DEMONSTRATE UNDERSTANDING OF MATERIAL DEVELOPMENT

How tennis rackets have been enhanced by the introduction of carbon fibre.

Introduction

This report contains information about the composite material of carbon fibre and how it has been used to develop and enhance tennis rackets, mainly the frame of the racket. Composites such as carbon fibre have become a leading innovation which has led to products being redesigned and developed to significantly improve the products performance. Initially, the first popular tennis racket introduced in the 1870s was made from wood, with a reasonably small head. Wilson introduced the first stainless-steel rackets, the T-2000 which was extremely popular. Larger headed aluminium frames were then introduced but wore due to fatigue which was an issue. Composites were soon to follow which strengthened the frame and therefore improved the products performance.

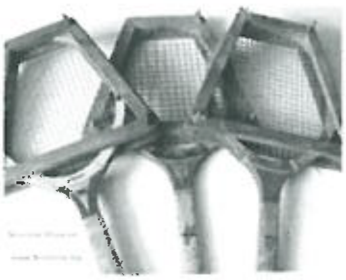
Definition

Carbon fibres are combined with other materials to form a composite. When combined with a plastic resin and wound or moulded it forms carbon-fibre-reinforced polymer (often referred to as carbon fibre) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle.
en.wikipedia.org/wiki/Carbon_fibers

A composite is a general term that has evolved to mean an article moulded from plastic material reinforced by strong fibre. The plastic material is known as the matrix or resin. There are several types of reinforcing fibre used in the manufacture of composite rackets. Glass fibre, or fiberglass, is inexpensive, heavy, relatively weak and rather flexible. Carbon fibre is more expensive, but lighter and stronger and also stiffer - in the sporting world it is known as graphite but this is not strictly accurate: true graphite comes in pencils and is used as a lubricant. Boron fibre is more expensive than carbon, but even lighter and stronger. Other substances which have limited use are Kevlar, which is used in making bullet-proof vests and of course in Kevlar racket strings in hybrid compositions, and ceramics, of which many varieties exist, all of them expensive.
All of these fibres are very strong, but they are threadlike in form, and consequently have to be bonded into a matrix in order to be used to make tennis rackets. Composites are much denser than wood, and a system which moulds a hollow racket had to be used in the manufacturing process. Two different methods have been developed to accomplish this-- compression moulding and injection moulding.

History

Tennis Rackets



As the theory goes, the game of tennis was created by 11th Century French monks who used their hands as rackets, making it more like handball than modern tennis. Gloves were introduced but still wasn't really tennis.

In 1874, Major Walter C. Wingfield registered his patent in London for the equipment and rules of an outdoor lawn tennis that is considered the first version of modern tennis. Within a year, Wingfield's equipment sets had been sold for use in Russia, India, Canada, and China. These rackets were made from wood fashioned and glued into many variations of the key-hole shape. The shape of the heads produced weren't quite as oval, with the head usually wider and often flattened toward the top. Rackets went through minor changes and development between 1874 and the end of the wooden racket era more than 100 years later. Improvements in laminating technology and strings improved the products performance but they still remained heavy (350-400grams) with small heads. Compared to the todays tennis rackets, even the best wood rackets were nowhere near as good and certainly lacking in power.

The first stainless steel frame made its debut in 1967 was the Wilson T-2000, an "absolute sensation" of a racket. Stronger and lighter than wood, it became a top seller. But by today's standards, the T-2000 was heavy, the head was tiny, and the coiled hooks at the edges made stringing it a chore.

In 1976, Howard Head, working with the Prince brand, introduced the first oversized racket that gained widespread popularity. These had aluminium frames and a string area more than 50% larger than the standard wood racket.

