METALS

Aluminium Alloys

Overview

In the bicycle industry aluminium alloys are often simply referred to as 'alloy'. Pure aluminium is quite soft and ductile. It is alloyed with small amounts of copper, manganese, silicon, magnesium and zinc to improve hardness and durability. It has good strength to weight; the same strength can be achieved with roughly half the weight of aluminium as of steel.

Properties

Aluminium alloys are designated with a four number code to indicate the type and amount of alloying elements: 1XXX is almost pure aluminium; 2XXX contains copper; 3XXX contains manganese; 4XXX contains silicon; 5XXX contains magnesium; 6XXX contains magnesium and silicon (these medium strength alloys are often the material of choice for bicycle frames); and 7XXX contains zinc. Each of these alloying elements produce different levels of strength, corrosion resistance, conductivity and workability.

In the presence of oxygen the surface reacts to form a protective oxide layer, which makes it almost maintenance free, although it can affect the appearance of brightly polished metal. The protective layer is enhanced and can be coloured with the anodising process. The surface of aluminium alloy can be polished to produce a very bright and highly reflective finish.

Extracting aluminium from bauxite is an energy intensive process. It takes roughly 3 kg of bauxite to produce 0.5 kg of aluminium. This is why it is so efficient to recycle aluminium rather than extract if from new bauxite.

Processing

Aluminium alloys are shaped by panel beating, metal spinning, metal stamping, deep drawing, superforming, forging, tube and section bending, casting, press braking and extrusion.

Aluminium alloys can be joined by certain arc welding processes (MIG and TIG), power beam welding (laser and electron beam), mechanical fixings (threads or rivets) and adhesive bonding. TIG welding is suitable for very thin materials and precise and intricate work. Whereas MIG welding is limited to materials between 1 mm and 5 mm.

Suitable finishing processes include anodising, spray painting, grinding, sanding, polishing and printing. Certain aluminium alloys are suitable for heat treatment. This is the process of controlled heating and cooling, and is used to produce either hard and brittle, or ductile and tough metals. A suffix – F, O, H or T – is added to the end of the four digit material identification code to indicate the type of heat treatment.

Relevant Applications

Bike Frames

Aluminium alloys are popular materials used in the construction of mass produced bike frames. Bicycle frames have to cope with high flexural load. High strength aluminium alloys tend to have low fatigue strength. As a result, aluminium alloy frames are made from thicker section tube (2–3 mm) than steel equivalents to reduce deflection and fatigue and so are not much lighter. Increased stiffness means that aluminium frame bikes tend to feel stiffer to ride.

Bike Locks

Aluminium alloys have low sheer strength and so are not usually suitable for bike lock applications that have to withstand cutting, breaking and impact.

Magnesium Alloys

Overview

Magnesium has greater strength to weight than aluminium. However, it is more expensive, because the extraction process is energy intensive and costly. In the past it has been widely used in the production of bicycle components. Recently, bike frame manufacturers have begun to utilise its lightness, strength and durability in bespoke bike frame construction.

Properties

Magnesium is lightweight and strong. It is often alloyed with aluminium and zinc to improve its performance in specific forming applications and improve strength and resilience. Magnesium alloys are particularly susceptible to stress cracking, so sharp corners and notches should be designed out to avoid stress concentrations and potential stress cracking.
Magnesium is explosive in powdered form – it has a bright flame and is used for pyrotechnics and flares. The surface of magnesium tarnishes easily, and is corroded by saline and acidic solutions.

Processing

Magnesium alloys can be formed by metal spinning, superforming, casting, extrusion and are very easy to machine. Parts can be joined by certain arc welding processes (MIG and TIG), mechanical fixings (threads or rivets) and adhesive bonding. Typically, metal bike frames are constructed from tubular sections. Recent designs utilising cast, as opposed to extruded, magnesium sections have emerged that have the potential to redefine bike frame engineering. The surface of magnesium alloys are generally coated to reduce corrosion. Suitable processes include powder coating, spray painting and metal plating.

