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(54) **Golf club shafts**

(57) This invention relates to a method of manufacturing golf club shafts to required torsional stiffness and also to sets of golf clubs or shafts therefor matched with regard to torsional stiffness. The golf clubs or shafts therefor may in addition be matched with regard to other torsional characteristics, for example overall torsional deflection per unit torsional load or torsional vibrational frequency.

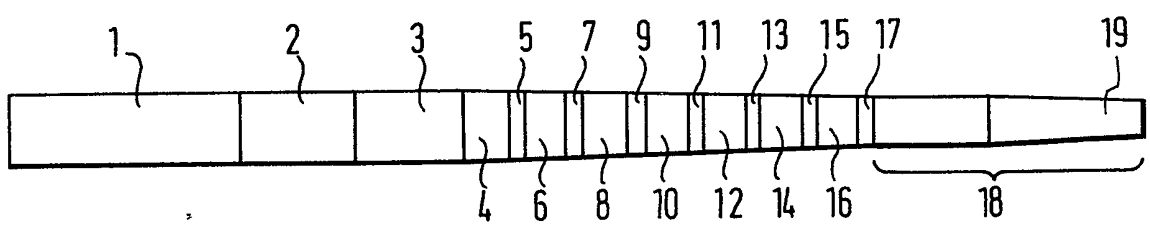

FIG.2.

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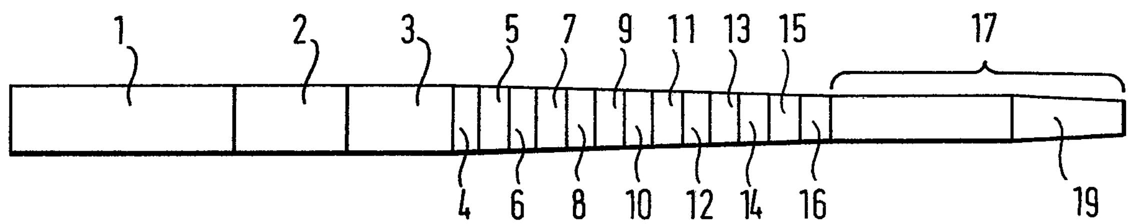
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FIG.1.