Advanced players needed a stiffer frame material. The recognised success of metal rackets in the 1970's led to experimentation with other non-traditional materials, particularly glass fibre and the newly developed carbon fibre. The best material proved to be a mixture of carbon fibres and a plastic resin to bind them together. Although very expensive, carbon fibre was the best option as it had greater stiffness and strength, several times stronger than steel, and allowed further development for the frame. Carbon Fibre remains the most common choice for stiff rackets, and the technology for adding stiffness without adding weight continues to improve. Over the years since, average racket weights have decreased to around 10.5 ounces, with some rackets as light as 7 ounces. This significant decrease in weight is due to the advancing of materials and processes.

Carbon Fibre

Tomas Edison created the first all-carbon filament in 1879. This was created by baking cotton threads and bamboo silvers. He used these carbon fibres as filaments for early light bulbs. Although these fibres lacked the tensile strength of today's carbon fibres, their tolerance to heat made these fibres ideal for conducting electricity. Inventors and scientists experimented with this concept for many of the years following Tomas' creation. More recently with Roger Bacon in 1958 and Dr. Akio Shindo in the early 1960s. Bacon created fibres that were manufactured by heating strands of rayon until they carbonized. This resulting in a composite that lacked carbon levels with only about 20% carbon, which caused it to be weak and lack stiffness. Dr. Shindo used polyacrylonitrile (PAN) as a raw material that resulted in a higher carbon level, about 55% carbon. This improved its strength and durability. In 1960 Richard Millington developed a process for producing a much high carbon content (99%) fibre using rayon. These carbon fibres had high elasticity and tensile strength and were used as reinforcement for composites having high strength to weight properties and for high temperature resistant applications.

The first major use of carbon fibre began in 1963 by W. Watt, L. N. Phillips and W. Johnson who developed and used carbon fibre in engines produced by Rolls-Royce. Within a few years, after successful use in 1968 of carbon-fibre fan assemblies, Rolls-Royce took advantage of the new material's properties to break into the American market with its RB-211 aero-engine with carbon-fibre compressor blades. The applications for this material soon grew significantly, with a main feature in the sporting field.

Classification of Carbon Fibres

Carbon fibres are classified by the tensile modulus of the fibre. Tensile modulus measures how much pulling force the fibre can handle without breaking. The English unit of measurement is pounds of force per square inch of cross-sectional area, or psi. Carbon fibres classified as "low modulus" have a tensile modulus below 34.8 million psi. Other classifications include "standard modulus," "intermediate modulus," "high modulus," and "ultrahigh modulus." Ultrahigh modulus carbon fibres have a tensile modulus of 72.5 - 145.0 million psi. Steel has a tensile modulus of about 29 million psi, the strongest carbon fibre is about five times stronger than steel. The term graphite fibre refers to certain ultrahigh modulus fibres made from petroleum pitch. These fibres have a three-dimensional crystal alignment internal structure that is characteristic of a pure form of carbon known as graphite.

Manufacturing

The first part of the production process is the design phase. Designers create 2D and 3D working drawings of the frame. 3D simulation software's are also used to understand that forces and strains on the racket when in use. This helps the designers to understand the model and further develop the designs. The racket designs have been made to maximise efficiency and to best suit the different types of players. After the concept design is finalised, a mould is produced from this design. Most of today's composite tennis rackets are made by compression moulding.

The matrix (the plastic material) is almost always epoxy resin, which is thermosetting, which means when heated it solidifies and can't be re-melted. The long fibres are coated with epoxy and placed in the mould, which is then closed and heated. To make the racket hollow, internal pressure is created by inflating an inner tube. In the construction of the racket, normal percentages of materials are matrix [resin] 40 per cent and fibres 60 per cent. A mixture of fibres is often used so that a racket may not be too expensive - a common example would be matrix 40 per cent, carbon fibre 30 per cent, and glass fibre 30 per cent. A racket in which all of the fibres are carbon is known as 100 per cent graphite, and, although this is not strictly true (since the 40 per cent that is made up of matrix is not carbon fibre), it is generally accepted for most trading purposes.

