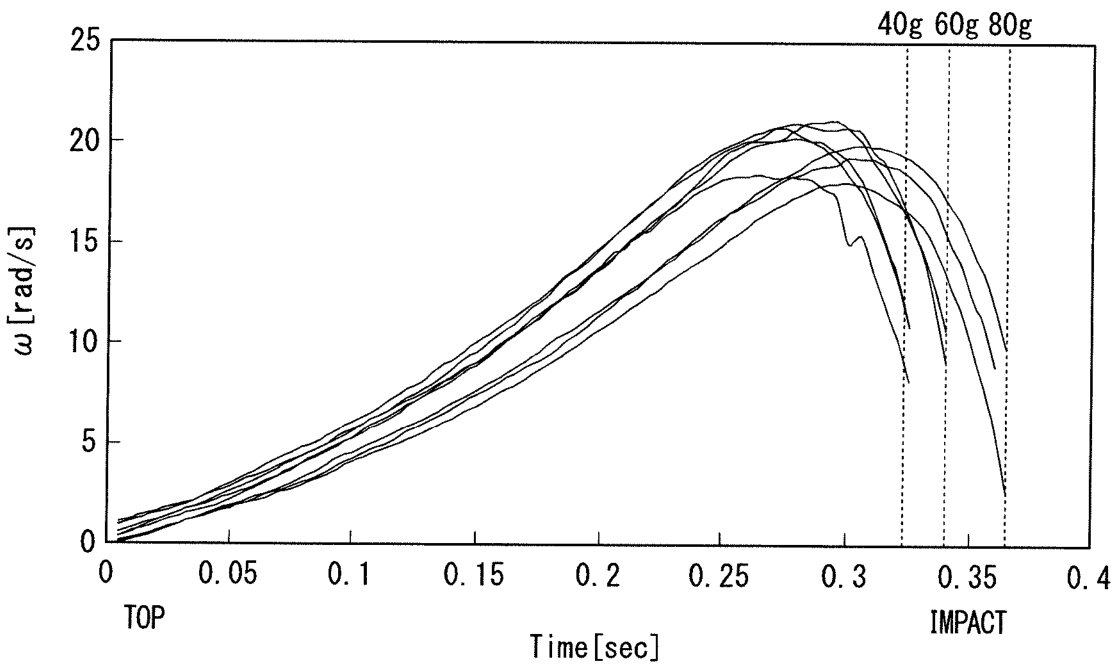
FIG. 8

FIG. 9



25
20
15
10
5
0
ω[rad/s]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
TOP
IMPACT
Time[sec]

FIG. 10



40g 60g 80g
25
20
15
10
5
0
ω[rad/s]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
TOP
IMPACT
Time[sec]