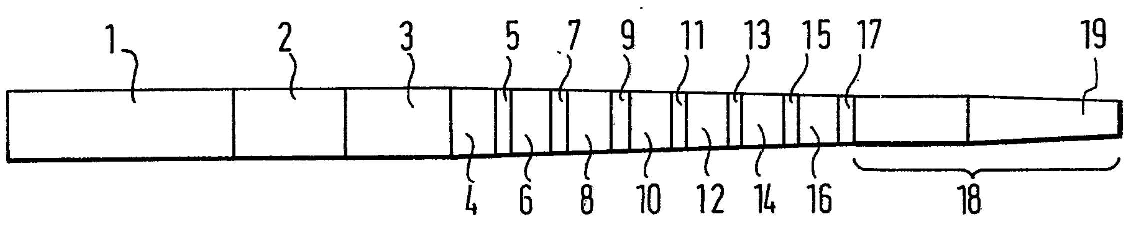
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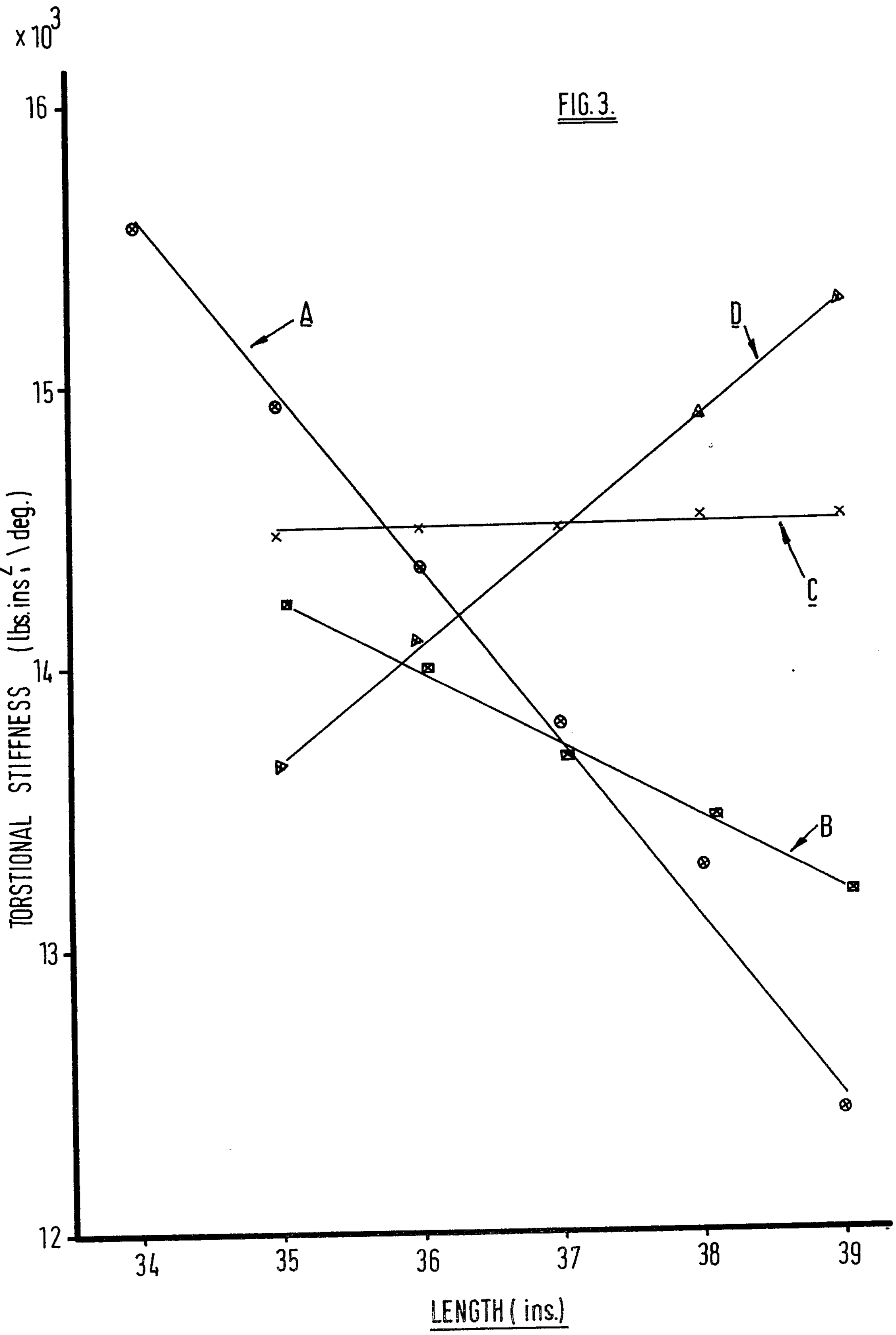
FIG.2.

FIG. 3.


x 10^3
16
15
14
13
12
TORSTIONAL STIFFNESS (lbs.ins^2 \ deg.)
A
B
C
D
34
35
36
37
38
39
LENGTH (ins.)

SPECIFICATION

Golf club shafts

The present invention relates to the manufacture of golf club shafts and in particular to the matching of sets of golf club shafts.

Conventionally in a set of golf clubs, the club shafts vary in length, for example the lengths may differ in one or half inch increments from 39" to 35" for "irons" and from 45" to 42" for "woods". These sets of shafts, apart from the difference in length, are substantially identical in external appearance, for example having a step pattern in which the lengths and dimensions of the steps are constant from shaft to shaft, although it may be that shafts for the "woods" have one or two additional steps as compared to the shafts for the "irons".

Furthermore, it is common practice to match one or more of the physical characteristics of each shaft in a set, in an attempt to produce a set of shafts which will provide a uniform reaction to a consistent golf swing. The physical characteristics that have been used to match golf club shafts in the past, include: the mass of the shaft, the bending frequency of the shaft, and also the static shaft deflection.

In use, torsional loads are induced into a golf club shaft during the swing and to a greater degree at the point of impact of the golf club head with the ball or the ground. During the swing, the shaft accelerates pulling the head of the club after it, the club head is offset from the centre line of the shaft, this therefore induces a torsional stress in the shaft.

