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(19)

(54) IMPROVEMENTS IN OR RELATING TO SPORTS IMPLEMENTS

(71) We, DUNLOP HOLDINGS LIMITED, a British Company of Dunlop House, Ryder Street, St. James's, London S.W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to shafts for games rackets and to rackets provided with the shafts.

The invention is an improvement in or modification of the invention described in the Specification of our British Patent Application No. 52861/69 (Serial No. 1,321,235), hereafter referred to as "the parent invention".

The parent invention provides racket shafts which have very desirable playing characteristics and which, in comparison with conventional tubular racket shafts are stronger and generally more flexible at any given weight and have a greater resistance to breakage in use.

The parent invention provides a games racket comprising a head, a handle and a tubular shaft connecting the head and the handle, the shaft having a tapered portion in which the taper is towards the head and the amount of taper in said portion being such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is in the range 80 to 110% of the surface stress at the wider end of said tapered portion. The surface stress at said narrower end can be, for example, in the range 80 to 100%, 90 to 100% or 90 to 110% of that at said wider end.

The surface stress under load referred to herein is as measured when the racket is firmly clamped by its handle with its head substantially horizontal, and a load is applied to the centre of the stringing (or, in the absence of strings to the centre of the stringing area of the head), for example by suspending a weight therefrom. Electrical strain gauges can be used for the measurement of the surface stress using well-known techniques.

We have now discovered that the major advantages of the parent invention can be achieved by providing a shaft in which the surface stress is uniformly controlled in one plane only of the shaft. This plane is the one containing the longitudinal shaft axis, and which, when the shaft is fitted to the racket head, is at right angles to the plane of the racket head. In other words this plane is at right angles to the plane of the strings of the racket. This plane will hereafter be referred to as the plane of the minor axis of the shaft. The plane containing the racket head will be referred to as the plane of the major axis of the shaft.

Accordingly, the present invention provides a games racket comprising a head, a handle and a tubular shaft connecting the head and the handle, the shaft having a portion which when viewed to show the section in the plane of the minor axis (as herein defined) is tapered towards the head, the amount of taper in said portion being such that the surface stress in the tapered portion in the plane of the minor axis when the racket head is loaded is, at the narrower end of said tapered portion, in the range 80 to 110% of its value at the wider end of said tapered portion, said tapered portion being of substantially elliptical transverse cross-section. The surface stress at said narrower end can be, for example, in the range 80 to 100%, 90 to 100% or 90 to 110% of that at said wider end.

The shaft of the present invention can be obtained by a relatively simple pressing or flattening operation as it is only necessary to achieve the desired tapered sectional form in the one said plane, i.e. of the minor axis. This pressing operation can conveniently be carried out, for example, by using suitably shaped dies. The original starting tube may be, for example, a parallel tube of circular

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cross-section and uniform wall thickness. In this case the finished shaft will have a narrowed portion corresponding to the taper in the plane of the minor axis but it will have a corresponding bulging portion in the plane of the major axis, i.e. it will have a substantially elliptical transverse cross-section.

Alternatively, it is possible to start with a tube having a tapered wall and/or tube of non-circular cross-section. Moreover, the starting tube may be one which has been previously tapered by roll swageing or any other conventional technique. Where the starting tube is tapered it may be possible to arrange that the degree of initial tapering approximately cancels out the bulging that will take place in the plane of the major axis. Thus the walls of the finished shaft may appear to the eye to be parallel in that plane.

The design principles for a shaft of the present invention are basically the same as those for the shaft of the parent invention.

Thus, in one embodiment the length of the shaft which is to comprise the free length between the head and handle tapers in the plane of the minor axis to such an extent that the bending moment acting on the shaft in use produces a uniform surface stress over said length, or so that the surface stress produced varies uniformly along the free length. This variation can be, for instance as much as 10% from one end to the other.

The taper of said tapered portion can be uniform or non-uniform. Where it is non-uniform the tapered portion can have a smooth configuration or can be constituted by a series of "steps".

The extent to which the free length can taper is in some instances limited by the extent to which the external major axis and minor axis diameters of the shaft can be reduced. (The major axis diameter can be reduced overall if the tube is tapered in the first instance). The well-known relationship between cross-sectional area and stiffness of a cantilever has to be considered. The external diameters of the shaft should not be reduced below the minimum necessary to provide adequate bending strength, having regard to the nature of the material from which the shaft is made and the magnitude of the forces acting on the shaft in play. The actual shape of the shaft will thus depend on the nature of the racket in which it is incorporated. For a badminton racket, in which a shaft of comparatively small external diameter is required, the external diameter of the free length in the plane of the minor axis conveniently decreases from the end where the shaft emerges from the racket handle over a major part of the free length to a minimum and it then may be increased slightly again towards the end where the shaft enters the head of the racket for bonding purposes. For other implements such as a tennis racket, where a shaft of larger external diameter is required, the shaft may conveniently taper in this plane over the whole of its free length.