Relevant Applications

Bike Frames

Magnesium alloys have very good mechanical dampening and high strength to weight. Dampening is the measure of a material's ability to absorb vibration. Magnesium alloys have been used in a small number of bespoke bicycle frames, but due to the high cost and reactive nature of the material applications are limited.

Steel

Overview

These are the most common metals and can be found in many industrial and domestic applications. The specific properties of each type are determined by the carbon content and alloys. There are four main groups of steels: carbon steels; stainless steels; low alloy steels; and tool steels. Prices range according to the type of steel. Carbon steels are the least expensive, followed by low alloy steels and stainless steels. Tools steels are the most expensive.

Properties

Carbon Steels

Carbon steels have a low, medium or high carbon content, ranging from approximately 0.2–2%. Higher carbon content produces a harder, less ductile and more brittle material. Mild steel (plain carbon steel) is a term that covers a range of carbon steels up to 0.25% carbon content. They are distinguished by ease of solid state forming and welding. Carbon steels are prone to oxidisation and corrosion, so are protected with a coating of some form.

Low carbon steels are relatively ductile, malleable and easy to shape. In contrast, high carbon steels are hard and as a consequence they are both resistance to abrasion and more brittle. Medium carbon steels have levels of carbon and alloys that are ideal for hardening by heat treatment.

Steels are classified as ferrous metals because they contain iron. Certain ferrous metals are prone to corrosion. In the presence of oxygen and water the iron reacts to form a layer of iron oxide, commonly known as rust. This is a degradation process that gradually consumes metal that contains iron form the outside inwards. Protective coatings are applied and must be maintained to prevent corrosion.

Low Alloy Steels

Low alloy steels are made up of iron, carbon and up to approximately 10% of other metals, such as chromium, molybdenum and nickel. The additional alloys are used to improve certain properties of the steel such as resistance to corrosion, formability and toughness. Certain high performance grades of these materials are also referred to as high strength low alloy steels (HSLA), which are commonly used in bike locks and other similarly demanding applications.

Cor-ten is a low allow steel that eliminates the need for a protective coating. The material develops a protective oxidised layer (rust) that prevents further corrosion of the metal.

Stainless Steels

Stainless steels are a group of alloy steels that contain iron, less than 1% carbon, 10% chromium or more and other alloys. The high levels of chromium result in very good resistance to corrosion. There are four main types, which are austenitic, ferritic, martensitic and precipitation hardening. Austenitic grades are ductile, strong and non-magnetic; ferritic grades are less strong, magnetic and generally used for indoor and decorative applications; martensitic grades are the hardest but least resistant to corrosion; and precipitation hardening are high strength and have moderate resistance to corrosion.

Stainless steels are less prone to corrosion than other grades due to the high chromium content. Electropolishing enriches the layer of the chromium on the surface of the metal, which improves brightness and resistance to corrosion.

Tool Steels

Tool steels are so called because they are used for cutting tools and dies. The carbon and alloy content make them very hard, tough and resistant to abrasion.

Processing

Steels are shaped using a wide range of processes including casting, extrusion, metal stamping, metal spinning, deep drawing, forging, press braking and tube and section bending.

Suitable joining processes include arc welding (MMA, MIG and TIG), power beam welding (laser and electron beam), mechanical fixings (threads or rivets) and adhesive bonding.

Protective coatings are applied and must be maintained to prevent corrosion on the surface of certain types of steel. Stainless steels are the most resistant to corrosion - electropolishing produces a chromium rich surface with improves the material's resistance to corrosion. Suitable protective finishing processes include galvanizing, powder coating, spray painting and polishing.

Relevant Applications

Bike Frames

Carbon steels are still used to mass-produced bike frames in the low to medium price range. Low alloy steels (in particular chromium molybdenum and manganese molybdenum) have superior properties, such as improved strength to weight, resistance to corrosion and resilience, and are used in the construction of high performance bike frames.

Bike Locks

HSLA steels are strong, resilient and durable. Bike lock manufacturers utilise these properties in both the chains and locks. The properties of these metals are further improved by heat treatment (often referred to as hardening), which greatly improves the steel's resistance to shearing and breaking on impact. This is the process of heating up the steel and cooling it at different rates to form different microstructures. Typical alloying elements include boron, manganese, chromium and molybdenum.