At some point before impacting the ball, the momentum of the head carries it past the shaft, thus twisting the shaft in the opposite direction. The twisting of the shaft is then reversed and maximised by the impact of the head with the ball or the ground. If no account is taken of this twisting of the shaft when matching sets of shafts, it may well be that there is a wide variation in the degree of deflection that occurs from shaft to shaft within the set. Consequently it may prove difficult to control the direction in which the ball will be projected.

We have now found that it is advantageous to match a set of golf clubs or shafts therefor with respect to their torsional characteristics. In order to achieve this, it is necessary to be capable of producing a golf club shaft having a specific torsional characteristic.

According to one aspect, the present invention provides a method of manufacturing a golf club shaft of desired length, in which the outer diameter and thickness of the shaft are varied along its length and the material from which the shaft is made is selected; to produce a shaft of predetermined desired torsional stiffness (as hereinafter defined).

According to another aspect, the present invention provides a matched set of golf clubs or shafts therefor, in which the torsional stiffness (as hereinafter defined) of each club or shaft is substantially constant or increases substantially uniformly with increase in length throughout the set. Preferably the torsional stiffness over a set of shafts, or the incremental increase of torsional stiffness from shaft to shaft in the set, varies by less than 5% of the mean torsional stiffness for the set.

For a golf club shaft:–

$$\text{Torsional Stiffness} = \frac{LT}{\Theta} = JC$$

where:

L is the length of the shaft;

T is the torsional load applied to the shaft;

Θ is the angular deflection of the shaft;

J is the mean 2nd moment of the area of the shaft; and

C is the torsional modulus of the material.

The mean 2nd moment of the area of the shaft;

$$J = \frac{L}{\frac{L_1}{J_1} + \frac{L_2}{J_2} + \frac{L_3}{J_3} + \ldots \frac{Ln}{Jn}}$$

where;

J_1; J_2; J_3 etc. are the 2nd moments of area of each of the step portions of the shaft.

$$= \frac{\pi}{32} \left(D_1^4 - d_1^4\right) \text{ etc.}$$

where;

D_1 = the outside diameter of the step portion of the shaft

d_1 = the inside diameter of the step portion of the shaft;

L_1; L_2; L_3; etc. are the lengths of each of the step portions of the shaft;

and L is the overall length of the shaft.

Consequently in order to maintain constant torsional stiffness throughout a set of shafts, for a constant torsional load it is necessary to maintain the ratio L/Θ at a constant value. The amount of angular deflection Θ of the shaft for a given torsional load T, is not only proportional to the length L of the shaft but also to the mean diameter and wall thickness of the shaft. For example, if the shaft is of constant wall thickness, angular deflection Θ will decrease with increasing diameter and for shafts of constant diameter, angular deflection Θ will decrease with increasing wall thickness.

One method of producing a set of golf club shafts, used hitherto, is to maintain a constant length grip portion, constant length dimensions over the central stepped portion and constant overall mass. Length variations are provided by modifying the length of the small diameter end portion and by increasing or decreasing the thickness in order to provide constant mass. By reducing the length of the small diameter end portion of the shaft, the angular deflection Θ will be reduced proportionally to a greater degree than

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the length L of the shaft, with respect to the mean for the shaft, the ratio of L/Θ and consequently the torsional stiffness of the shaft will increase as the length of the shaft decreases. Further more, the increase in thickness of the shaft will further decrease the angular deflection Θ, increasing the torsional stiffness. As a result, this method of producing shafts can give a variation in the torsional stiffness of about 20% across a set of shafts, as illustrated by Line *A* in the graph, shown in figure 3.

The variation in torsional stiffness may be reduced to about 10%, as illustrated by Line *B* of the graph, shown in figure 3, by maintaining a constant wall thickness. This of course will be at the expense of the uniformity of the shaft weights.

According to a further aspect of the present invention a method of producing a set of golf clubs or shafts therefor comprises maintaining the lengths of the small diameter end portion and central stepped portion of the shaft constant and decreasing the length of the large diameter end portion, whilst increasing the wall thickness of the shaft, or vice versa, so as to produce a set of shafts in which the torsional stiffness (as hereinbefore defined), of each shaft is substantially constant or increases substantially uniformly with increase in length.