FIG. 11

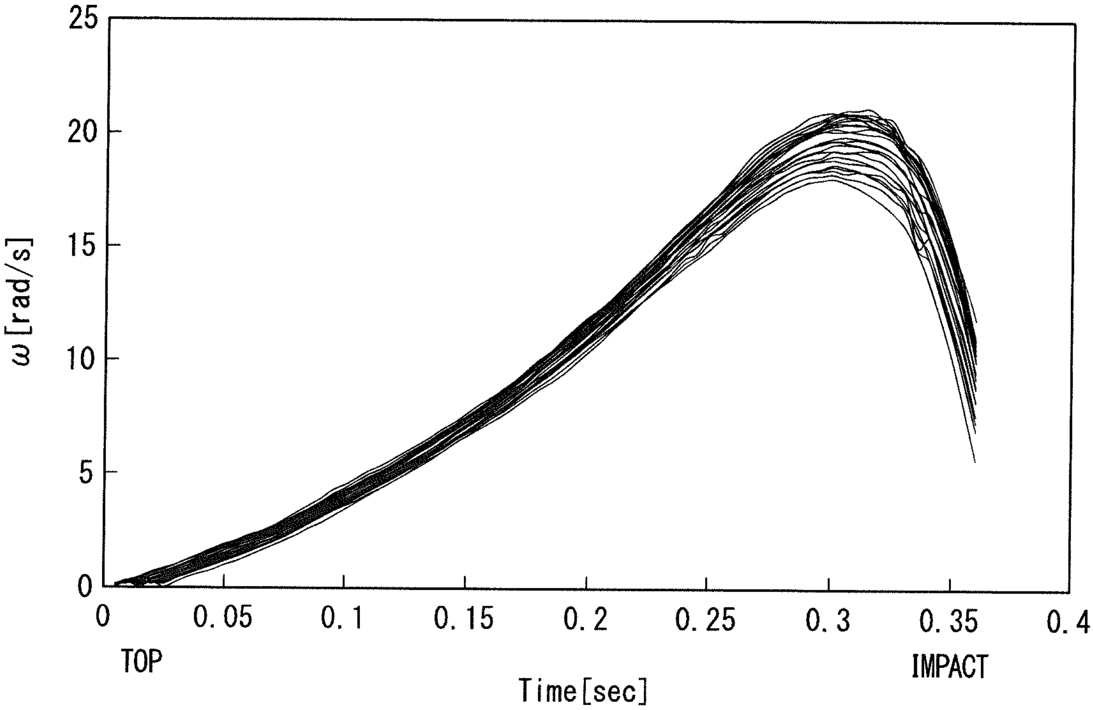

25
20
15
10
5
0
ω[rad/s]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
TOP
IMPACT
Time[sec]

FIG. 12

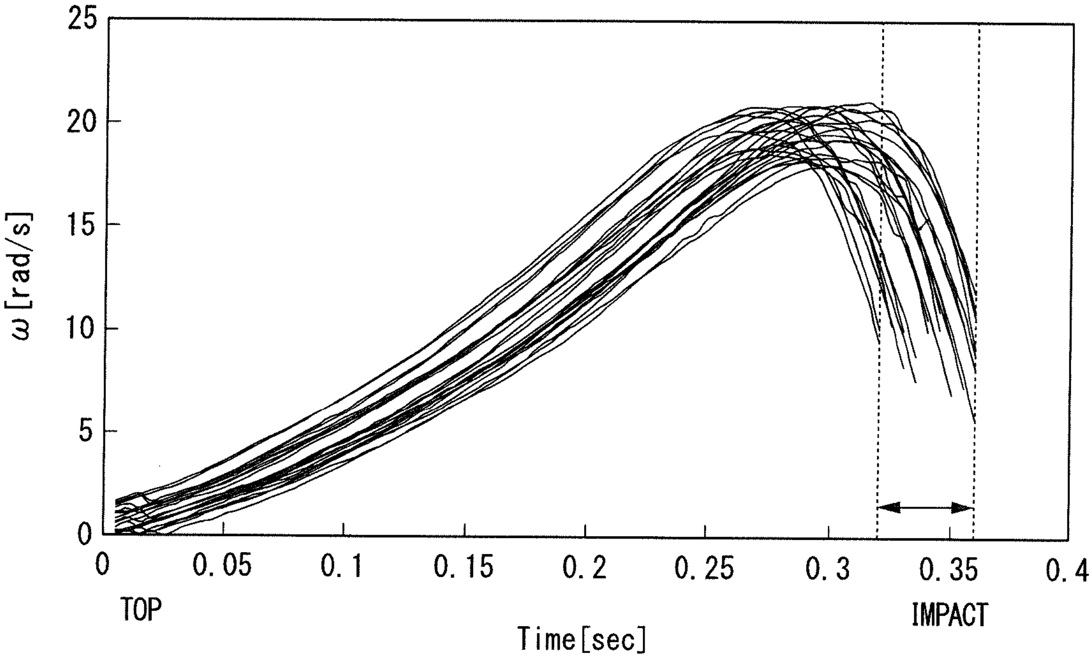

25
20
15
10
5
0
ω[rad/s]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
TOP
IMPACT
Time[sec]

