Materials in Pole Vaulting

Pole vaulting is derived from the Dutch habit of dyke jumping, where men used long poles to cross canals. The first true pole vaulting stand was found in Germany and dates back to 1791 when the activity first became a competitive sport. Poles were originally made from solid hickory wood but it was found that bamboo was much lighter and more flexible and so for many years this became the norm. Players used bamboo poles with a sharp end which they pushed into the grass to vault over a pole and then landed on the grass again. In 1886 the Olympic record stood at 3.2m (10 feet 6 inches). As the height increased landing mats were introduced and nowadays athletes run up an all weather surface plant their pole into a box and land on a well padded area. By the 1960's the record had reached around 4.5 m and this increase was mainly due to a change in technique with athletes now going over the bar upside down. Then as carbon fibre poles were introduced the height jumped increased further with the record currently standing at 6.15m. Modern poles are constructed from layers of carbon and glass fibres embedded in a polymer (epoxy) resin. The fibres can be oriented to give maximum flexibility whilst maintaining sufficient strength.

During pole vaulting the kinetic energy produced by the athlete during the run-up is transformed into potential energy, which is stored by the pole as it bends. This stored energy is then released as the pole straightens and the athlete is propelled over the bar. Composite poles are an excellent choice as they do not loose much of the potential energy during bending and since the energy required to lift the vaulter depends on their weight the stiffness of the composite pole can be tailored to a specific person. Consider the example of an 80kg athlete running at 10m/s (this is equivalent to running 100m in 10s). If all of his kinetic energy is converted to potential energy then we can calculate the height he could jump (assuming the acceleration due to gravity $g=9.8ms^{-2}$):

$$\frac{1}{2}mv^2 = mgh$$

$$\frac{1}{2}v^2 = gh$$

$$h = \frac{v^2}{2g}$$

$$h = \frac{10^2}{2\times 9.8}$$

$$h = 5.1 metres$$

As the vaulters centre of gravity is 1m off the ground to start with this gives a jump height of 6.1m which is around wha athletes can achieve today.

Useful sources of information…

www.howstuffworks.com
'Good Vibrations – materials swing into action' by Mike Jenkins, Materials World, Vol 8, No 6, June 2000
'Game, set and match without the crunch' by Mark Bartlett, Materials World, Vol 8, No 6, June 2000

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Materials in Sport

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Materials in Sport

Advances in materials technology have greatly influenced the equipment used in sport over the centuries. In this modern age the limits of human performance have been reached and further improvements can only be made by developing the equipment used. The introduction of strong, lightweight materials has also allowed new sports and activities to be developed.

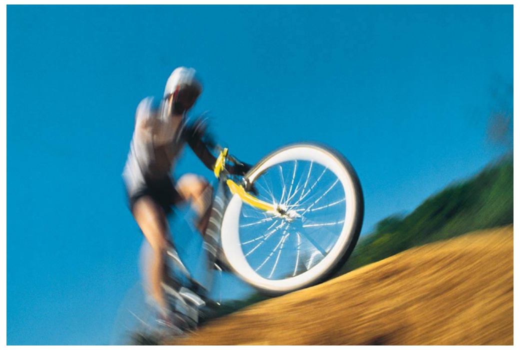
Not only have advances in materials had a great impact on professional sports men and women, but amateur players have also seen improvements in performance as a result of materials developments. A good example is in golf where it is now possible for the amateur players to achieve distances equal to those of the professionals. The introduction of oversized driver clubs made from lightweight materials (for example titanium), which have a large 'sweet spot' has given the amateur player a greater chance of hitting the ball accurately.

Materials have not only played an important role in sports equipment, they have also had a huge impact on sports venues. The introduction of steel and aluminium to sports stadium construction has allowed larger capacities to be accommodated whilst maintaining good visibility of the sports arena. The new National Stadium in Cardiff can be covered in bad weather and it is only through the introduction of lightweight materials that this could be achieved. In fact more steel is used in one sports stadium than is used per year to make bicycles.