The rackets with which the invention is particularly concerned are those with shafts whose free length has a double taper in the plane of the minor axis. In other words these shafts have a first taper from the region of the handle towards the head and a second taper in the opposite direction from the region of the head end. Thus the shaft of this type, in the minor axis, is wider in the region of the head and shaft ends than it is in between. In one form the middle region of the shaft comprises a zone having parallel sides, though this is not essential.

If the shaft does not have this double taper shape, it has been found in some instances that the shaft width at the head end thereof is too small to provide a satisfactory securement with the head of the racket. This is because the surface area of the shaft at that end is correspondingly small. This may be the case where securement is by means of adhesive. It is also preferable that the extreme head end of the second taper section should be circular in cross-section, since this makes attachment to the head much easier than when the section is non-circular.

In the double taper design it will be seen that the taper from the handle towards the head is related to strength and flexibility of the shaft; while the other taper—from the head towards the handle end—is related to the minimum shaft surface area for bonding with the head, and with convenience of attachment to the head.

Although the invention is concerned with sports rackets in general, for example, badminton, squash and tennis rackets, the description which follows is with particular reference to badminton rackets.

When the racket is used to strike a shuttlecock in play, the inertia of the head causes a shear force and a bending moment to be set up in the free length of the shaft, i.e. the total length between the handle and the head of the racket. For any given force the magnitude of the shear stress is determined by the cross-sectional area of the tube. The magnitude of the surface stress due to bending is determined in the plane of the minor axis by the cross-sectional area of the tube, its radius of gyration, its external major and minor diameters, and the distance along the tube measured from the point where the shaft enters the head. The shaft must therefore have a sufficiently large cross-sectional area and external major and minor diameters over its free length such that the shear stress and bending stress set up in the plane of the minor axis in normal usage does not exceed the fatigue strength of the shaft material in shear or in bending.

However, for acceptable playing properties,

the shaft must be as light as possible so that its inertia is as low as possible. It should have a low flexural rigidity over its free length (preferably between 1.0 and 0.5×10^7 g.cm.^{2} or lower) such that its flexibility gives the desired feel and playing characteristics to the badminton racket. For lightness and flexibility, the cross-sectional area and external major and minor diameters of the shaft should be as small as possible. The requirements of strength, lightness and flexibility of the badminton racket shaft are obviously conflicting requirements. Thus if conventional tubular steel shafts are made so as to eliminate all risk of breakage they are found to be too heavy or rigid, and consequently give a poor "feel" or response in play. On the other hand, shafts having desirable flexibility or of very low weight have generally suffered from a tendency to break in use. The present invention provides rackets having a unique combination of strength, low weight and flexibility.

Materials from which a shaft of the invention may be made are, for example, metals such as steel or aluminium but other materials, for example, composite materials such as plastics reinforced with fibreglass or with carbon fibres may be used.

The invention will now be further described with reference to the accompanying drawings in which:—

Figure 1 is a view of a racket diagrammatically illustrating the planes of the major and minor axis;

Figure 2 is a longitudinal section through a racket shaft;

Figure 3 is a cross-section through a circular shaft normal to its longitudinal axis;

Figure 4 is a similar section through an elliptical shaft; and

Figure 5 is a graph showing stress against minor semiaxis of a shaft.

In Figure 1, the racket has a handle 10, a shaft 11, a head 12 and strings 13. The longitudinal axis of the racket is shown as line LL', the plane of the minor axis is shown as ABCD and the plane of the major axis shown as EFGH.

Where the tube used for the shaft is of metal the various values for the external minor radius B of the tube required at points along the free length of the shaft to ensure substantially uniform stress (assuming unit load and unit modulus) can be obtained by use of the following calculations:—

If Figure 3 represents a circular badminton shaft with the handle fitted at 'x' and the head at 'y' (as illustrated in Figure 2) then if a force W is applied at 'y' during play, the surface stress (S) at any point on the outer surface of the shaft and lying in the plane of the minor axis at distance d from the head for unit force and unit modulus is given by:

$$S = \frac{4.d.R}{\pi(R^4 - r^4)} \quad \ldots\ldots\ldots\ldots (1)$$

where R and r are the external and internal section radii.

The corresponding expression for an elliptical section (Figure 4) with external and internal semi-axes of A, B, a and b is:—

$$S = \frac{4.d.B}{\pi(A.B^3 - a\,b^3)} \quad \ldots\ldots\ldots (2)$$

where bending is considered in the plane of the minor semi-axis (B).