Bike Furniture

The majority of metal street furniture is manufactured from carbon steel, because it is inexpensive, versatile and durable. It is essential that a suitable and protective coating is applied and maintained to ensure the longevity of parts.

Titanium Alloys

Overview

Titanium alloys are very lightweight and up to twice as strong as aluminium alloys. However, even through titanium is an abundant material, it is more energy intensive to produce than aluminium and so is more expensive. Even so, applications in the bicycle industry are expanding – such as frames and components – due to its superior properties.

Properties

Titanium alloys have superior resistance to corrosion, especially to salt water and certain chemicals. Like aluminium, titanium is protected by a naturally occurring oxide that forms on its surface. Anodising thickens the layer and increases protection. The anodised surface can be dyed with a range of vivid colours.
Titanium is non-toxic and so is used for medical implants such as bone and joint replacement and strengthening or dental implants.

Processing

Titanium is reactive with oxygen at high temperature so casting is carried out in a vacuum or inert atmosphere. Low temperature processes, such as metal spinning and metal stamping, can be carried out in normal atmospheric conditions, so titanium alloys can be processed with similar ease to aluminium alloys. It is also suitable for superforming and extrusion.

TIG welding, friction welding and adhesive bonding are all suitable for joining titanium alloy sections. TIG welding is particularly suited to very thin materials and precise and intricate work. Titanium parts are typically finished by anodising to keep the weight to a minimum. It can also be spray painted and printed.

Relevant Applications

Bike Frames

Titanium alloys are resilient, lightweight and very strong, which makes them an ideal material for bike frames. However, titanium is an expensive material and TIG welding is time consuming and requires a highly skilled operator, which means titanium bike frames tend to be very costly.
It is possible to manufacture titanium alloy bike frames that are much lighter than steel equivalents (up to 50%). Titanium alloy frames are typically produced with large diameter thin-walled tubing to reduce flexibility.

Bike Locks

So far, titanium alloys have not proved to be cost effective for mass produced bike locks.

ENGINEERING THERMOPLASTICS

Overview

Engineering thermoplastics are suitable for a range of demanding and high performance applications that are traditionally associated with metals. The most widely used of this group of materials includes acrylonitrile butadiene styrene (ABS), polyamide (PA) also known as nylon, polycarbonate (PC), polyoxymethylene (POM) also known as acetal, and thermoplastic polyester (PET).

Properties

ABS is a relatively low cost material. It has high impact resistance, toughness, superior chemical resistance and temperature resistance. It is produced in a range of vivid colours and it is possible to mould a high gloss surface. ABS is used for a range of applications including housings for power tools, telephones, computers and medical equipment.

Processing

The advantage of thermoplastics is the ease with which they can be injection moulded. Off cuts and scrap can be reprocessed with virgin material without a significant effect on the properties of the material. Acetal and nylon are also suitable for machining. Thermoplastics can be applied as an overmoulding (by injection moulding) onto metal components, such as bike locks, to provide a contoured and ergonomic outer surface.
There are a range of suitable joining processes including welding (ultrasonic and hot plate), mechanical fixings (threads or rivets) and adhesive bonding.
A major advantage of plastics is that they can be removed from the mould finished, and so do not require any additional finishing. Suitable processes for post-mould finishing include spray painting, metal plating and printing.

Relevant Applications

Bike Locks

These engineering thermoplastics are tough and resistant to impact, which makes them suitable materials for certain parts of bike locks. They can be cut through and so are often overmoulded (by injection moulding) onto suitably tough metal components or combined with metal fibres.

Overview

Engineering thermoplastics are suitable for a range of demanding and high performance applications that are traditionally associated with metals. The most widely used of this group of materials includes acrylonitrile butadiene styrene (ABS), polyamide (PA) also known as nylon, polycarbonate (PC), polyoxymethylene (POM) also known as acetal, and thermoplastic polyester (PET).