Materials in Cycling

Ever since the wheel was invented 5000 years ago Man has been looking for new ways to move himself and other objects around more easily. The first two-wheeled device was shown in Paris in 1808 and it was developed and introduced in England as the Draisenne or Dandy-horse in 1818. This device essentially consisted of two wheels joined together by a wooden beam and it was propelled by the 'rider' striding along the ground. The addition of cranks in the 1840's allowed the cycle to be driven by the rider and the penny farthing was introduced in 1870. In the early days bicycles were made from wood and the ride was often very uncomfortable. The invention of pneumatic tyres in 1846 by Thomson (they were reinvented by Dunlop in 1888) and the introduction of iron in the 1860's allowed designs to be improved and the bicycle became a viable mode of transport for all. In the 1890's T I Reynolds started producing relatively lightweight frames from steel rather than iron, but after this few major advances in materials were made until after the Second World War when aluminium, titanium and composites were introduced. Modern day bicycles are made from a variety of materials but the design considerations (weight, stiffness, strength, aerodynamics, cost and safety) are essentially the same, it is only the relative importance of these which changes.

Most commercial cycles for everyday use are still made from steel and the grade varies from low carbon to low alloy to high strength steel depending on the cost and final use. The tubes for the conventional diamond shaped frame can either be made seamlessly by extrusion or by rolling followed by welding. In order to reduce the weight of the frame set the tubes are butted, which means they are thicker at the ends where more strength is required. The tubes are then joined by brazing or welding.



High performance cycling is a very competitive sport and new materials are continually being introduced to further improve performance. Different types of bicycles have different requirements, for example a road racing cycle will have different requirements to an off road bike which will have different requirements again to those for the speed racers used in the velodrome. A wide variety of more 'exotic' materials are now available for these applications.

- Aluminium is probably the closest competitor to steel as it is relatively cheap and easy to form. The density of aluminium is about one third of that of steel and even though the tubes have to be thicker to compensate for the lower strength, aluminium bikes are often quite light. Alloys from the 5000, 6000 and 7000 series are used.
- Titanium frames are stronger than aluminium and lighter than steel and this combined with the excellent corrosion and fatigue resistance makes this material an ideal choice for bicycles. However there are problems concerned with joining and machining as above 400°C titanium reacts with air. Originally Ti+6%Al+4%V was used but this has been replaced by Ti+3%Al+2.5%V as it is easier to form
- Magnesium alloys opened up a whole new world in bike building as it has an excellent strength to weight ratio. Magnesium can be extracted from sea water and it only takes 1.5m^3 of water to produce the 2kg of metal needed to build a bicycle frame. The alloy used is Mg+9%Al+1%Zn and this is heated to 650°C and die cast into a one piece frame. The main reason why magnesium bicycles are not more popular is the cost.
- Carbon fibre frames are made from carbon fibres laid down in the desired orientation fixed together using an epoxy resin. The frame is made in one piece using a mould made specifically to fit the size of the rider. The resulting frame is extremely light and stiff and the fibres can be oriented so that strengthening is achieved where it is required most. The main drawbacks of carbon fibre frames are the mode of failure (they snap without yielding), the material is very difficult to machine and join and the cost since the production process is both time and labour intensive. As a result carbon fibre bikes are only found at the top end of the market.

Materials in Tennis

Tennis is another sport with which we are all familiar and another sport in which materials have played a key role in improving performance. Tennis racquets were originally made from solid wood (ash, maple or okume) but the grain within the wood meant that the properties were anisotropic so laminate racquets were developed. The laminated structure allowed the stiffness and strength of the racquet to be improved in all directions and performance was significantly increased. Laminate racquets did have drawbacks however, as they warped as water was absorbed. In both cases natural gut strings were used.

Aluminium racquets were introduced in the 1970's and these offered increased stiffness and reduced mass. However the relatively poor fatigue resistance of aluminium meant that there was a marked drop off in properties after about 6000 hits and its low damping capacity had implications on the player's health (tennis elbow or lateral epicondylitis occurs when too much of the vibration from the racquet is transferred through to the player).

Modern racquets are made from carbon fibres embedded in an epoxy resin matrix and offer a considerable weight saving over both wooden and aluminium frames. The woven nature of the carbon fibres allows layers to be built up to give strength and stiffness where they are most needed. Most modern racquets also have an oversized head to increase the size of the sweet spot (the area where vibration is at a minimum) which further enhances performance.