To relate any elliptical section to its original circular form, it can be assumed that the wall thickness (t) and mid-wall circumference are unchanged during pressing, so that, equating the circumferences of the two sections:

$$2\pi R' = 2\pi \left[\frac{A'^2 + B'^2}{2}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots (3)$$

where $R' = (R + r)/2$ etc.

Thus by using equation (2) and (3), the semi-axes of an elliptical section to give a specified surface stress can be calculated.

The method chosen for performing this calculation can be as follows. Suppose at some point along the shaft, the outside radius of the unpressed section is R_1 and the wall thickness is t. Ten equally spaced values of B, the outside minor semi-axis, are taken from $B_1 = R_1$ to $B_{10} = t$, the last value corresponding to the case where the section is completely flattened, and for each value the corresponding major semi-axis (A) is calculated using equation (3), together with the surface stress (S) using equation (2). A typical graph of stress (S) versus minor semiaxis (B) is shown in Figure 5, and the value of B corresponding to some required value of S can be computed by a method of interpolation, as follows:—

Suppose the required surface stress is S_r as shown on Figure 3, then the calculated values of B and S from 1 to 10 are tested in order until S exceeds S_r which occurs at point number 8. The values of B and S at points 7, 8 and 9 are then taken and used to calculate the coefficients of a quadratic equation describing the solid curve joining points 7, 8 and 9. In other words, over the small portion of the total function in which we

are interested, stress and the minor semi-axis are related by the equation:

$$B = L + M.S + N.S^2 \qquad (4)$$

where L, M and N are the calculated coefficients.

Thus by substituting S_r for S in equation (4), B_r, the required semi-axis, can be calculated.

The shafts of the invention have a novel shape and a degree of taper which is much greater than on any conventional tubular racket shaft, and the flexural rigidity of the shaft is therefore much less (i.e. the shaft is much more flexible).

The invention is further illustrated in the following Examples.

EXAMPLE I.

The shaft of this example was formed from a tube of circular cross-section and varying wall thickness and having a partially tapered shape as shown in column B. The dimensions shown in columns B and C are referred to positions indicated in column A measured along the shaft of the finished racket, from the end of the shaft which is sunk into the handle of the racket. Columns D and E give the external dimensions of the minor and major axes of the shaft at these same positions after it has been formed by the pressing operation.

	Tube		Formed Shaft	
A	B	C	D	E
Distance from end of Shaft	Diameter	Wall Thickness	Minor Axis	Major Axis
(in.)	(in.)	(in.)	(in.)	(in.)
0 — 2½*	0.290	0.0185	0.290	0.290
3½	0.290	0.0185	0.260	0.317
4½	0.289	0.0190	0.238	0.332
5½	0.281	0.0195	0.218	0.330
6½	0.273	0.0200	0.200	0.330
7½	0.265	0.0205	0.184	0.323
8½	0.257	0.0210	0.174	0.316
9½	0.250	0.0215	0.218	0.280
10½ —11½ $	0.250	0.0215	0.250	0.250

Note: Whole length indicated * is fixed inside racket handle
Whole length indicated $ is fixed inside racket head

EXAMPLE II.

The shaft of this example was formed from a parallel tube of circular cross-section of external diameter 0.260″ and uniform wall thickness of 0.20″. Again, dimensions are given in 5 columns headed A, B, C, D and E where columns D and E give the dimensions of the minor and major axes of the racket shaft produced after the pressing operation corresponding to the positions given in column A measured from the end of the shaft inserted inside the handle of the racket.

	Tube		Formed Shaft	
A	B	C	D	E
Distance from end of shaft	External Diameter	Wall Thickness	External Minor Axis	External Major Axis
(in.)	(in.)	(in.)	(in.)	(in.)
0 — 2½*	0.260	0.020	0.260	0.260
3½	0.260	0.020	0.238	0.280
4½	0.260	0.020	0.214	0.298
5½	0.260	0.020	0.196	0.310
6½	0.260	0.020	0.180	0.319
7½	0.260	0.020	0.164	0.327
8½	0.260	0.020	0.148	0.334
9½	0.260	0.020	0.196	0.310
10½ —11¼ $	0.260	0.020	0.260	0.260

Note: Whole length indicated * is fixed inside racket handle
Whole length indicated $ is fixed inside racket head

When either of the shafts described in Examples I and II above is incorporated into a badminton racket and when the racket is used in play, the stress at any point measured along the length of each shaft between the 2½ and 8½ values of A does not differ by more than 2% to the stress at any other position.