By reducing the length of the large diameter end portion of the shaft, the angular deflection Θ of the shaft will be reduced proportionally to a smaller degree than the length L of the shaft. The ratio L/Θ and consequently the torsional stiffness of the shaft will decrease. This decrease in torsional stiffness can be corrected to give a constant value over the set by increasing the wall thickness of the various portions of the shaft, thereby further reducing the angular deflection Θ and increasing the L/Θ ratio and torsional stiffness. The increase in wall thickness will also, to a certain degree, compensate for the loss in mass of the shaft due to its reduction in length.

Alternatively, the wall thickness of the various portions of the shaft may be increased in order to provide a set of shafts in which the torsional stiffness increases uniformly with the length of the shaft. In particular, it is advantageous to match the set in this manner, such that the torsional deflection for a given torsional load, of each shaft in the set, is substantially constant, or preferably varies by less than 5% throughout the set.

The invention is now described, by way of example only, with reference to the accompanying drawings, in which:–

Figure 1 is a diagramatic representation of a golf club shaft formed in accordance with conventional design techniques;

Figure 2 is a diagrammatic representation of a golf club shaft formed in accordance with the present invention; and

Figure 3 is a graph of torsional stiffness against shaft length, lines *A* and *B* being plots for sets of shafts formed in accordance with conventional methods and as illustrated in figure 1; and lines *C* and *D* being plots for sets of shafts formed in accordance with the present invention and as illustrated in figure 2.

EXAMPLE A

A set of six golf club shafts corresponding to the representation illustrated in Figure 1 and of the dimensions given in Table I (example A) was produced by maintaining the lengths and diameters of the large diameter end portion 1 and step portions 2 to 16 of the shaft constant and reducing the length of the small diameter end portion 17, in inch increments, from 14.5 inches to 9.5 inches. The thickness of the various steps of the shaft was also varied as illustrated in Table II A, in order to compensate for the reduction in length, so that all six shafts were of the same weight as illustrated in Table III. As shown in Table III and plot *A* of the graph shown in Figure 3, as the shafts thus produced decrease in length, the torsional stiffness of the shaft increases quite rapidly, there being a 21.4% variation over the set of shafts.

EXAMPLE B

A set of shafts was produced similar to those represented in Figure 1 and the dimensions given for example A in Table I. The wall thicknesses of the shafts were, however, maintained constant at the values about the 37 inch shaft given in Table II A. The torsional stiffness of the shafts showed a reduced variation as illustrated by plot *B* of the graph shown in figure 3, but at the expense of a wide variation in the shaft weights.

TABLE I

Step	Length (inches)		Diameter (inches)	
	Example A (Prior Art)	Example C	Example A (Prior Art)	Example C
1	6.5	8.5 - 4.5	0.5800	0.6000
2	2.5	3.0	0.5700	0.5900
3	2.5	3.0	0.5600	0.5750
4	1.0	1.5	0.5480	0.5650
5	1.0	0.5	0.5360	0.5500
6	1.0	1.5	0.5240	0.5400
7	1.0	0.5	0.5120	0.5250
8	1.0	1.5	0.5000	0.5150
9	1.0	0.5	0.4880	0.5000
10	1.0	1.5	0.4760	0.4900
11	1.0	0.5	0.4640	0.4750
12	1.0	1.5	0.4520	0.4650
13	1.0	0.5	0.4400	0.4500
14	1.0	1.5	0.4280	0.4400
15	1.0	0.5	0.4160	0.4250
16	1.0	1.5	0.4040	0.4150
17	14.5 - 9.5	0.5	0.3920	0.4050
18	–	10.5	–	0.3950
TIP	–	–	0.3550	0.3550
TAPER 19	5.0	5.35	–	–

TABLE II A
(Example A)