The composite tube is then placed into the racket-shaped mould. Then the mould is heated, and air pumped into the internal tube. The pressure of the air in the tube, along with the heat, bonds the layers.

Workers remove the rackets from the moulds and begin inspection. This is where any defective ones are identified and removed. The end of the frame is cut, and then the rackets are placed in a drilling machine and the string holes are drilled. After drilling, the rackets are brushed with a polymer coating and placed in a dryer. This step is repeated several times, and then the rackets are sanded, followed by the final coating.

The next steps involve a grommet strip and yoke that are fixed in the grooves on the frame, and workers string the rackets on stringing machines. Butt caps are inserted in the bottom, and then apply tape and grip tape around the handle. Concept rackets are tested. For production line rackets, logos are put on the strings and the frame, packaged, and sent away to a warehouse or retailers.

Design and Development

In general, the use of carbon composites has allowed rackets to be made larger in head size, stiffer and lighter in weight. Larger heads allow larger sweet-spots (a larger contact area where higher ball velocity can be developed) and better control of off-centre ball contact.

All tennis rackets are made of strings and a frame. When a ball hits a racket's strings, they deflect, absorbing some of the ball's kinetic energy. These strings are elastic. On rebound, they transmit almost all of their absorbed kinetic energy back to the ball. Therefore, more elastic, looser strings return more power to a tennis ball than tighter strings. To support their strings' elasticity, however, racket frames must be inelastic. Although people used to think that flexible rackets could produce more power through a whip effect, research has shown that rackets do not have time to return absorbed kinetic energy to the ball. Hence, rackets that deflect less, or are stiffer, tend to be more powerful. This research and theoretical development aided the development of the racket.

Wooden Frames

The racket frames were initially made of ash that was bent to the required shape and glued with 'animal glues'. Development due to mechanisation in the 1940's allowed a larger number of thinner layers bonded with urea-formaldehyde adhesives, to be used so that more 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.

Most rackets had dimensions of 68.6 × 22.9 cm, which was limited due to the stress limits of the wood used. Wood was not strong enough which means increasing the head size was not possible with wood, as the stress limits would have been exceeded, leading to warping. This meant the size of the head was limited and therefore had a reasonably small contact area for the ball. The sweet spot was also limited due to this.

Another issue with the wooden frames is the mass of the material. Wood is considerably dense compared to modern composite materials. The wooden racket mass was approximately 400 g, which has decrease with composites to around 250 g today, despite being larger in size.

Despite being large in mass, wooden rackets aren't stiff enough to provide optimal results. They slightly deform, and so more ball energy is consumed in bending the racket.

Steel Frames

The age of metal, and technological advance, had come to tennis. In 1967 Wilson introduced the T2000, the first steel racket. Steel rackets were produced before then but weren't popular. It was a revolution in modern tennis but the T-2000 was heavy, the head was tiny, and the coiled hooks at the edges made stringing it a chore.

Aluminium Frames

The next jump in tennis racket technologies came in 1975, and was the introduction of aluminium, this material was lighter than steel and allowed the construction of oversized tennis rackets. Now players could hit with more spin or slice on the ball thanks to their 100+ in sq head sizes.

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' heads 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 International Tennis Federation, 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

Composite materials have become huge in the sporting industry, having higher tensile strength than steel while being lighter, it became extremely popular. To improve this, a tennis racket with a stiffer frame which was made from graphite or graphite composites was introduced with the incorporation of titanium and fiberglass which added stiffness and flexibility to a racket without adding weight.
A heavier frame allows the player to generate more power but with reduced control.
A heavier frame vibrates less reducing the risks of injuries.
A heavier frame has a larger sweet spot.
A stiffer frame generates more power.
A stiffer frame has a larger sweet spot.
A stiffer frame transmits more of the shock load to the arm than a more flexible frame.
A stiffer frame provides a more uniform ball response across the entire string plane.
A larger frame generates more power.
A larger frame is more resistant to twisting.
A larger frame has a larger sweet spot.

