HISTORY OF RACKETS AND STRINGS

Rackets for Tennis (or Lawn Tennis as it was originally called when first introduced in the 1870s) were developed from those used for Real or Royal Tennis played for centuries previously. These rackets were made from wood fashioned and glued into many variations of the now familiar key-hole shape. They were individually crafted in the early years and this led to a multiplicity of ideas regarding general form, strength, weight and stringing arrangements, many of which were covered by patents.

While racket frames were originally made mainly from ash because of its good specific strength, its toughness and its ability to be bent to the required shape, it was early recognised that metal tubing could also be used for the purpose but problems were experienced with the incompatibility of tensioned strings with the sharp edges of holes drilled in the tubing.

This was not a problem with wooden frames and successful metal frames had to wait until this was overcome and, importantly, until improved metal alloys were produced. The later development of composite frames became possible only because of the development of carbon fibre and associated manufacturing techniques in the 1960s.

Wooden Frames

Initially these were made from one or more sticks of ash bent to the required shape and glued with 'animal glues'. Mechanisation in the 1940's allowed a larger number of thinner 'veneers', bonded with urea-formaldehyde adhesives, to be used so that a multiplicity of layers could be incorporated which could be more easily bent to shape and so that the natural variability in wood could be 'averaged out'.

In addition to ash, other wood types including maple, sycamore and hornbeam have been used in the main frame member to provide desirable strength and stiffness properties; hickory, for wear resistance in the outer layer; beech and mahogany for throat and handle cosmetics and obeche as a lightweight filler in the shaft.

Over many years of evolution, the shape, size and resulting weight (a compromise to give satisfactory durability) became largely standardised across the industry and limiting parameters were not specified by the controlling authority, the ITF, until 1979, when the introduction of new materials made this necessary. The wooden tennis racket was manufactured in quantity until the early 1980's when metal and later composites took over.

Metal Frames

The problem of stringing metal rackets was not satisfactorily solved until a method was devised and patented by Lacoste in 1953[1] in which the racket strings were made to pass around metal wires looped to the frame. The result was the first commercially successful non-wood racket and this was subsequently marketed as the Wilson T2000 and successfully used by Jimmy Connors over many years, notably in winning the Wimbledon Singles title in 1974 and 1981.

The commercial success of this racket in the early 1970's encouraged competitors to develop other types – some based on hollow aluminium-alloy extrusions[2] and very stiff frames using carbon-steel[3]. The use of metal tubing determined that the racket frames invariably had twin shafts unlike the single shafted wooden frame. This meant that a 'bridge' member had to be incorporated between the shafts to complete the head loop which had to be welded-in but in some cases a plastic moulding positioned with screws was used for simplicity.

[1] Lacoste USP 3086777 (1961)
[2] US 3752478 (1971)
[3] Dunlop US 3909402 (1972)

Plastic 'grommets' were developed to insulate the strings from sharp hole edges and such developments together produced successful rackets which began to erode the market for wooden rackets. In the longer term, aluminium rather than steel rackets have been made in larger numbers because their simpler process of manufacture has made them commercially more competitive.

In the mid 70's, the increased stiffness and strength offered by metals led one manufacturer, Prince, to develop and patent a racket with a larger than normal or 'oversize' head[4] and this was subsequently followed by other manufacturers making rackets with a variety of head sizes. At that time, no limit on head size was specified by the ITF, but a limit was subsequently imposed in 1979. While this allowed the stringing area to be increased by up to around 100% compared with the standard wooden racket of the time, rackets of head size limited to some 30 to 50% larger have subsequently been favoured.

Composite Frames

The recognised success of metal rackets in the early 1970's led to experimentation with other non-traditional materials, particularly glass fibre and the newly developed carbon fibre (usually referred to as 'graphite' in the sports industry). Although very expensive, carbon fibre was preferred as it had greater specific stiffness and strength, in fact several times that of steel, and so offered significant prospects for further racket frame development.