Properties

PA (Nylon), commonly known as nylon, is a versatile material used in a wide range of applications. Aromatic polyamides are stronger than steel for their weight. There are many different grades of nylon, which are categorised as follows: nylon 6; nylon 6.6; nylon 6.12; amorphous nylon (transparent); and high temperature nylon. These grades can be modified in a number of different ways to produce reinforced, flame retardant, tough and super-tough versions. Nylon is self lubricating, has a low coefficient of friction, and has good resistance to abrasion and chemicals.

Processing

The advantage of thermoplastics is the ease with which they can be injection moulded. Off cuts and scrap can be reprocessed with virgin material without a significant effect on the properties of the material. Acetal and nylon are also suitable for machining. Thermoplastics can be applied as an overmoulding (by injection moulding) onto metal components, such as bike locks, to provide a contoured and ergonomic outer surface.
There are a range of suitable joining processes including welding (ultrasonic and hot plate), mechanical fixings (threads or rivets) and adhesive bonding.
A major advantage of plastics is that they can be removed from the mould finished, and so do not require any additional finishing. Suitable processes for post-mould finishing include spray painting, metal plating and printing.

Relevant Applications

Bike Locks

These engineering thermoplastics are tough and resistant to impact, which makes them suitable materials for certain parts of bike locks. They can be cut through and so are often overmoulded (by injection moulding) onto suitably tough metal components or combined with metal fibres.

PC

Overview

Engineering thermoplastics are suitable for a range of demanding and high performance applications that are traditionally associated with metals. The most widely used of this group of materials includes acrylonitrile butadiene styrene (ABS), polyamide (PA) also known as nylon, polycarbonate (PC), polyoxymethylene (POM) also known as acetal, and thermoplastic polyester (PET).

Properties

PC has excellent clarity and superior mechanical properties. It is available in rich and luminous colours. PC is often blended with other polymers, such as ABS, to increase rigidity and impact resistance, especially for thin walled parts.

Processing

The advantage of thermoplastics is the ease with which they can be injection moulded. Off cuts and scrap can be reprocessed with virgin material without a significant effect on the properties of the material. Acetal and nylon are also suitable for machining. Thermoplastics can be applied as an overmoulding (by injection moulding) onto metal components, such as bike locks, to provide a contoured and ergonomic outer surface.
There are a range of suitable joining processes including welding (ultrasonic and hot plate), mechanical fixings (threads or rivets) and adhesive bonding.
A major advantage of plastics is that they can be removed from the mould finished, and so do not require any additional finishing. Suitable processes for post-mould finishing include spray painting, metal plating and printing.

Relevant Applications

Bike Locks

These engineering thermoplastics are tough and resistant to impact, which makes them suitable materials for certain parts of bike locks. They can be cut through and so are often overmoulded (by injection moulding) onto suitably tough metal components or combined with metal fibres.

POM

Overview

Engineering thermoplastics are suitable for a range of demanding and high performance applications that are traditionally associated with metals. The most widely used of this group of materials includes acrylonitrile butadiene styrene (ABS), polyamide (PA) also known as nylon, polycarbonate (PC), polyoxymethylene (POM) also known as acetal, and thermoplastic polyester (PET).

Properties

POM (Acetal)
POM, commonly known as acetal, has excellent mechanical properties that help to bridge the gap between polymers and metals. A high level of crystallinity means acetal is dimensionally stable even at high temperatures. It is resistant to many chemicals, fuels and oils, and its low coefficient of friction reduces wear. It is tough, even at low temperatures, and has high fatigue resistance.

Processing

The advantage of thermoplastics is the ease with which they can be injection moulded. Off cuts and scrap can be reprocessed with virgin material without a significant effect on the properties of the material. Acetal and nylon are also suitable for machining. Thermoplastics can be applied as an overmoulding (by injection moulding) onto metal components, such as bike locks, to provide a

contoured and ergonomic outer surface.
There are a range of suitable joining processes including welding (ultrasonic and hot plate), mechanical fixings (threads or rivets) and adhesive bonding.
A major advantage of plastics is that they can be removed from the mould finished, and so do not require any additional finishing. Suitable processes for post-mould finishing include spray painting, metal plating and printing.

