

[54] **DYNAMICALLY MATCHED SET OF GOLF CLUBS**

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[58] Field of Search73/65

[56] **References Cited**

UNITED STATES PATENTS

1,351,768	9/1920	Lawton.....	73/65
3,473,370	10/1969	Marciniak	73/65
1,953,916	4/1934	Adams.....	73/65

2,349,736 5/1944 Knobel et al.73/65

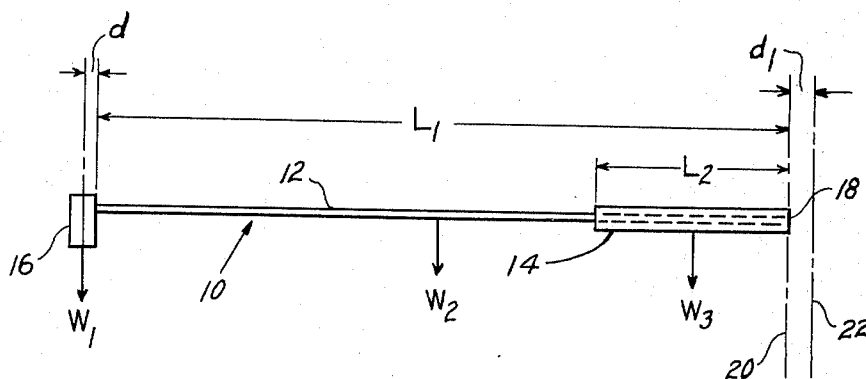
Primary Examiner—Charles A. Ruehl

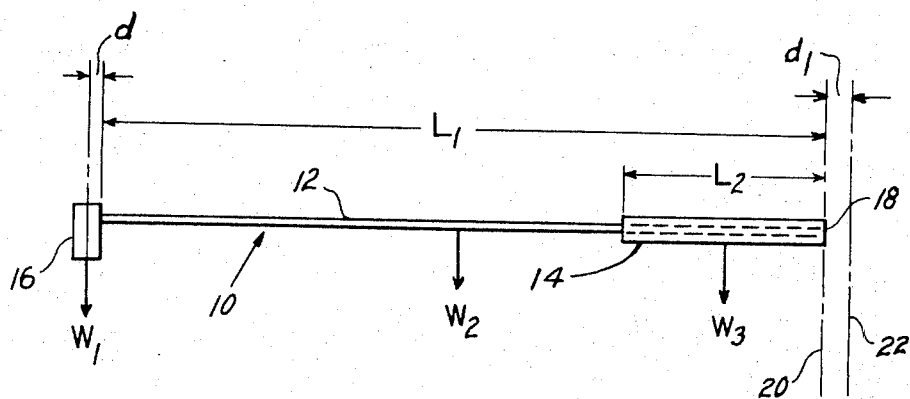
Attorney—Frank Kahn

[57] **ABSTRACT**

A dynamically matched set of golf clubs having identical moments of inertia with respect to a common swinging axis and, starting with a selected favored club, the method of determining by calculation from simple length and weight parameters, the head weights required for dynamically matching the other clubs of the set to the favored club. Use is made of the fact that the moment of inertia of a conventional golf club with respect to a swinging axis can be represented by the summation of the moments of inertia of the grip, the shaft and the head components.

2 Claims, 1 Drawing Figure





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DYNAMICALLY MATCHED SET OF GOLF CLUBS

BACKGROUND OF THE INVENTION

A. Field of the Invention

This invention relates to golf clubs and, more particularly, to a method of dynamically matching a set of clubs so that all of the clubs of the set will have the same moment of inertia with respect to a common swinging axis.

B. Description of the Prior Art

In present conventional matched sets of golf clubs, particularly the irons, the club grips are substantially identical, the club shafts substantially differ only in length, being progressively shorter with increasing club number, and the club heads are all of similar design but differ in weights in accordance with the "swinging weight" characteristic obtained by measurement of static balance on the swinging weight matching scale described in the Adams Pat. No. 1,953,916. All the clubs of such a conventional matched set balance at the same setting of the Adams' scale, the scale reading at the balance point being used to designate the swinging weight characteristic of the set. Although the irons of a swing weight matched set are thus statically balanced and heft substantially alike when picked up, they do not all have the same feel while swinging because they are not dynamically matched to have the same moment of inertia. Provided the clubs are matched in moment of inertia, for the same torque applied by the hands to the grip of the club, the clubs will accelerate the same way in angular motion and this produces the same dynamic feel for each of the clubs regardless of length.