WHAT WE CLAIM IS:—

1. A games racket comprising a head, a handle and a tubular shaft connecting the head and the handle, the shaft having a portion which when viewed to show the section in the plane of the minor axis (as herein defined) is tapered towards the head, the amount of taper in said portion being such that the surface stress in the tapered portion in the plane of the minor axis when a load is applied to the centre of the racket head in a direction normal to the plane of the head is, at the narrower end of said tapered portion, in the range 80 to 110 per cent of its value at the wider end of said tapered portion, said tapered portion being of substantially elliptical transverse cross-section.

2. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is in the range 80 to 100 per cent of the surface stress at the wider end of said tapered portion.

3. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is not more than 10 per-cent different from that at the wider end of said tapered portion.

4. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is in the range 90 to 100 per cent of the surface stress at the wider end of said tapered portion.

5. A racket according to any one of the preceding claims, in which the taper of said tapered portion is non-uniform.

6. A racket according to Claim 5, wherein the non-uniform tapered portion is constituted by a series of steps.

7. A racket according to any of the preceding claims, in which the shaft is made of a fibre-reinforced plastics material.

8. A racket according to any one of Claims 1 to 6, in which the tubular shaft is of metal and said taper has been obtained by pressing a parellel tube of circular cross-section and uniform wall thickness.

A	Tube		Formed Shaft	
	B	C	D	E
Distance from end of shaft	External Diameter	Wall Thickness	External Minor Axis	External Major Axis
(in.)	(in.)	(in.)	(in.)	(in.)
0 — 2½*	0.260	0.020	0.260	0.260
3½	0.260	0.020	0.238	0.280
4½	0.260	0.020	0.214	0.298
5½	0.260	0.020	0.196	0.310
6½	0.260	0.020	0.180	0.319
7½	0.260	0.020	0.164	0.327
8½	0.260	0.020	0.148	0.334
9½	0.260	0.020	0.196	0.310
10⅛ —11¼ $	0.260	0.020	0.260	0.260

Note: Whole length indicated * is fixed inside racket handle
Whole length indicated $ is fixed inside racket head

When either of the shafts described in Examples I and II above is incorporated into a badminton racket and when the racket is used in play, the stress at any point measured along the length of each shaft between the 2½ and 8½ values of A does not differ by more than 2% to the stress at any other position.

WHAT WE CLAIM IS:—

1. A games racket comprising a head, a handle and a tubular shaft connecting the head and the handle, the shaft having a portion which when viewed to show the section in the plane of the minor axis (as herein defined) is tapered towards the head, the amount of taper in said portion being such that the surface stress in the tapered portion in the plane of the minor axis when a load is applied to the centre of the racket head in a direction normal to the plane of the head is, at the narrower end of said tapered portion, in the range 80 to 110 per cent of its value at the wider end of said tapered portion, said tapered portion being of substantially elliptical transverse cross-section.

2. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is in the range 80 to 100 per cent of the surface stress at the wider end of said tapered portion.

3. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is not more than 10 per-cent different from that at the wider end of said tapered portion.

4. A racket according to Claim 1, in which the amount of taper in said tapered portion is such that the surface stress at the narrower end of said tapered portion when the racket head is loaded is in the range 90 to 100 per cent of the surface stress at the wider end of said tapered portion.

5. A racket according to any one of the preceding claims, in which the taper of said tapered portion is non-uniform.

6. A racket according to Claim 5, wherein the non-uniform tapered portion is constituted by a series of steps.

7. A racket according to any of the preceding claims, in which the shaft is made of a fibre-reinforced plastics material.

8. A racket according to any one of Claims 1 to 6, in which the tubular shaft is of metal and said taper has been obtained by pressing a parellel tube of circular cross-section and uniform wall thickness.

9. A racket according to any one of Claims 1 to 6, in which the tubular shaft is of metal and said taper has been obtained by swaging an initially tapering tube, whereby the walls of the finished shaft appear substantially parallel in the plane of the racket head.

10. A racket according to any one of the preceding claims, in which the end portion of the shaft adjacent the head has an enlargement to facilitate securement of the head to the shaft.

11. A racket according to any one of the preceding claims, in which the shaft additionally has a taper towards the handle, whereby the width of the shaft is greater in the regions of the head and the handle than in between them.

12. A racket according to Claim 11, in which the two tapered portions of the shaft are connected by a portion having parallel sides.

13. A racket according to any one of the preceding claims, substantially as described herein.

14. A games racket substantially as described herein with reference to Example 1.

15. A games racket substantially as described herein with reference to Example 2.

16. A games racket according to Claim 1 which is a badminton racket.

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