Relevant Applications

Bike Locks

These engineering thermoplastics are tough and resistant to impact, which makes them suitable materials for certain parts of bike locks. They can be cut through and so are often overmoulded (by injection moulding) onto suitably tough metal components or combined with metal fibres.

PET

Overview

Engineering thermoplastics are suitable for a range of demanding and high performance applications that are traditionally associated with metals. The most widely used of this group of materials includes acrylonitrile butadiene styrene (ABS), polyamide (PA) also known as nylon, polycarbonate (PC), polyoxymethylene (POM) also known as acetal, and thermoplastic polyester (PET).

Properties

PET

There is a range of PET engineering materials. All have high dimensional stability and are resistant to chemicals. It is possible to modify PET with glycol (PETG) to reduce its brittleness and premature ageing.

Processing

The advantage of thermoplastics is the ease with which they can be injection moulded. Off cuts and scrap can be reprocessed with virgin material without a significant effect on the properties of the material. Acetal and nylon are also suitable for machining. Thermoplastics can be applied as an overmoulding (by injection moulding) onto metal components, such as bike locks, to provide a contoured and ergonomic outer surface.
There are a range of suitable joining processes including welding (ultrasonic and hot plate), mechanical fixings (threads or rivets) and adhesive bonding.
A major advantage of plastics is that they can be removed from the mould finished, and so do not require any additional finishing. Suitable processes for post-mould finishing include spray painting, metal plating and printing.

Relevant Applications

Bike Locks

These engineering thermoplastics are tough and resistant to impact, which makes them suitable materials for certain parts of bike locks. They can be cut through and so are often overmoulded (by injection moulding) onto suitably tough metal components or combined with metal fibres.

PLASTIC COMPOSITES

Glass Fibre

Glass fibre is a general purpose plastic reinforcement material and relatively inexpensive. It is durable, has good heat resistance and has good tensile strength. Non-woven materials are the least expensive and are known as chop strand mat. Weaves include plain, twill and specialist.

Overview

High performance composites are used to make lightweight structures that would otherwise not be feasible. The most talked about composite in the bicycle industry is carbon fibre and epoxy resin (CRP). Other high performance composites include glass fibre reinforced plastic (GRP), aramid fibre reinforced plastic (ARP) and metal fibre reinforced plastic (MRP). Additives, fillers and reinforcement are used to enhance the properties of plastics. They are used to improve specific mechanical properties, such as stiffness and durability. Carbon and aramid fibres are very expensive, so every effort should be taken to minimise material consumption while maximising strength.

Properties

A range of fillers are used to improve the mechanical properties of plastics including talc, minerals, fibers and textiles. Fibre reinforced composite materials have superior strength for their weight, several times greater than metal, and different grades are suitable for everything from racing cars to bike frames.
Various weaves are available to provide different strength characteristics. The direction of weave will affect the mechanical properties of the part. For high performance products this is calculated using finite element analysis (FEA) prior to manufacture. Certain weaves have better drape and so can be formed into deeper profiles. However, fibre alignment is critical; just five degrees of movement can reduce strength by up to 20%. Unlike metals that deform under load, composites shatter, making them vulnerable under certain loads.
Core materials are used to increase the depth of the part and thus increase torsional strength and bending stiffness. The role of the core material is to maintain the integrity of the composite skin. Examples of core materials include DuPont Nomex honeycomb (their trademark for aramid sheet), polyurethane foam and aluminium honeycomb.

Processing

Thermoplastics can be injection moulded, extruded and compression moulded with all of these fillers. Fibre reinforcement may be less than 1 mm long in thermoplastic moulding. Long and continuous strand fibre reinforcement is incorporated into thermosets by compression moulding, composite laminating, filament winding and 3D thermal laminating. The types of fibre used include glass, aramid, carbon and more recently hemp and jute.

Relevant Applications

Bike Frames

Fibre reinforced plastics are relatively new materials in bike frame construction. The high strength to weight, stiffness and resilience of composites makes them very desirable materials. The weave and binder resin can be adjusted to suit the unique stressed and strains on a bike frame, thus producing stiffness and flex where necessary. However, the loads on a bike frame are very complex, even for the most advanced FEA programs, and the full potential of composites has yet to be realised.