The Marciniak Pat. No. 3,473,370 discloses a method of producing a dynamically matched set of golf clubs, all having the same moment of inertia. This method comprises first selecting a club of the desired swinging and playing action for the user, determining its moment of inertia with respect to its center of gravity by means of a torsional pendulum, and then selecting another club of the set and applying thereto heads of different weights until measurement with the torsional pendulum indicates that the same moment of inertia has been obtained. These data are used to plot a graph from which can be read the required head weights for any of the other clubs of the set.

Although the Marciniak dynamic matching method overcomes the shortcomings of the Adams swinging weight system, it involves the complexity of requiring measurements with a torsional pendulum and the plotting of graphs.

SUMMARY OF THE INVENTION

The primary object of this invention is to provide a method for dynamically matching a set of golf clubs which is of utmost simplicity and overcomes the disadvantages of the prior art.

Another object of the invention is to provide a method for determining solely by calculation from simple length and weight parameters the head weights for a dynamically matched set of golf clubs in which each club of the set has the same moment of inertia with respect to the swinging axis.

A further object of the invention is to provide a method for determining the head weights for a dynamically matched set of golf clubs in which each club of the set has the same moment of inertia with respect to the

swinging axis, using only simple length and weight parameters and without the necessity for making measurements with a torsional pendulum or plotting graphs.

Accordingly, the invention comprises selecting a club having the favored swinging and playing characteristics, determining its moment of inertia of mass with respect to a selected swinging axis by calculation from simple length and weight parameters, and then also by calculation determining for the clubs of the other shaft lengths the head weights to give the same moment of inertia. The determination of moment of inertia is very simply made by adding together the three moments of inertia of the head, shaft and grip components of the club. Since the shaft and the grip may for practical purposes be considered to be uniform cylindrical elements, their moments of inertia may be calculated with adequate accuracy from a very simple approximate relation.

Using an approximation which considers the compact mass of the head to be concentrated at its centroid, or center of gravity, the moment of inertia of the head may be determined with very little error by taking as the radius of gyration the distance between the swinging axis and the center of gravity of the head.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE of the accompanying drawing is a diagrammatic side view of a golf club illustrating the swinging axes and the parameters used in calculating the moments of inertia.

DETAILED DESCRIPTION OF THE INVENTION

The drawing illustrates a conventional golf club 10, typically one of a set of irons, having a shaft 12, a grip 14 and a head 16. The shaft 12 is conventionally a strong cylindrical element of substantially uniform weight per unit length which is uniformly diminished in length for increasing club numbers of the set, as is well known in the art. The grip 14 is a conventional sleeve of material suitable for providing a comfortable non-slip grasp by the user, in fixed engagement with the upper end 18 of the shaft, and is the same for all the clubs of the set. The head 16 is of conventional shape and the heads of all the clubs of the set are of similar design.

The transverse axis of swing 20, or dynamic axis, is assumed to be at the top end 18 of the club, as this is a good approximation of the normal axis of rotation of the swinging wrist action. It will, however, become evident from the ensuing description that the dynamic axis, instead of being at the end 18 of the club, may be taken as located at any desired point along the grip or beyond the end 18, such as at an alternate axis 22 beyond the grip. A favored club, such as club 10 having the desired swinging characteristic for the user, is selected and the following parameters are determined for it:

W_1 , the weight of the club head 16.

W_2 , the weight of the shaft 12.

W_3 , the weight of the grip 14.

L_1 , the length of the shaft 12.

d , the distance from the end of the shaft adjacent the head to the center of gravity of the head.

L_2 , the length of the grip 14.

The moment of inertia of the club with respect to the axis 20 is then readily determined from the following equation:

$$I = (L_1 + d)^2 \times (W_1/g) + (L_1^2/3) \times (W_2/g) + (L_2^2/3) \times (W_3/g) \quad (1)$$

wherein I is the moment of inertia of mass of the club with respect to the axis 20, the letter g represents the acceleration of gravity and the terms on the right side of the above equation (1) represent approximations of the moments of inertia respectively of the head 16, the shaft 12 and the grip 14. The value of I for the favored club as determined from equation (1) will be referred to as I_1 .