FIG. 13

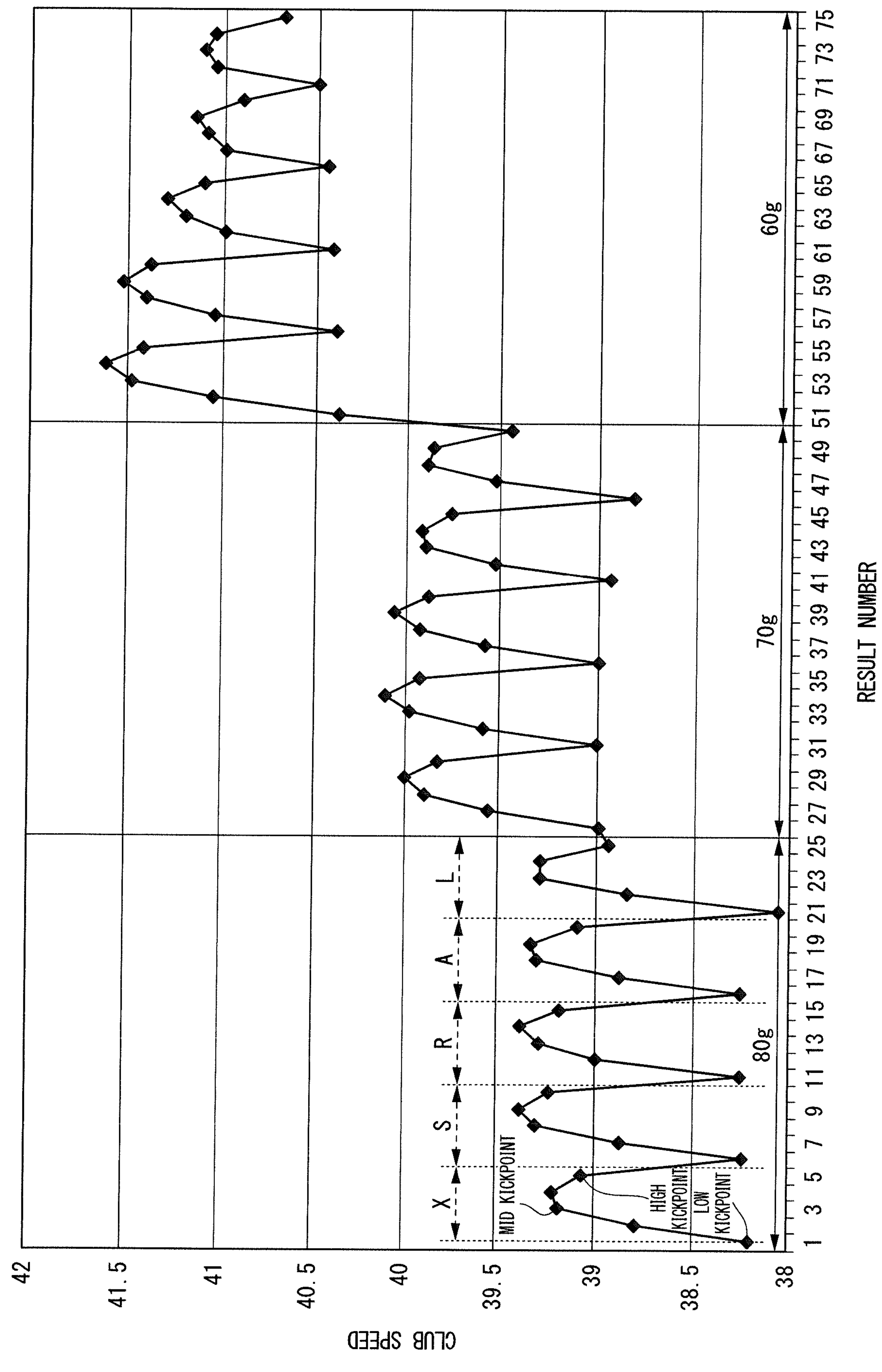

CLUB SPEED
42
41.5
41
40.5
40
39.5
39
38.5
38
RESULT NUMBER
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75
80g
70g
60g
X
S
R
A
L
MID KICKPOINT
HIGH KICKPOINT
LOW KICKPOINT

FIG. 14

	DESIGN VARIABLE	DEGREE OF IMPACT
SHAFT	FLEXURAL RIGIDITY	4
	TORSIONAL RIGIDITY	3
	WEIGHT	3
	FLEXURAL RIGIDITY DISTRIBUTION	3
	TORSIONAL RIGIDITY DISTRIBUTION	1
	WEIGHT DISTRIBUTION	3
CLUB	TOTAL WEIGHT	5
	BALANCE	3
	STIFFNESS	4
	LENGTH	5
HEAD	WEIGHT	5
	DEPTH OF CENTER OF GRAVITY	3
	HEIGHT OF CENTER OF GRAVITY	1
	DISTANCE OF CENTER OF GRAVITY	3
	ANGLE OF CENTER OF GRAVITY	3
	LOFT ANGLE	2
	LIE ANGLE	2
	FACE ANGLE	2
GRIP	WEIGHT	3
	DIAMETER	3
	HARDNESS	3