Carbon Fibre

Carbon fibre has higher heat resistance, tensile strength and durability than glass fibre. When combined with a precise amount of thermosetting resin, such as epoxy, it has exceptional strength to weight ratio. Carbon fibre twill is the most common weave.

Overview

High performance composites are used to make lightweight structures that would otherwise not be feasible. The most talked about composite in the bicycle industry is carbon fibre and epoxy resin (CRP). Other high performance composites include glass fibre reinforced plastic (GRP), aramid fibre reinforced plastic (ARP) and metal fibre reinforced plastic (MRP). Additives, fillers and reinforcement are used to enhance the properties of plastics. They are used to improve specific mechanical properties, such as stiffness and durability. Carbon and aramid fibres are very expensive, so every effort should be taken to minimise material consumption while maximising strength.

Properties

A range of fillers are used to improve the mechanical properties of plastics including talc, minerals, fibers and textiles. Fibre reinforced composite materials have superior strength for their weight, several times greater than metal, and different grades are suitable for everything from racing cars to bike frames.

Various weaves are available to provide different strength characteristics. The direction of weave will affect the mechanical properties of the part. For high performance products this is calculated using finite element analysis (FEA) prior to manufacture. Certain weaves have better drape and so can be formed into deeper profiles. However, fibre alignment is critical; just five degrees of movement can reduce strength by up to 20%. Unlike metals that deform under load, composites shatter, making them vulnerable under certain loads.

Core materials are used to increase the depth of the part and thus increase torsional strength and bending stiffness. The role of the core material is to maintain the integrity of the composite skin. Examples of core materials include DuPont Nomex honeycomb (their trademark for aramid sheet), polyurethane foam and aluminium honeycomb.

Processing

Thermoplastics can be injection moulded, extruded and compression moulded with all of these fillers. Fibre reinforcement may be less than 1 mm long in thermoplastic moulding. Long and continuous strand fibre reinforcement is incorporated into thermosets by compression moulding, composite laminating, filament winding and 3D thermal laminating. The types of fibre used include glass, aramid, carbon and more recently hemp and jute.

Relevant Applications

Bike Frames

Fibre reinforced plastics are relatively new materials in bike frame construction. The high strength to weight, stiffness and resilience of composites makes them very desirable materials. The weave and binder resin can be adjusted to suit the unique stressed and strains on a bike frame, thus producing stiffness and flex where necessary. However, the loads on a bike frame are very complex, even for the most advanced FEA programs, and the full potential of composites has yet to be realised.

Aramid Fibre

Aramid fibre is commonly referred to as DuPont Kevlar. Aramid is available only as spun fibres or sheet material because there is no other practical way to make it. It has very high resistance to abrasion and cutting, very high strength to weight and superior temperature resistance.

Overview

High performance composites are used to make lightweight structures that would otherwise not be feasible. The most talked about composite in the bicycle industry is carbon fibre and epoxy resin (CRP). Other high performance composites include glass fibre reinforced plastic (GRP), aramid fibre reinforced plastic (ARP) and metal fibre reinforced plastic (MRP). Additives, fillers and reinforcement are used to enhance the properties of plastics. They are used to improve specific mechanical properties, such as stiffness and durability. Carbon and aramid fibres are very expensive, so every effort should be taken to minimise material consumption while maximising strength.

Properties

A range of fillers are used to improve the mechanical properties of plastics including talc, minerals, fibers and textiles. Fibre reinforced composite materials have superior strength for their weight, several times greater than metal, and different grades are suitable for everything from racing cars to bike frames.

Various weaves are available to provide different strength characteristics. The direction of weave will affect the mechanical properties of the part. For high performance products this is calculated using finite element analysis (FEA) prior to manufacture. Certain weaves have better drape and so can be formed into deeper profiles. However, fibre alignment is critical; just five degrees of movement can reduce strength by up to 20%. Unlike metals that deform under load, composites shatter, making them vulnerable under certain loads.