NZQA Assessed

In tennis, carbon fibre frames are much stiffer than the previous rackets. This reduces energy absorbed by the frame on ball contact and so increases applied ball velocity, therefore improving the performance of the product. Light weight in combination with a larger head and greater stiffness, the composite racket today provides a player with huge advantage over other wooden rackets. A current composite racket can have a 40% larger head, be 3 times stiffer and 30% lighter than the most highly developed wooden versions which are a significant improvements. It is possible to make lighter rackets but this wouldn't be helpful as the transfer of momentum to the ball becomes less effective if the racket is too light.

The decrease in mass has the important spin off that players are able to swing the racket faster, which generates higher impact speeds, resulting in faster ball speeds. Swing speeds are also a function of the distribution of mass: for any given racket mass, placing more of that mass close to the handle of the racket will allow it to be swung more rapidly. Conversely, if more of the mass is close to the tip of the racket, it will be harder to swing. It has been shown that a moment of inertia is inversely related to swing speed. By being wider, modern rackets have more resistance of the racket to rotating about its long axis, which makes them better for off centre hits. These changes have helped novice players to be more successful more quickly.

Although heavier rackets will produce faster ball speeds, if the racket is lighter, it can be swung faster, which more than makes up for the loss of mass. There are a large variety of different weighted frames. Given that faster shots are less likely to be returned than slower ones, players tend to hit the ball as hard as possible. Thus rackets of the same mass as wooden ones are no longer made.

To provide a variety of playing characteristics for different users, rackets have been developed with many special features; for example, ultimate stiffness by increasing shaft cross-section, special combinations of weight, stiffness and balance and by the incorporation of special shock and vibration absorbing elements, all of which have been developed, tested and critiqued.

Despite being lighter, modern rackets are also much stiffer than wooden ones. As a result, they deform less, and so less ball energy is consumed in bending the racket. Even the stiffest racket will bend to a certain extent, and there is a theoretical relation between stiffness and ball speed. When the ball leaves the strings, the racket head velocity will affect its speed. Old wooden rackets vibrate at about 90 Hz, whereas modern rackets can be made to vibrate at frequencies up to 200 Hz which is more ideal for the 5-6 millisecond contact time.

It is obvious when watching any tennis match that the game is based on power. The faster a player can hit the ball, the less likely it is that the opponent will return it. A faster ball will tend to travel further than a slower one, so players have to use a lot of topspin to keep the ball in play. Due to the larger and lighter rackets, topspin is more easily applied on modern rackets, which has majorly contributed to today's playing style.

The development of carbon fibre as the material in the product of the racket has significantly improved the product performance and has improved the game itself to by making it faster and more entertaining. Developments in carbon fibre have also allowed improvements in the product. The original carbon fibre wouldn't have worked with this product as it was not stiff enough for the forces on the racket. As carbon fibre developed becoming stronger, lighter and cheaper, the more it was considered in the sporting field. Different mixtures of fibres, processes and glues have been developed to optimise the material to suit sporting products including tennis rackets.

Improvements are also due to advancements in technology. Rackets are now being designed by laboratory scientists who use mathematics to calculate the effects of weight, size, and material changes. New rackets are also being made with computer-aided design (CAD) and computer-aided manufacturing (CAM), which allows precise calculation of material rigidity and centre of gravity. As such advanced science is being lavished on the tennis racket; doubtless new models with eccentric features will continue to be developed. The trend today is toward lighter, bigger rackets, and these are viable because of advanced materials engineering.