FIG. 15

GROUP	CLUB SPEED [m/s]	CLUB PATH [deg]	ATTACK ANGLE [deg]
1			≦-3
2		≦-3	-3＜, ＜+3
3			+3≦
4			≦-3
5	＜30	-3＜, ＜+3	-3＜, ＜+3
6			+3≦
7			≦-3
8		+3≦	-3＜, ＜+3
9			+3≦
10			≦-3
11		≦-3	-3＜, ＜+3
12			+3≦
13			≦-3
14	30≦, ＜35	-3＜, ＜+3	-3＜, ＜+3
15			+3≦
16			≦-3
17		+3≦	-3＜, ＜+3
18			+3≦
19			≦-3
20		≦-3	-3＜, ＜+3
21			+3≦
22			≦-3
23	35≦, ＜40	-3＜, ＜+3	-3＜, ＜+3
24			+3≦
25			≦-3
26		+3≦	-3＜, ＜+3
27			+3≦
28			≦-3
29		≦-3	-3＜, ＜+3
30			+3≦
31			≦-3
32	40≦, ＜45	-3＜, ＜+3	-3＜, ＜+3
33			+3≦
34			≦-3
35		+3≦	-3＜, ＜+3
36			+3≦
37			≦-3
38		≦-3	-3＜, ＜+3
39			+3≦
40			≦-3
41	45≦	-3＜, ＜+3	-3＜, ＜+3
42			+3≦
43			≦-3
44		+3≦	-3＜, ＜+3
45			+3≦

FIG. 16

GROUP	WEIGHT	FLEX	KICKPOINT
1	30-40g	A	High
2			Mid
3			Low
4		L	High
5			Mid
6			Low
7		<L	High
8			Mid
9			Low
10	40-50g	R	High
11			Mid
12			Low
13		A	High
14			Mid
15			Low
16		L	High
17			Mid
18			Low
19	50-60g	SR	High
20			Mid
21			Low
22		R	High
23			Mid
24			Low
25		A	High
26			Mid
27			Low
28	60-70g	SX	High
29			Mid
30			Low
31		S	High
32			Mid
33			Low
34		SR	High
35			Mid
36			Low
37	70-80g	X	High
38			Mid
39			Low
40		SX	High
41			Mid
42			Low
43		S	High
44			Mid
45			Low

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/063390

A. CLASSIFICATION OF SUBJECT MATTER
A63B53/00(2015.01)i, *A63B60/46*(2015.01)i, *A63B69/36*(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)
A63B53/00, A63B60/46, A63B69/36

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	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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.
Y A	JP 2014-233430 A (Bridgestone Corp.), 15 December 2014 (15.12.2014), paragraphs [0018] to [0038]; fig. 1 to 5 & US 2014/0357393 A1 paragraphs [0024] to [0048]; fig. 1 to 5 & CN 104208864 A	19 1-18,20-22
Y A	US 2003/0040380 A1 (Ian C. Wright), 27 February 2003 (27.02.2003), abstract; paragraphs [0030] to [0058]; fig. 1 to 5 & GB 2391489 A & WO 2002/081039 A1	19 1-18,20-22

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 June 2016 (20.06.16)	05 July 2016 (05.07.16)

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

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/063390

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2008-224654 A (Base Vision Oy), 25 September 2008 (25.09.2008), paragraphs [0018] to [0025]; fig. 2 & US 2008/0136907 A1 & EP 1930841 A1 paragraphs [0018] to [0025]; fig. 2 & FI 20065777 A & CN 101195072 A & AT 505768 T & DK 1930841 T3 & ES 2361862 T3	19 1-18,20-22
Y A	JP 2001-202379 A (President of Kobe University), 27 July 2001 (27.07.2001), abstract (Family: none)	19 1-18,20-22
Y A	JP 2003-6211 A (Nippon Telegraph and Telephone Corp.), 10 January 2003 (10.01.2003), paragraph [0002] (Family: none)	19 1-18,20-22
A	WO 2014/132885 A1 (Mitsubishi Rayon Co., Ltd.), 04 September 2014 (04.09.2014), abstract; paragraphs [0028] to [0105]; fig. 1 to 18 & JP 5825430 B2 & US 2015/0375073 A1 abstract; paragraphs [0050] to [0141]; fig. 1 to 18 & EP 2962741 A1	1-22

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2015102548 A **[0002]**
- JP 2005312734 A **[0009]**
- JP 4871218 B **[0009]**
- JP 2011000425 A **[0009]**
- WO 2014132885 A **[0009]**