Core materials are used to increase the depth of the part and thus increase torsional strength and bending stiffness. The role of the core material is to maintain the integrity of the composite skin. Examples of core materials include DuPont Nomex honeycomb (their trademark for aramid sheet), polyurethane foam and aluminium honeycomb.

Processing

Thermoplastics can be injection moulded, extruded and compression moulded with all of these fillers. Fibre reinforcement may be less than 1 mm long in thermoplastic moulding. Long and continuous strand fibre reinforcement is incorporated into thermosets by compression moulding, composite laminating, filament winding and 3D thermal laminating. The types of fibre used include glass, aramid, carbon and more recently hemp and jute.

Relevant Applications

Bike Frames

Fibre reinforced plastics are relatively new materials in bike frame construction. The high strength to weight, stiffness and resilience of composites makes them very desirable materials. The weave and binder resin can be adjusted to suit the unique stressed and strains on a bike frame, thus producing stiffness and flex where necessary. However, the loads on a bike frame are very complex, even for the most advanced FEA programs, and the full potential of composites has yet to be realised.

Natural Fibres

Hemp and jute are suitable alternatives to glass fibre in certain applications. In recent years there has been a great deal of research, especially in the automotive industry, to assess the potential benefits and implications of replacing glass fibre with natural fibres. The aim is to reduce the environmental impacts of composite materials whilst maintaining their superior mechanical properties.

Overview

High performance composites are used to make lightweight structures that would otherwise not be feasible. The most talked about composite in the bicycle industry is carbon fibre and epoxy resin (CRP). Other high performance composites include glass fibre reinforced plastic (GRP), aramid fibre reinforced plastic (ARP) and metal fibre reinforced plastic (MRP). Additives, fillers and reinforcement are used to enhance the properties of plastics. They are used to improve specific mechanical properties, such as stiffness and durability. Carbon and aramid fibres are very expensive, so every effort should be taken to minimise material consumption while maximising strength.

Properties

A range of fillers are used to improve the mechanical properties of plastics including talc, minerals, fibers and textiles. Fibre reinforced composite materials have superior strength for their weight, several times greater than metal, and different grades are suitable for everything from racing cars to bike frames.

Various weaves are available to provide different strength characteristics. The direction of weave will affect the mechanical properties of the part. For high performance products this is calculated using finite element analysis (FEA) prior to manufacture. Certain weaves have better drape and so can be formed into deeper profiles. However, fibre alignment is critical; just five degrees of movement can reduce strength by up to 20%. Unlike metals that deform under load, composites shatter, making them vulnerable under certain loads.

Core materials are used to increase the depth of the part and thus increase torsional strength and bending stiffness. The role of the core material is to maintain the integrity of the composite skin. Examples of core materials include DuPont Nomex honeycomb (their trademark for aramid sheet), polyurethane foam and aluminium honeycomb.

Processing

Thermoplastics can be injection moulded, extruded and compression moulded with all of these fillers. Fibre reinforcement may be less than 1 mm long in thermoplastic moulding. Long and continuous strand fibre reinforcement is incorporated into thermosets by compression moulding, composite laminating, filament winding and 3D thermal laminating. The types of fibre used include glass, aramid, carbon and more recently hemp and jute.

Relevant Applications

Bike Frames

Fibre reinforced plastics are relatively new materials in bike frame construction. The high strength to weight, stiffness and resilience of composites makes them very desirable materials. The weave and binder resin can be adjusted to suit the unique stressed and strains on a bike frame, thus producing stiffness and flex where necessary. However, the loads on a bike frame are very complex, even for the most advanced FEA programs, and the full potential of composites has yet to be realised.

WOOD

Engineering Timber

Overview

Engineering timbers are composite constructions of wood and high strength adhesive. Wood particles, strands or veneers are locked into a laminated structure, which is dimensionally stable and durable. These materials are used in a variety of combinations to produce lightweight structures, engineered to precise requirements.

Properties

Engineering timbers utilise the high strength and stability of laminated wood. The visual and mechanical properties are affected by the type of wood, adhesive and method of production. Examples include laminated strand lumber (LSL), oriented strand board (OSB), medium density fiberboard (MDF), plywood and I-beams. It is possible to produce flame retardant and water resistant grades.