Issues

Although modern racket technology has produced many positive effects, it is arguable that injury rates have increased as a result. Anecdotal evidence suggests that the vast majority of upper limb injuries are chronic, having been developed over time through repetition. Although research evidence has yet to be produced, it is not unreasonable to suggest that the trend for increased power is responsible for the increased number of injuries seen in today's game. There is little evidence of acute injury to tennis players. Increased stiffness in modern rackets means the racket vibrates faster, which has been linked with tennis elbow. Although a larger head size allows off centre hits that are further from the central axis of the racket to be successful, they also generate a higher torque (twisting force) of the racket in the hand. This torque must be resisted by the forearm muscles, which are eccentrically loaded. This has been proposed as a cause of micro-trauma to the extensor muscles of the wrist, which is a possible cause of tennis elbow. By allowing the racket to be swung faster, the decrease in mass generates greater shock to the hand for impacts that are not at the centre of percussion. On the basis of a review of biomechanical evidence, it has been concluded that shock is the most likely cause of tennis elbow.

Development in the Production of Carbon Fibre

The cost of making carbon fibers has been reduced drastically in the last 20 years, and researchers are bringing that cost down every day. As they do, many of the applications once considered impossible will become reality. Carbon fibre is used sparingly, mainly due to the cost. Now most modern tennis rackets are made of carbon fibre. The carbon fibre itself has developed over the last few decades resulting in high quality products. Since the late 1970s, further types of carbon fibre yarn entered the global market, offering higher tensile strength and higher elastic modulus. Scientists experiment with different ratios of fibres and new materials to create new composites, each unique material having different characteristics. With this development, we have stronger, lighter, cheaper versions of carbon fibre. With the higher strength composites, there are fewer restrictions within the design and therefore more flexible designs are possible.

Continuous fibres can be woven into a variety of weave styles, giving increased control of the racket's characteristics. For example, unidirectional fibres are incorporated along the main racket axis for high bending stiffness, and 0/90° weaves are stacked at ±45° for high shear strength and stiffness. A variety of fibre grades are used, each with different levels of strength and stiffness. These fibres are coupled with epoxy resin matrices that often contain one or more property modifiers, such as rubber particles and thermoplastics that increase the toughness of the resin.

Production methods have improved resulting in higher quality outcomes. Now the raw materials are stored in the ideal temperature to ensure a long life. The environment is also kept extremely clean to keep particles out of the composites that would otherwise affect its strength. Small changes to these conditions will affect the outcome.

Future - The next step in the evolution of the tennis racket may be the inclusion of piezoelectric materials that are capable of controlling the frame vibration. This movement will help stop the 'tennis elbow' condition which will be a large step for the sport. Advances in the technology used in skiing have already led to piezoelectric materials being attached to the surface of skis. The piezoelectric plates have a damping effect by converting the mechanical vibrations into electrical energy that is dissipated through a shunt circuit. A future possibility may be the conversion of the passive configuration to an active form in which the vibrations in the frame are sensed and then cancelled by inverting the electrical signal applied to piezoelectric actuators sited in the handle. It could even be this technology that finally leads to the end of tennis elbow.

Maintenance and Preservation

Carbon fibre rolls have to be stored in a freezer room at -16 degrees so they can keep their flexibility and not affect the quality of the material when making the product. Once the rackets are produced, they are easy to maintain in reasonable conditions. The extreme heat and cold make quick work of the frame and strings. Extreme heat causes the fibres in the racket to soften. Together with the soft graphite and the constant pressure caused by the strings, the racket will begin to warp. As for the strings, heat causes the strings to stretch and lose tension, and the extreme cold causes the strings to become brittle and hard. Hitting with a racket that has been in deep freeze will cause issues in vibration and contribute to tennis elbow. Cleaning carbon fibre is best with non-abrasive cleaning products so the fibres aren't exposed to oxygen, water and other chemicals that could damage the material.

Performance rackets made with a composite of graphite fibres are actually quite sensitive. Every extreme impact breaks the fibres down, even if you can't see any damage. Too many knocks on the concrete floor or iron net posts and you'll soon be buying a new racket.