A set of clubs will be dynamically matched if each club of the set has the same moment of inertia with respect to a common axis of swing. To produce a set of clubs dynamically matched to the favored club, it is therefore only necessary to adjust the head weight of each of the other clubs to have the moment of inertia I_1 .

To determine the head weight required for any of the other clubs of the desired set, the value I_1 is substituted for I on the left side of equation (1), the new value of L_1 for a respective selected club is entered in the first two terms on the left side of equation (1), the new value of W_2 is entered in the second term (it being understood that the value of W_2 is directly proportional to L_1) and the third term of equation (1) remains the same. The new equation is then readily solved for W_1 , the desired weight of the head of the selected club. The desired head weights for the rest of the clubs of the set are similarly determined.

It is to be understood that to give the true moment of inertia of the club head, the distance d in the first term of the right side of equation (1) should be the distance from the center of gyration of the head to the adjacent end of the shaft 12 rather than to its center of gravity. However, for equation (1) the distance d was chosen to the center of gravity rather than to the center of gyration because the center of gravity can be conveniently located with adequate precision by balancing the head on a knife-edge, and also because the distance between the center of gyration and center of gravity is so small as to negligibly affect the distance to the axis 20. Moreover, since the club heads are of similar design, the distance d can be considered constant for the entire set of clubs with inconsequential error.

For the true moment of inertia of the shaft 12, the second term of equation (1) would necessarily include a component equal to $(r_1^2/4) \times (W_2/g)$, where r_1 is the shaft radius. This component has been disregarded because its omission introduces an error of less than 0.01 percent in the moment of inertia of the shaft.

For the true moment of inertia of the grip 14, the third term of equation (1) would include a component equal to

$$\left(\frac{r_2^2}{4} - \frac{r_1^2}{4}\right) \times \frac{W_3}{g}$$

where r_2 is the outside radius of the grip and r_1 the shaft radius. This component has been disregarded because its omission introduces an error of less than 1 percent in the moment of inertia of the grip and less than 0.01 percent in the total moment of inertia of the club.

Should it be desired to use a swinging axis location other than the axis 20 at the end 18 of the club 10, this

may be readily accomplished for the favored club in the following manner, based on the parallel axis theorem.

Taking d_1 as the distance between the axis 20 and the desired new parallel axis 22, it being understood that d_1 is positive if the new axis is farther from the center of gyration than the axis 20 and negative if closer, the equation for the moment of inertia I' of the club with respect to the new axis becomes

$$I' = (L_1 + d + d_1)^2 \frac{W_1}{g} + \left(\frac{L_1^2}{3} + L_1 d_1 + d_1^2\right) \frac{W_2}{g} + \left(\frac{L_2^2}{3} + L_2 d_1 + d_1^2\right) \frac{W_3}{g} \quad (2)$$

Since all the parameters on the right side of the above equation (2) are known, the value of the moment of inertia I' of the favored club with respect to the new axis 22 may be readily calculated.

As before, to determine the head weight required for any of the other clubs of the desired dynamically matched set, the value I' is substituted for I in equation (2), the new value L_1 for a respective selected club is entered in the first two terms, the new value of W_2 is entered in the second term and the third term is unchanged. The equation is then solved for W_1 , the desired weight of the head of the selected club. The desired head weights of the rest of the clubs of the set are similarly determined.

For facilitating production of my dynamically matched set of clubs, advantage may be taken of presently available manufacturing techniques for producing statically matched sets of clubs, using the Adams swinging weight system as will now be described.

Swinging weight matched sets of golf clubs, now in universal use, are manufactured in accordance with standard specifications based on the Adams swinging weight matching scale, so that the weight distribution of each club of a designated set is completely specified. The balance arm of the conventional swinging weight matching scale has alphabetically designated major divisions which are subdivided into numerical tenths so that the position of the poise on the balance arm has an alphanumeric designation such as C-8, D-2, etc. The balance position of the poise is the same for each club of the swinging weight matched set and the set is identified by the alphanumeric designation of this poise position. Such alphanumeric designations will be used hereinafter to refer to the weight distribution of a specific club in terms of the swinging weight system of Adams. Having determined the club head weights of a set of clubs dynamically matched to a chosen club, as previously described, it is now required to determine the head weights of a set of clubs matched with the same chosen club for static balance by the Adams swinging weight matching scale method.