Processing

Engineering timbers are produced as lumber, sheet and panel materials, which are cut to size. Many are produced by compression moulding with heat and pressure. Therefore, it is possible to mould finished parts with integrated profiles, ribs and other design details. An example of this is the compressed wood pallet, which is produced using the same ingredients as OSB and so has a similar visual appearance.

There is nothing new about bonding two or more layers of wood together to form a laminate. However, as a result of developing stronger, more water-resistant and temperature durable adhesives, lighter and more reliable structures can now be engineered in laminated wood and so greater creative opportunities have arisen in design.

Engineering timber parts are typically joined by mechanical fixings (rivets or bolts) and adhesive bonding. Suitable finishing processes include polishing and spray painting. For indoor applications no protective coatings are necessary and in such cases engineering timbers are often left 'exposed' to maintain their visual appearance.

Relevant Applications

Bike Frames

Over the years many concept engineering timber bike frames have emerged from design schools and competitions. Laminated and compressed wood cannot compete with high performance plastic composites for strength to weight. However, they do offer a more sustainable alternative, provided they are designed and specified using suitable materials and processes.

Bike Furniture

Engineering timbers are suitable for bike furniture in both the domestic and public environments, except in security applications due to the ease with which they can be cut through.

Solid Timber

Overview

The strength and lightness of solid timber have been exploited for millennia. The qualities of wood are the result of natural growth and the influence of the elements. Each species of tree produced timber with particular strengths, weaknesses and visual characteristics. Some grow fast tall and straight; others are slow growing with interlocking grain.

Properties

Wood is a naturally springy, resilient and durable material. It is a natural composite material made up of xylem tissue, which is a fibrous material consisting mostly of elongated, rigid walled cells that provide trees and shrubs with an upwards flow of water an mechanical support.
Wood is a sensual material that is warm to the touch. As a natural, edible and biodegradable material, it is prone to disease, insect attack and decay. A famous example is Dutch elm disease, which wiped out much of Europe and North America's elm population and is still active today.
Softwoods are coniferous and typically evergreen trees, and include pine, spruce, fir and cedar. Hardwoods are typically broad leaved and deciduous trees. The terms hardwood and softwood are misleading. For example, balsa is very soft and light but is classified as a hardwood, while certain softwoods are dense and hardwearing like certain hardwoods.
Bamboo is a fast growing grass that is harvested and used as a hardwood-like material. It is lighter and harder than many hardwoods. There are many different species of bamboo, which have different rates of growth. Certain species grow up to 1 m per day and reach heights of 30 m or more. Demand for bamboo is increasing because it is proving to be an economic, environmental alternative to wood in many applications.

Processing

Wood is available for manufacturing as a sheet material, solid lumber, and as chips, particles and shavings. Most timber can be purchased as solid lumber. Limiting factors are price and availability such as in the case of decorative burled wood. Planks more than 150 mm wide are typically stabilised by cutting the wood into strips and bonding them back together alternating alternate directions of growth. This means that as it shrinks and expands the wood works against itself and is less likely to buckle, bow or twist.
Solid timber parts are typically joined by mechanical fixings (rivets or bolts) and adhesive bonding. Suitable finishing processes include polishing and spray painting. For indoor applications no protective coatings are necessary and in such cases solid timbers are often left 'exposed' to maintain their visual appearance. Certain woods can be left 'exposed' outdoors and will gradually turn silvery or grey with exposure to sunlights and the atmosphere. Of the softwoods, cedar and larch produce natural oils that protect them from decay: they can be used untreated outdoors. Hardwoods that are suitable for use outdoors untreated include oak, walnut, iroko and certain exotic species.

Relevant Applications

Bike Frames

Solid timber and bamboo bike frames do exist. However, these materials are inevitably heavier than composites and cannot be designed and engineered to the same precise requirements. The use of wood and bamboo tends to be driven by fashion and a desire to produce a more sustainable product.

Bike Furniture

Solid timbers are suitable for bike furniture in both the domestic and public environments, except in security applications due to the ease with which they can be cut through.