Fibrous materials, by their nature, have uni-directional strength properties and so have to be used in a form where this can be properly utilised. This is done by alternatively weaving tows of fibres into a fabric which is subsequently impregnated with a thermo-setting 'epoxy' resin, or by using such a resin to coat fibre tows and aligning them to form a 'warp sheet' in which the resin holds the tows together in sheet form. Several sheets of the impregnated fabric and/or warp sheet (now termed a 'composite material') are then layered together with their tow alignments angled to provide subsequent multi-directional strength properties.

[4] Prince US 3999756 (1975)

The process of making a racket frame from such laminated sheet material involves forming it first into tubular form by rolling it around a plastic tube capable of subsequently being pressurised with air. Local areas are reinforced with extra material and the whole assembly is fitted into a mould of the appropriate shape and cross-section to form the main keyhole-shaped structure of the frame. An extra 'bridge' component is added of similar material to complete the loop of the head and the assembly is moulded under heat and applied internal air-pressure to cure and so harden the resin. This procedure[5] has been developed by many manufacturers to become recognised as the basic method for making composite racket frames. In some cases the internal pressurisation is obtained by the heat-expansion of a plastic-foam core[6] instead of pressurised air in an inflation tube.

While the manufacture of such a frame requires much handwork, one advantage is that specific areas of the frame can be individually strengthened, as noted above, prior to moulding. This allows just sufficient strength and stiffness to be created were necessary so that the overall structure is as light as possible. Metal rackets using uniform drawn or extruded metal tubing are at a disadvantage in this respect.

Many variations have been developed on the basic method described. One is where the tubular assembly is made up from a concentric assembly of tubular braids made with carbon fibre to which are assembled onto the inflation tube and then arranged in the mould. The mould is closed and the resin then injected prior to internal pressurisation and heating. Another is where the hollow tube is formed from two separate mouldings of 'C' cross-section are joined together by adhesive bonding to form the 'O' section of the tube.

Other variations involve using a thermoplastic matrix rather than a thermosetting type. One such method[7] involves combining thermoplastic filaments, usually nylon, with the carbon fibre filaments in the tows when using the tubular braiding method above. On heating and subsequent cooling, the nylon melts and fuses the carbon fibres together to form a rigid structure.

[5] US 3755037 (1971)
[6] Cecka et al US 4061520 (1976)
[7] Prince US 5176868 (1991)

A method based on a thermoplastic matrix departs radically from any of the foregoing. In this method[8], to reduce hand-work involved in manufacture, 'chopped' carbon fibres a few millimetres in length are mixed into a nylon matrix and the resulting compound injected into a mould the shape of a tennis racket where it solidifies. To form a hollow moulding, a 'core' of a fusible metal alloy is placed in the mould prior to injection and this becomes sheathed in the carbon fibre-reinforced nylon. The core is subsequently melted-out and a hollow frame results. This method, while used to produce rackets by Dunlop in the 10-year period 1980-1990 and successfully used to win Wimbledon Championships in this time, could not be adapted to make the larger headed, lighter frames subsequently becoming available using conventional manufacturing techniques[9].

In general, the use of carbon composites has allowed rackets to be made larger in head size, stiffer and lighter in weight than the most up-to-date wooden rackets of the 1980's. Larger heads allow larger 'sweet-spots' (i.e. a larger contact area where higher ball velocity can be developed) and better control of off-centre ball contact. Increased stiffness reduces energy absorbed by the frame on ball contact and so increases applied ball velocity. While light weight is not in itself an unconditional virtue, in combination with a larger head and greater stiffness the composite racket of today provides a player with distinct advantage over its wooden fore-runner. A current composite racket can have a 40% larger head, be 3 times stiffer and 30% lighter than the most highly developed wooden version.

To provide a variety of playing characteristics, rackets have been developed successfully with a variety of special features; for instance, with the ultimate in stiffness by grossly increasing shaft cross-section[10], with special combinations of weight, stiffness and balance[11] and by the incorporation of special shock and vibration absorbing elements[12]. As noted previously, the patent literature is full of ideas on different racket features, only a few of which have been referred to here.

Note: The above is a selection from the vast number of published tennis racket patents and are included to illustrate points made in the text above.

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[8] Dunlop GB 2015886 (1978)
[9] Head US 5766103 (1996)
[10] Kuebler US 4664380 (1985)
[11] Frolow US 4165071 (1976)
[12] Dunlop GB2243790 (1991)