Disposal

Carbon fibre is difficult to recycle. By its very nature it is neither biodegradable nor photodegradable. It is simply a product designed to last. For the user that's good news. That means that frame will last for a while, only replacing strings after they lose their touch. Carbon fibre of products such as aircrafts will endure years of changes in pressure, temperature and other extreme conditions. In the case of large aircraft small cracks, dings and scratches can be repaired and the structural integrity maintained. The same cannot be said for many sporting products, like tennis rackets and other products that take advantage of carbon fibre. Due to the precision in design, weight and material distribution, repairing the crack or dent will affect the performance. Most of the time, the racket is too damaged to repair anyway. The falling price of the material makes it easier just to replace it. The result is that a product that doesn´t biodegrade could be going to a landfill, where it could take hundreds of years or longer to break down.

Carbon fibre is not easy to recycle. To recycle carbon fibre it is cut down into one inch strips. These cannot be reused in the place of the original carbon fibre as it wouldn´t have the strength or rigidity necessary for most products. Instead carbon fibre is cut down into the strips and melted, where it can be transformed into a thermoplastic. This has benefits, and some recycling efforts are turning the recycled carbon fibre into phone cases, laptop shells or even water bottle cages for bicycles. Recycling really needs to be cost effective to make it worth the time, effort and most importantly the energy used. And with carbon fibre it hasn´t reached the levels of which it is more effective to recycle than to reproduce.

Conclusion

Every aspect of a racket influences where the ball ends up when playing tennis. Tennis rackets have come a long way in the production, design and materials used in producing each racket. The advancements in materials has allowed more complex analysis and production methods to produced precise rackets to suit the best players, every player in reality. Carbon fibre has impacted and revolutionised how the rackets are made and had a huge impact on the performance of the product as well as the game in general. It's obvious that carbon fibre is the best for the performance of the product, much better than wood, steel and aluminium due to its light weight, strength and stiffness. Would the game be as fast and exciting without these rackets? The players wouldn't be able to perform at the level they are currently playing without this new innovative material. Carbon fibre has enhanced and revolutionised all aspects of the racket making it light weight, stiff, and more durable improving the level of the game.

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Grade Excellence

Context Tennis/Sport

Material Carbon fibre

Enhancement weight and racket speed

Product Tennis Racket

Assessment Schedule. AS91613 **VERSION 3 annotated 2016** **Demonstrate understanding of material development**		
Commentary This candidate structured a clear report addressing the criteria with a bibliography outlining references used. The material (carbon fibre) was clearly defined, described in its historic context and that of the Tennis sporting arena. The candidate makes clear the impact of the material development on the design, development and implementation if the product (the racket) and the interaction between the racket and the human performance, for example, racket head speed, lightness and relationship to increased power and the structure of the racket. The implementation of the racket using CAD, CAM resources and the impact of composites in this part of the racket production demonstrated the candidates understanding of the implications of stages and resources in development, for example the precision required to get the centre of gravity of the racket and the rigidity factors exact to enhance the racket's performance. The maintenance and disposal of the material and implications on the racket were also explained demonstrating understanding of the implications if using greater amounts of composite materials on landfill and the economics of reusing and recycling materials .		
Issues from the Specifications • Where a candidate has provided a brief answer, the answer should not be penalised because of length. • Candidate work in excess of 10 pages must not be marked. • Where a candidate has used a small font markers should make a judgement about where to stop marking. This judgement should be made relative to 10 pages at Arial font • Where work is illegible, it cannot be marked. • Digital submissions that cannot be read cannot be marked. • Material must be referenced to acknowledge original sources, texts, URLs and websites		
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Demonstrating understanding of material development involves.	Demonstrating in-depth understanding of material development involves.	Demonstrating comprehensive understanding of material development involves.
describing the **development of a material designed to enhance** a product's performance describing the **implications of the material** on the design, development, implementation, maintenance, and disposal of products. **MEP** A **Material** must be specified and its **development** must be evident- considering such things as historical and or technical aspects and properties; manipulation, transformation, formulation of the material(s) The **enhancement** must be identified in relation to a specified product (product specified) for example washability, durability, strength, speed enhancement, viscosity The Material must be described in its relationship to and impact on the design, development, production , on-going maintenance and disposal of the **product**	explaining how the **material enhanced the performance of a product** explaining how the **material impacts** on the design, development, implementation, maintenance, and disposal of **products.** As for achievement plus Explain (give detail , example and reason) how Material interacts with the product to enhance the performance of the product Explain how the material impacts on (influences the choices relating to) design production maintenance and disposal of product(s)	explaining the **concepts and processes e**mployed in the **development of a material.** As for achieved and merit plus Explaining (detail of description with example and reasoning) the concepts and processes used in the development of the material Development, processes such as raw material to refined material and its development and enhancements