Step	Thickness (thousandths of an inch)					
	39″ shaft	38″ shaft	37″ shaft	36″ shaft	35″ shaft	34″ shaft
1	13.35	13.68	14.03	14.14	14.78	15.19
2	13.47	13.81	14.16	14.52	14.91	15.32
3	13.59	13.93	14.28	14.66	15.05	15.46
4	13.75	14.09	14.44	14.82	15.22	15.63
5	13.90	14.25	14.61	14.99	15.39	15.81
6	14.06	14.41	14.78	15.16	15.57	16.00
7	14.23	14.59	14.96	15.35	15.76	16.19
8	14.41	14.76	15.14	15.53	15.95	16.39
9	14.59	14.95	15.33	15.73	16.15	16.59
10	14.78	15.14	15.53	15.93	16.36	16.81
11	14.97	15.34	15.73	16.14	16.57	17.03
12	15.18	15.55	15.95	16.36	16.80	17.26
13	15.39	15.77	16.17	16.59	17.03	17.50
14	15.61	16.00	16.40	16.83	17.28	17.75
15	15.84	16.23	16.64	17.08	17.53	18.01
16	16.08	16.48	16.90	17.34	17.80	18.29
17	21.84	22.24	22.67	23.11	23.59	24.08
TIP	24.95	25.41	25.89	26.40	26.94	27.50

EXAMPLE C

A set of five shafts was produced in accordance with the representation shown in Figure 2 and to the dimensions given in Table I (Example C) by maintaining the lengths and diameters of the small diameter end portion 18 and Stepped portions 2 to 17 constant, while reducing the length of the large diameter end portion 1, in inch increments between 8.5 inches and 4.5 inches. The wall thickness of the various steps of the shaft were varied in accordance with Table II C, so that the resulting shafts had a substantially uniform torsional stiffness, as illustrated in Table III and by plot *C* of the graph shown in Figure 3.

EXAMPLE D

A further set of five shafts was produced in accordance with the representation shown in figure 2 and the dimensions given in Table 1 (Example C), but in this case the thickness of the various step portions of the shafts were varied in accordance with Table II D, so that the torsional stiffness of the shafts increases substantially uniformly with increasing length as illustrated in Table IV and by plot D of the graph shown in figure 3 and also the torsional deflection per unit torsional load for each shaft in the set was substantially constant, as shown in Table IV

TABLE II C
(Example C)

Step	Thickness (thousandths of an inch)				
	39" shaft	38" shaft	37" shaft	36" shaft	35" shaft
1	12.68	12.84	13.02	13.21	13.42
2	12.79	12.95	13.14	13.33	13.54
3	12.96	13.13	13.31	13.50	13.71
4	13.07	13.25	13.43	13.62	13.84
5	13.26	13.43	13.62	13.82	14.03
6	13.38	13.56	13.75	13.95	14.16
7	13.58	13.76	13.95	14.15	14.37
8	13.71	13.89	14.09	14.29	14.51
9	13.92	14.11	14.30	14.51	14.73
10	14.07	14.25	14.45	14.66	14.89
11	14.30	14.48	14.69	14.90	15.13
12	14.45	14.64	14.85	15.06	15.29
13	14.70	14.89	15.10	15.32	15.56
14	14.87	15.07	15.28	15.55	15.74
15	15.14	15.34	15.56	15.78	16.02
16	15.33	15.53	15.75	15.97	16.22
17	15.52	15.72	15.95	16.18	16.42
18	23.40	23.61	23.83	24.06	24.32
TIP	26.63	26.86	27.12	27.39	27.68

TABLE III

Shaft Length (Ins)	39	38	37	36	35	34
Example A						
Shaft Weight (oz)	4.25	4.25	4.25	4.25	4.25	4.25
Head Weight (oz)	9.8	9.8	9.8	9.8	9.8	9.8
Torsional Stiffness (lbs.ins²/deg)	12814	13283	13790	14335	14925	15561
Torsional Frequency (Hz)	58.99	60.91	62.97	65.17	67.53	
Example C						
Shaft Weight (oz)	4.25	4.187	4.125	4.062	4.0	
Head Weight (oz)	9.8	9.8	9.8	9.8	9.8	
Torsional Stiffness (lbs.ins²/deg)	14517	14503	14491	14474	14458	
Torsional Frequency (Hz)	62.79	63.65	64.55	65.49	66.47	

TABLE II D
(Example D)

