FACTFILE: GCSE Technology and Design

OPTION C: PRODUCT DESIGN - MATERIALS, COMPOUNDS AND FABRICATION

Rewarding Learning

2.50 Smart Materials and Composites

Learning Outcomes

You should be able to:

- discuss the reasons for using the following in product designs;
  - smart materials (shape memory alloy (nitinol) and polymorph); and
  - composites (glass reinforced plastic (GRP) and carbon fibre).

Smart materials are designed to have special properties that can change from one state to another. The change can be triggered by an external stimulus. The stimulus can be from a controlled source or as a reaction to its environment.

Shape memory alloy (Nitinol) is a metal that is incredibly flexible (super-elastic) and returns to its original shape after being stretched or twisted. It is an alloy of two different metals (Nickel and Titanium).

Nitinol is used as the shaping wire for orthodontic braces on teeth. It is manufactured into an 'Arch-wire' to correct the alignment of teeth. The Nitinol 'arch-wire' can be bent out of shape, by the dentist, to fix onto the brackets of the misaligned teeth. Over time the Nitinol wire returns to its original arch shape, overcoming the resistance of the jaw bone, and forcing the teeth to move to the preformed arch.

Nitinol is also used to make the frames of spectacles that keep their shape when squashed. As the frames are made from Nitinol, which is super-elastic, they can be deformed. The frames will automatically return to their original frame shape when heated.

Polymorph

Polymorph is a thermoplastic that can be heated and shaped an unlimited amount of times. The polymorph melts at relatively low temperatures of approximately 60°c degrees. This low melting point means that it is cool enough to hold, can be easily shaped by hand, and cools into a strong nylon type plastic.

Polymorph can be used for self-disassembling electronic devices. The polymorph is moulded into strong and durable components and fixings that hold the electrical device together. When the product comes to the end of its useful life, the polymorph is heated, which returns to its original state, and the product falls apart. This means the components are easier to retrieve and recycle.

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Polymorph granules illustrated above are melted in hot water (60°c degrees). The molten granules fuse together to form a malleable plastic. The polymorph can then be formed into any shape and when it cools it becomes hard plastic. The low melting point, reusability and strong plastic make polymorph the perfect material for prototyping or model making.

Composite materials

Composite materials are made by bonding two or more materials together. The materials have different properties, but used together, make one new material with completely new properties.

Examples of composites materials include:

- glass reinforced plastic (GRP)
- carbon Fibre

GRP is made from glass fibres and plastic resin. Molten glass is blown and spun into thin strands to create fibres that are woven into sheets or mats. These are then laid in a pre-made mould of the required shape. Resin is poured over the fibres to fix them into the shape of the mould. When cured, the GRP is removed from the mould and a smooth thin shell is revealed.

A roll of Chopped Strand Mat (left) & (right) two rolls of Plain Weave Cloth tape.

The advantages of glass reinforced plastic are:

- high strength;
- lightweight;
- rigid;
- easily mouldable;
- can be formed into complex shapes;
- easily cut and drilled;
- does not rot or corrode; and
- non-conductive.

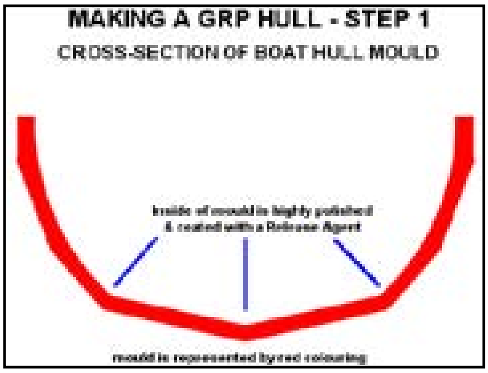
GRP has multiple uses and is successfully used in products ranging from car bodywork to boat hulls and aeroplane wings. Its ability to be formed into complex shapes and its strength-to-weight ratio make it a versatile and useful material.

The ladder above is made from GRP with aluminium components of steps, braces and shelf. The rails are made from GRP which is used for its lightweight, rigidity and electrical insulating properties. Step ladders are frequently used in the construction trade where there is potential risk of electric shock at height.

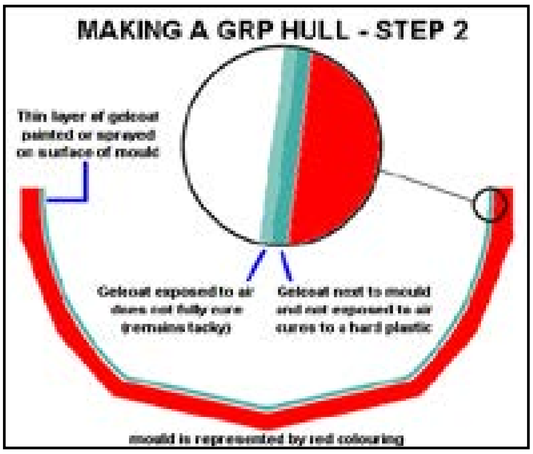
Activity

The following three steps outline the stages in the production of a GRP boat hull.

STEP 1 – Preparing the Mould
The mould has a highly polished surface and is coated with a release agent to prevent the GRP sticking to it.



STEP 2 – Adding the Gelcoat
The gelcoat has pigment added to give it colour. Catalyst is added and it is then painted or sprayed on to the surface of the mould. The catalyst initiates a chemical reaction which gradually turns the liquid gelcoat into a hard but flexible plastic.



STEP 3 – Adding the laminate
Catalysed lay-up resin is painted on to the tacky gelcoat surface. A sheet of fibreglass fabric or matting is stippled down on to the resin. More resin is added to the sheet to ensure that it is completely wetted out. Another layer of fabric or mat is added followed by more resin. This process is repeated until the laminate is of the required thickness. It is then left to cure.

http://www.pettigrews.org.uk/lm/page028b.htm

Carbon fibre is a thread made mostly of carbon atoms. This incredibly strong thread is woven into a textile and then sealed with plastic resin to make a composite material.

The advantages of carbon fibre are:
- high strength to weight ratio;
- high tensile strength;
- resistance to high temperatures;
- rigidity;
- high resistance to chemicals;
- low expansion and contraction due to temperature;
- electrical conductor;
- easily to mould and can be formed into complex shapes; and
- easily cut and drilled.

These properties make carbon fibre components highly desirable in high performance applications in engineering sectors including motor sports, aerospace and the military.

Formula One car suspension components illustrated above are manufactured from carbon fibre due to its properties.

The process of manufacturing components from carbon fibre is similar to the fabrication process of the glass reinforced plastic. The carbon fibre fabric is laid into the mould and resin is applied to lock the strong fibres together. An additional process is to bake the resin and carbon fibre in an oven to cure resin and form a strong composite structure.

Drone aircraft propellers illustrated above can be manufactured from carbon fibre. The strength to weight ratio of carbon fibre and ability to be moulded into complex shapes, make the additional cost of carbon fibre products worthwhile.

Revision Questions

1. Explain how polymorph materials are being used to improve recycling.

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2. Illustrate the manufacturing steps of producing a carbon fibre product.

3. What is the definition of a composite material?

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4. Formula 1 car suspension is made from carbon fibre as it is easily formed into aerodynamic shapes. Think of the conditions that suspension components operate in during a race. Match 3 properties of carbon fibre that meet these specific conditions.

1. Operating condition: ____

   Relevant carbon fibre property: ________________________________

2: Operating condition: ____

   Relevant carbon fibre property: ________________________________

3: Operating condition: ____

   Relevant carbon fibre property: ________________________________