Technology AS91613 Schedule Appendix 1

<table>
<tr><td colspan="2">Markers must exercise professional judgement to decide if a report demonstrates understanding. The following appendix provides guidance for markers making this judgement.
A report must use information to demonstrate understanding.
Reports described wholly or substantially by one or more of the statements in the left column demonstrate understanding.
Reports described wholly, or substantially, by one or more of the statements in the right column do not demonstrate understanding.</td></tr>
<tr><td colspan="2">Where the report is made up of both used and reproduced information the marker must decide if the report is successful against the standard when the reproduced information is ignored.</td></tr>
<tr><td>Evidence of use of information(understanding)</td><td>Evidence of reproduction of information (copy and paste/plagiarism)</td></tr>
<tr><td>Candidate’s report describes and explains the Material development related to their context practice, or information relating to the standard</td><td rowspan="2">Information is unrelated to the context, unreferenced and is not relative to the understandings expected at NZC Level 8
Downloaded material that is not mediated, interpreted or synthesised is not acceptable as this does not show understanding of the concepts related to the development of a material or the material’s relationship with product design, development, implementation, maintenance, and disposal
• Comparing various materials for their use in a product or comparison of various products is not part of this standard</td></tr>
<tr><td>Information from the candidate’s practice, research, the practice of others, and teaching is related to the development of a material and then in relation to products..
The report describes understandings you would expect to come from a course of instruction derived from the Technology Learning area of the NZC at Level 8.
These could include but are not limited to
• The context of the products’ development links to the material development and the implications of the material on the design, development, implementation, maintenance, and disposal of products.
• Describe/ explain the material, the product and the enhancement
• Candidates begin with the development and processing of a material and then moved to link to the product development and implications of the material on the design, development, implementation, maintenance, and disposal of products
• Explanations should have detailed description plus how and/or why statements to give reasons
• Information is presented in alignment to context of study and is referenced appropriately and is relevant to the context at level 8 of the New Zealand curriculum
• the design, development, implementation, maintenance, and disposal of products the product in relation to the ,material under review must be part of the candidate description/explanation (some products may not have all parts of this due to the nature of the product but this should be addressed in the report)
• Products may include existing or feasible future products. In the case of feasible future products, the candidate must have covered the range of implications of the material within the context of the future focused product.</td></tr>
<tr><td>Information from research, the practice of others, visiting experts or teaching is reported in the candidate’s own voice to enhance their understandings. Information synthesised from a range of credible evidence and sources is synthesised in a coherent report</td><td>Information is not in the candidate’s voice. The word choice, sentence structure, sentence length, punctuation and so on are not what a candidate could be expected to produce.
However, care must be taken where students have synthesised material to a high degree and presented an articulate report</td></tr>
<tr><td>Referenced, complex research information unchanged by paraphrase (ie use of quotations) is related to other information in a manner that constructs meaning within the context.
Use of credible evidence (not reliant on Wikipedia or wise geek as a sole reference)</td><td>Unreferenced, complex, research information is presented as though it is the candidate’s own work. Plagiarism evident</td></tr>
<tr><td colspan="2">Where the marker suspects a report is a deliberate attempt to deceive the report should be referred to the panel leader using the Irregular Booklet process.</td></tr>
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