Starting with the chosen club of known head weight, the unbalanced moment about the pivot of the swinging weight matching scale or apparatus of Adams is calculated. It is to be understood that it is this moment which is counterbalanced by positioning the poise of the Adams scale. In making the calculation it is to be observed that the distance from the grip end of the club to the pivot of the conventional swinging weight matching scale is approximately 14 inches, which is the preferred length set forth in the Adams patent.

The respective head weights of the other clubs of the swinging weight matched set which includes the chosen club are then readily calculated from the requirement that each of these other clubs must have the same unbalanced moment about the pivot as was determined above for the chosen club.

Comparing the head weights of the clubs of the dynamically matched set with those of the respective like-numbered swinging weight matched set, determined as above, there will be a zero difference in head weight for the chosen club, which is common to both sets. It will be found, however, that for each of the other numbered clubs the head weight increases incrementally with increasing club number for the clubs of the dynamically matched set as compared with the like-numbered clubs of the swinging weight matched set.

For the club of next higher number than the chosen club the amount of the incremental increase in head weight is of the order of one-sixteenth oz (the weight unit conventionally used in this art). The differentials in head weight for the higher-numbered clubs taken in numerical sequence are respectively of the order of two such units, three such units, and so forth. Conversely, for sequential decreasing club numbers there will be a similar decremental difference in head weights for the clubs of the dynamically matched set as compared with the clubs of the associated swinging weight matched set.

Table 1, following, compares the club head weights of a C-8 set of clubs with those of a set of clubs dynamically matched to the No. 2 club of the C-8 set, the No. 2 club being therefore identical in the two sets. The differential in head weight of the two sets of clubs is also shown for each numbered club.

TABLE 1

Comparison of Head Weights of a C-8 Set of Golf Clubs and of a Set of Clubs Dynamically Matching the C-8 No. 2 Club

CLUB HEAD WEIGHTS

Club No.	C-8 Set	Dynamically Matched Set Based on the C-8 No. 2 Club	*Club Head Weight Differentials
2	136	136	0
3	139	140	1
4	143	145	2
5	147	149	2
6	150	153	3
7	154	158	4
8	159	164	5
9	163	169	6

Notes: All weights shown in this table are in conventional 1/16-oz units and have been rounded off to the nearest integer.

*The weights shown in this column are the respective differences between the club head weights of the dynamically matched set and the head weights of the same-numbered clubs of the C-8 swinging weight matched set.

Table 2, following, is a tabulation similar to Table 1 except that the dynamically matched set referred to in Table 2 is based on the C-8 No. 5 club as the favored club.

TABLE 2

Comparison of Head Weights of a C-8 Set of Golf Clubs and of a Set of Clubs Dynamically Matching the C-8 No. 5 Club

CLUB HEAD WEIGHTS

Club No.	C-8 Set	Dynamically Matched Set Based on the C-8 No. 5 Club	*Club Head Weight Differentials
2	136	134	-2
3	139	138	-1
4	143	143	0
5	147	147	0
6	150	151	1
7	154	156	2
8	159	162	3
9	163	167	4

Notes: All weights shown in this table are in conventional 1/16-oz units and have been rounded off to the nearest integer.

*The weights shown in this column are the respective differences between the club head weights of the dynamically matched set and the head weights of the same-numbered clubs of the C-8 swinging weight matched set.

With the information from Tables 1 or 2, or from similar comparisons based on other club sets, the Adams swinging weight specification may also be arrived at for each club in a dynamically matched set by adjusting the head weight of each club of an Adams matched set and reweighing each on the Adams scale to determine a new swinging weight for each club of the dynamically matched set. A desired dynamically matched set of clubs may be obtained from a golf club manufacturer by simply ordering each club in the set with a designated swinging weight based on the Adams scale. Each club of such a set will have a different swinging weight designation. Also, the club head weights of a stock swinging weight matched set may be adjusted to the required dynamic matching values by adding or removing modicums of weight by any suitable means.

It is also evident that a dynamically matched set of clubs may be assembled by selecting specific numbered clubs from dealers' stocks of different swinging weight matched sets. For example, a dynamically matched set could include a C-8 No. 2 iron, a D-0 No. 4 iron, a D-2 No. 6 iron, etc.