Step	Thickness (thousandths of an inch)				
	39" shaft	38" shaft	37" shaft	36" shaft	35" shaft
1	13.52	13.28	13.02	12.75	12.47
2	13.63	13.39	13.14	12.86	12.58
3	13.81	13.57	13.31	13.04	12.75
4	13.94	13.69	13.43	13.15	12.86
5	14.13	13.88	13.62	13.34	13.04
6	14.27	14.01	13.75	13.46	13.16
7	14.47	14.22	13.95	13.66	13.36
8	14.62	14.36	14.09	13.79	13.49
9	14.84	14.58	14.30	14.01	13.69
10	15.00	14.73	14.45	14.15	13.84
11	15.24	14.97	14.69	14.38	14.06
12	15.41	15.13	14.85	14.54	14.22
13	15.67	15.39	15.18	14.79	14.46
14	15.85	15.57	15.28	14.96	14.63
15	16.14	15.86	15.56	15.23	14.89
16	16.34	16.05	15.75	15.42	15.08
17	16.55	16.25	15.95	15.61	15.27
18	24.44	24.14	23.83	23.50	23.14
Tip	27.82	27.48	27.12	26.73	26.33

TABLE IV
(Example D)

Shaft Length (ins.)	39	38	37	36	35
Torsional stiffness (lbs.ins²/deg)	15281	14891	14491	14073	13644
Torsional deflection of shaft (deg/lbs,ins) x 10^3	2.55	2.55	2.55	2.56	2.57
Head weight (oz)	9.8	9.8	9.8	9.8	9.8
Torsional frequency (Hz)	64.42	64.49	64.55	64.57	64.56

This invention applies to both "woods" and "irons", the "woods" and "irons" may be matched together to give a single matched set of clubs or may be matched as individual types to give separate sets of matched "woods" and matched "irons".

In addition to controlling the torsional stiffness or torsional deflection of the golf clubs or shafts therefor, the present method also produces a set of golf clubs or shafts having substantially constant torsional vibrational frequency as illustrated in the results given in Tables III and IV for the shafts produced in Examples *C* and *D*. Consequently a set of golf clubs or shafts therefor produced in accordance with the present invention may be matched with respect to their torsional vibrational characteristics and/or torsional deflection characteristics as well as their torsional stiffness.

Where shafts are matched in respect to torsional characteristics which are affected by the size, shape and mass of the heads fitted thereto, for example torsional deflection or torsional vibrational frequecy, the heads are also preferably matched throughout the set, so that the resulting set of clubs are also matched in some manner, with respect to these characteristics.

CLAIMS

1. A method of manufacturing a golf club shaft of desired length, in which the outer diameter and thickness of the shaft are varied along its length and the material from which the shaft is made is selected, to produce a shaft of predetermined desired torsional stiffness (as hereinbefore defined).

2. A golf club shaft of desired length and torsional stiffness made by the method of claim 1.

3. A set of golf clubs or shafts therefor, in which the torsional stiffness (as hereinbefore defined) of each club or shaft, is substantially constant or increases substantially uniform with increase in length, throughout the set.

4. A set of golf clubs or shafts in accordance with claim 3 in which the torsional stiffness over the set of shafts, or the incremental increase of torsional stiffness from shaft to shaft over the set, varies by less than 5%, of the mean torsional stiffness for the set.

5. A set of golf clubs or shafts in accordance with claims 3 or 4 in which the torsional deflection of each shaft for a constant torsional load is substantially constant throughout the set.

6. A set of golf clubs or shafts in accordance with claim 5 in which the torsional deflection varies by

less than 5% over the set of shafts.

7. A set of golf clubs or shafts in accordance with any one of claims 3 to 6 in which the torsional vibrational frequency of each club or shaft is substantially constant througout the set.

8. A set of golf clubs according to any one of claims 5 to 7 in which the shafts are in accordance with any one of claims 3 to 7 and the heads attached to these shafts are matched with regard to their size, shape and mass.

9. A method of producing a set of golf clubs or shafts therefor comprising maintaining the lengths of the small diameter end portion and central stepped portion of the shaft constant and decreasing the length of the large diameter end portion, whilst increasing the wall thickness of the shaft, (or vice versa), so as to produce a set of shafts, in which the torsional stiffness (as hereinbefore defined), of each shaft within the set, is substantially constant or increases substantially uniformly with increase in length.

10. A set of golf clubs or shafts therefor substantially as described herein with reference to, and as shown in figure 2 of the accompanying drawings.

11. A method of producing a set of golf club shafts substantially as described herein with reference to figure 2 of the accompanying drawing.

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