The foregoing described method of matching golf clubs for equal moments of inertia is particularly applicable to the irons, but it is evident that it is equally applicable to the wood clubs. However, because of the larger size of the heads of the wood clubs, it may be desirable to use an adjusted value of d in equations used for calculating the moment of inertia, the new value of d being readily obtained from a knife-edge determination of the location of the center of gravity of a wood head of the desired design.

In carrying out the herein disclosed method of producing a dynamically matched set of golf clubs by using the principle of superposition of the moments of inertia of the head, shaft and grip components, I prefer to use the approximations represented by the simplified equations (1) and (2) because the results obtained are

of adequate accuracy. However, it is obvious that, if desired, the exact mathematical expressions for the moments of inertia of mass for these components, previously explained above, may alternatively be used. Thus, in the expression for the true moment of inertia of the head, the symbol d should represent the distance between the center of gyration of the head and the adjacent end of the shaft, and the expressions for the moments of inertia of the shaft and grip should ideally include the terms which comprise the radius effects.

The foregoing method of determining head weights for a dynamically matched set of clubs is based in part on the assumption that the club shafts of the set are all uniform cylindrical elements of constant weight per unit length. In practice, however, some club manufacturers make slight departures from complete uniformity of shaft elements among the clubs of a swinging weight matched set. Corrections in head weight determinations for such departures from uniformity of shaft elements would yield results having insignificant differences from those obtained by my above method. If attempts were made by the club manufacturers to take such small differences into account, they would be dealing with minutiae much smaller than the tolerances of manufacture they are able to meet.

Accordingly, a set of golf clubs produced by using the dynamic matching method set forth herein will feel perfectly matched, since it would be well beyond the ability of the user to perceive any difference caused by the slight discrepancies from exact dynamic matching which result from the approximations used.

I claim:

1. A method of producing a dynamically matched set of golf clubs in which the clubs have substantially a common moment of inertia with respect to a selected swinging axis,
 - a. said clubs having respective head, shaft and grip components,
 - b. the heads of said clubs being of similar design but having different respective weights,
 - c. the shafts of the respective clubs having different lengths but being of substantially identical weight per unit length and
 - d. the grips of said clubs being substantially identical,
 which comprises the steps of
 1. determining solely by calculation the moment of inertia of a favored club of the set with respect to said axis from known length and weight parameters of its head, shaft and grip components, including the distance between the center of gravity of its head and the adjacent end of its shaft,
 2. determining solely by calculation from known length and weight parameters of the shafts and grips of the other clubs of the set the respective

head weights which will produce for each of said other clubs the same moment of inertia with respect to said axis as had been determined for said favored club,

3. providing said other clubs of the set with heads of the weights so determined
 4. whereby all the clubs of the set will be dynamically matched by having substantially the same moment of inertia with respect to said axis, and
 5. determining for each of the clubs of the set head weight distribution in terms of the Adams' swinging weight matching system, for the purpose of facilitating manufacture of said dynamically matched set of clubs.
2. A method of producing a dynamically matched set of golf clubs in which the clubs have substantially a common moment of inertia with respect to a selected swinging axis,
 - a. said clubs having respective head, shaft and grip components,
 - b. the heads of said clubs being of similar design but having different respective weights,
 - c. the shafts of the respective clubs having different lengths but being of substantially identical weight per unit length and
 - d. the grips of said clubs being substantially identical,
 which comprises the steps of
 1. determining solely by calculation the moment of inertia of a favored club of the set with respect to said axis from known length and weight parameters of its head, shaft and grip components, including the distance between the center of gravity of its head and the adjacent end of its shaft,
 2. determining solely by calculation from known length and weight parameters of the shafts and grips of the other clubs of the set the respective head weights which will produce for each of said other clubs the same moment of inertia with respect to said axis as had been determined for said favored club,
 3. providing said other clubs of the set with heads of the weights so determined
 4. whereby all the clubs of the set will be dynamically matched by having substantially the same moment of inertia with respect to said axis, and
 5. determining head weights for a second set of clubs matched with said favored club for static balance by the Adams' swinging weight matching method and determining the incremental differences in head weights between respective like-numbered clubs of the dynamically matched set and said second set, whereby production of said dynamically matched set is facilitated.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,698,239 Dated October 17, 1972

Inventor(s) James L. Everett, III

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 6, that portion of equation (1) reading
 (W_3/gan) should read (W_3/g)

Column 3, line 26, cancel "left" and insert --right--.

Signed and sealed this 10th day of April 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents