Pearson BTEC Levels 4 Higher Nationals in Engineering (RQF)

Unit 14: Production Engineering for Manufacture

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Production Processes

In this we will use the terms "casts" and dies", both do the same job, as something that is used to make the shape of the product, however, a cast will typically be made of sand, as they are designed to produce one product before being destroyed, whereas a die is more permanent and will not perish.

When considering the processes that are available to create a product, we need to consider a number of factors:

- Is the process suitable for the material we are using?
- Is the lead time for the product suitable for the volume we are producing (i.e. are we spending too much for a small volume of products?)
- Will it produce a high-quality product, as is it necessary to have the highest quality product for the application?
- How much material will the product waste, and can this waste be recycled?

We will first discuss the manufacturing techniques that are involved in creating a product, including how you can attach them together in assembly. We will then discuss how we choose the best method for the product we want to make.

2.1 Ceramic Manufacturing Processes:

Theory

Ceramics are one of the largest groups of materials, they have the properties of non-metals and are made by firing or burning. In terms of their starting materials, ceramics are cheap. Their electrical, magnetic properties are valuable to the electronics industry. Relative to metals, ceramics are lightweight and can retain their strength up to $1000°C$, whereas most metals would be significantly weaker.

2.1.1 Powdered Sintering

Sintering is a process where the ceramic is heated until it almost reaches the melting point. This helps to eliminate any pores and voids in the ceramic, the ceramic is then cooled. If there are any large voids in the ceramic that sintering has not eliminated, the product will be very fragile and will probably collapse when handled. Sintering is typically used to create products in high volumes, as it is quick and easy process.

2.1.2 Hot pressing

Similar to sintering, but this also incorporates the application of high pressures, this is only useful for simple shapes and gives a rough surface finish which will need to be corrected by diamond grinding.

2.1.3 Chemical Vapour Deposition

Chemical vapour deposition (CVD) is the result of the chemical reaction of a gas on a heated substrate, the reaction leaves a ceramic deposit, this method is typically used to produce freestanding thick-walled structures.

2.1.4 Reaction Bonding

Reaction bonding (or reaction sintering) is a means of producing dense covalent ceramics. It is usually for silicon-based ceramics such as reaction-bonded silicon nitride or reaction bonded silicon carbide. Silicon nitride is made from silicon powders that are already shaped, they are then put in a furnace reaching $1{,}200°C$ in a nitrogen/hydrogen or nitrogen/helium atmosphere. The nitrogen permeates and gets inside the pores to react with the silicon to form silicon-nitride. The piece is then heated to $1{,}400°C$, which is just below the

2.2 Composite Manufacturing Processes

Theory

Composites are lightweight and advanced non-metal materials. A composite is built up in layers of fibres bonded together with a resin (or "matrix"), for a stronger composite, you can change the material of the fibres. and bonding resin, or you can change the direction the layers of fibre are placed. The most common point of failure in composites is grains along the fibre, by adding fibres facing a different direction, you can brace the material in more than one direction, shown in Fig.2.1. The ceramic making process can be either done by hand or automated,

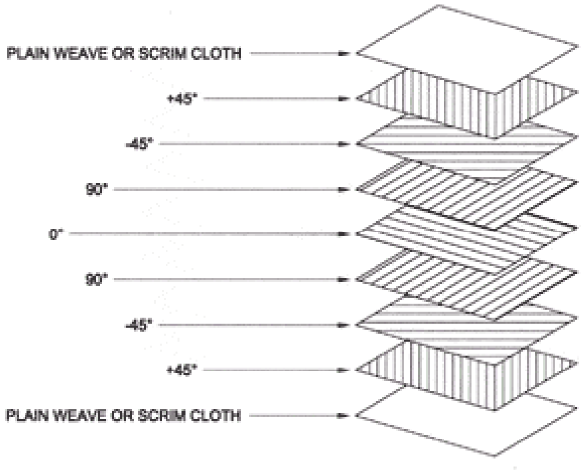

Fig.2.1: A composite manufactured with a $45°$ *overlay*

2.2.1 Hand Layup

The simplest composite manufacturing technique and used in low-volume production for large products. A pigmented gel coat is sprayed onto the mould to give a high-quality surface. When the coat has cured the fibres are placed onto the mould, before the catalysed resin is added (by pouring, spraying or brushing it on). Someone then rolls the resin in manually, this will also remove any entrapped air, compact the composite and thoroughly wets the fibres with the resin. The resin is catalysed in order to accelerate the bonding process, and also remove the demand for external heat to be applied.

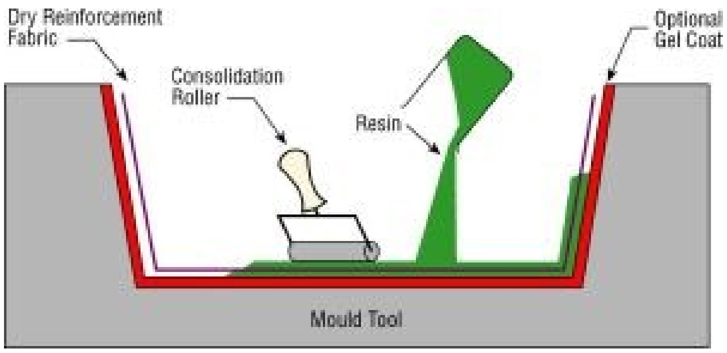

Fig.2.2: Hand lay-up method

2.2.2 Spray Up

Spray up is similar to the hand layup technique, but the process has become more automated by the incorporation of the spray to apply the ingredients. The fibres are chopped into smaller $(25 - 50\ mm)$ and then sprayed by an air jet with the bonding resin at a ratio which has already been predetermined for the application. Fig.2.3 shows a diagram of a spray up process.

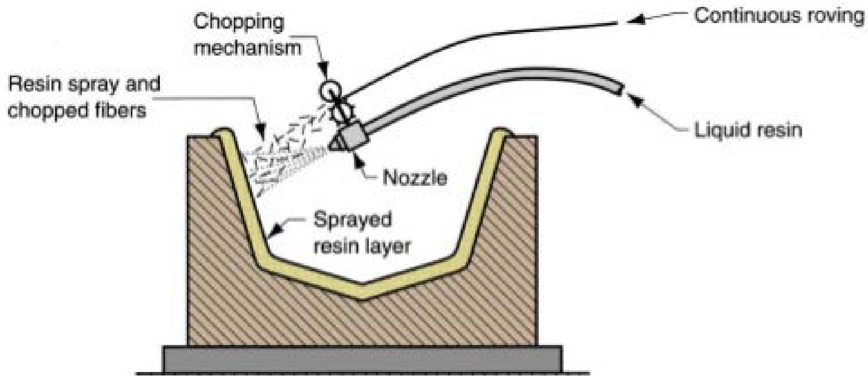

Fig.2.3: Spray up method.

2.2.3 Filament Winding

Video

A continuous filament of reinforcing material is wound onto a rotating mandrel in layers. If a liquid resin is applied to the filament prior to winding it is known as wet filament winding. If the resin is sprayed onto the mandrel with the wound filament, the process is called dry filament winding. This is used when creating round or cylindrical shapes The URL below explains the filament winding process in full.

https://www.youtube.com/watch?v=ign6W5ENJAA

2.2.4 Pultrusion

Video

The fibres are pulled from a “creel” and directly into a resin bath, where they are impregnated with the liquid resin. The wet fibres exit the bath and into a “pre-former” where any excess resin is removed from the fibres and shaped. The preformed fibres then pass through a heated die when the final cross-sectional dimensions are determined, and the resin begins to cure. Once the resin is cured the required length is removed by the cut-off saw. The URL below will show a video about the pultrusion process.

https://www.youtube.com/watch?v=4MoHNZB5b_Y

2.2.5 Resin Transfer Moulding

Video

Resin transfer moulding (RTM) requires a pre-shaped fibre skeleton (otherwise known as the preform). The preform is then placed into a die. The resin is then injected into the die and the part will remain there until it is cured. Once cured the die will be opened and the part will be removed. The URL below shows the resin transfer moulding process.

https://www.youtube.com/watch?v=NzpHCjL_AnE

2.2.6 Prepreg

A prepreg is used as a term for a composite which has already been pre-impregnated with resin. The resin also includes the curing agent, so once the prepreg is placed into the mould, the product simply just needs to be cured. It is difficult to store prepregs for an extended period of time, as the curing agent will be working

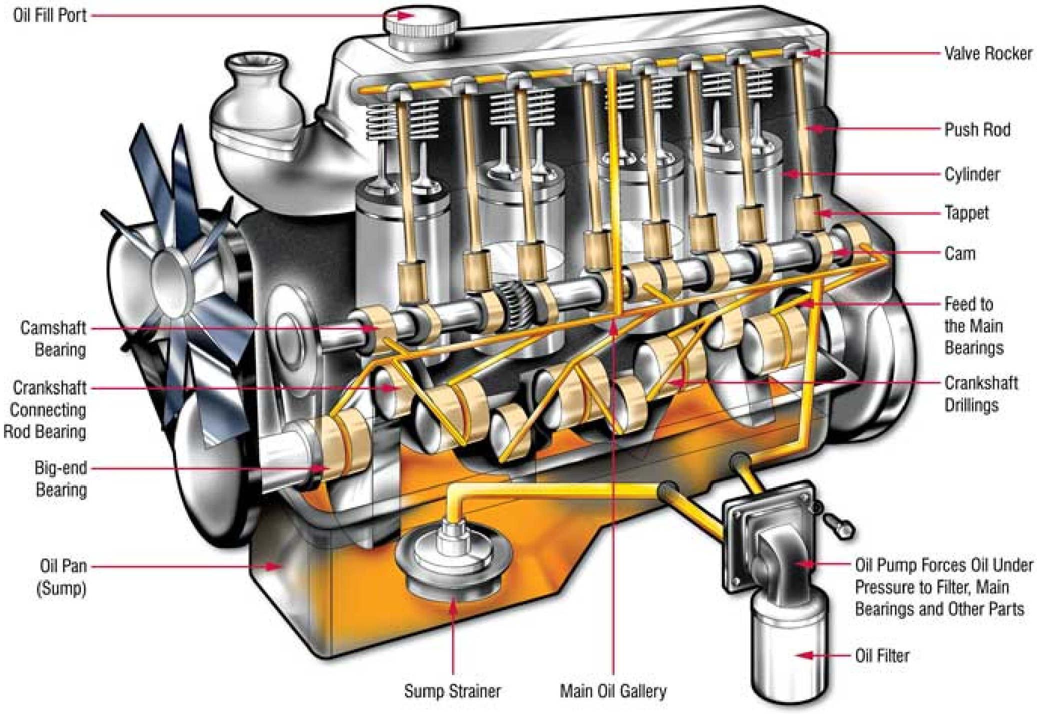

Fig.2.4: The flow of lubricating oil through an engine, notice the complexity of the oil channels, this will be generated by creating a core during the casting process.

2.3.2 Forming

Forming is using plastic deformation of the metal, which means once enough force is applied to the solid metal, it will not return to its original shape (**The in-depth definition of plastic deformation is given in "Other Resources"**). We can form metals at different temperatures for different mechanical properties.

Cold Forming

This process typically takes place around room temperature, this causes a lot of "strain hardening" (the metal is stronger and harder because of plastic deformation taking place) The yield point of the metal is also higher at lower temperature, meaning more force is required for cold forming than hot forming. The material is also more brittle at the lower temperature, which means the metal is more likely to fracture than if it was formed at a higher temperature where the metal could become more ductile and softer. Although more force is required with cold working, there is less energy required than hot forming.

Warm Forming

Hotter than room temperature, but not hot enough to cause recrystallisation in the metal's molecular structure. There is less force required than cold working, and because the metal does not strain harden. The metal does not need to undergo as much toughening processes as it would with cold working.

Hot Forming

The metal is formed at a temperature high enough to trigger recrystallisation in the metal, at this temperature the behaviour of the metal differs. Hot forming utilises these different behaviours. However, as temperature of the working metal increases, the temperature gradient between the working metal and

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the die would increase, which means that the working metal near the die would be a lot cooler and would not flow as effectively as the centre of the working metal, which can lead to defects. There is also a reduction in the yield strength of the metal and, typically reduce porosity of the metal as the atoms redistribute themselves. Forming processes can be classed as either bulk deformation and sheet metal working.

Bulk Deformation

The available bulk deformation methods are:

- Extrusion – metal is pushed through a die opening, this will give a constant cross section of metal, which can then be cut to various lengths
- Drawing – this is essentially the same as extrusion, except the metal is not pushed through the die, it is pulled through instead.
- Forging - utilises a force to compress the metal into a die. This could be a flat die, or can it can take a certain shape.
- Rolling – large metal rollers are used to produce the desired shape.

Sheet Metal Working

The sheet metal working options are:

- Cutting – using shearing forces to cut the worked metal, such as punch holes; while shearing is not technically caused by plastic deformation, it is a very important process in sheet metal working and should be understood with the other forming processes.
- Bending – deformation by bending on the desired axis.
- Deep drawing – a metal sheet is forced into a die to take a simple shape, like a bowl.

2.3.3 Sintering

Sintering is the same process for metals as it is for ceramics, powder is poured into the die, before a hot press bonds the powder together under the high heat and pressures.

2.3.4 Cutting and Milling

Cutting and milling are machining techniques that take a solid block of metal and grind it down into the desired shape. The advantage of this is the accurate finish that is available with this method; however, these methods cannot create the complex shapes when compared with casting.

2.3.5 Metal Comparison

Table.2.3 compares the advantages and disadvantages of the various metal processes

Technique	Advantages	Disadvantages
Sand Casting	• Quick • Short set-up time • Complex shapes possible • Low waste • Only needs a cheap wooden pattern	• Rough surface finish • Need to control flow of molten metal to prevent cavities
Die Casting	• Improved surface finish • Low waste • Good mechanical properties • Good dimensional accuracy	• Expensive to produce dies • Long set-up time • Need to control flow of molten metal to prevent cavities

Shell Mould Casting	• Good surface finish • High dimensional accuracy • Can create very thin wall castings	• Needs to produce an expensive metal pattern • Special sand required is more expensive and not recyclable • Only small and lightweight products can be made • Need to control flow of molten metal to prevent cavities
Investment Casting	• Can create several smaller products at once • Heated ceramic prevents premature cooling • Wax moulds can give a cheap visualisation of prototypes	• Long set-up time • Labour intensive prep • Only small and lightweight products can be made • Need to control flow of molten metal to prevent cavities
Extrusion / Drawing	• Continuous • High volume production • Cheap	• Cannot create complex shapes
Forging	• Improved mechanical properties • Good dimensional accuracy • Good surface finish	• Long set-up time • Expensive equipment required • Requires highly skilled workforce
Rolling	• Good surface finish • Continuous • High dimensional accuracy	• Cannot create complex shapes • High initial cost
Bending	• Good surface finish • High dimensional	• Cannot create complex shapes
Deep Drawing	• Can create seamless objects • Improved mechanical properties	• Cannot create complex shapes • High set-up costs
Sintering	• Porosity of the system produces vibration damping • Reduced weight • Low Waste • High surface finish • High dimensional accuracy • Complex shapes possible	• Sintering does not crystallise as effectively as other methods – reduced mechanical properties • Expensive equipment and dies • Long set-up time
Cutting and Milling	• Smooth surface finish • Accurate	• Lubrication on the cutting tool means the metal cannot be recycled • Expensive equipment • Labour Intensive

2.4 Polymer Manufacturing Processes

Theory

Polymers (or plastics) are defined by two distinct groups, thermoplastics and thermoset plastics. Thermoset plastics, once heated and formed, cannot be reheated and have their shape changed, whereas a thermoplastic can be reheated and reshaped.

2.4.1 Injection Moulding

Video

Small granulates of polymer are placed into a hopper, which slowly distributes into a tube with a large screw in it. As the screw rotates, the plastic granulates advance further into the tube, where there are heating pads that begin heating the tube. This will melt the plastic and the screw will keep turning until the tube is filled with melted plastic. The screw then retreats and begins to force forward to push plastic into the mould. The moulds are then quickly replaced, and the process can be repeated while the tube is filled. The video link below will help describe it more effectively.

2.5 Bonding and Joining Technologies

Purpose All the manufacturing techniques are used to create the parts of the product, but we also need to consider how to join the parts together to create the final assembled product. There are various aspects to consider when considering the bonding technique:

- Do we want the part to move?
- The chemical reactivity between the materials of the parts and the joint
- The environment the joint will be exposed to
- The stresses the joint will experience
- The heat required to create the joint

2.5.1 Welding

The URL below is an extensive breakdown of the different welding types, as well as links to further reading.

http://weldinghelmetpros.com/different-types-of-welding-processes

2.5.2 Adhesives

The URL below explains the different types of adhesive bonding available.

http://www.adhesives.org/adhesives-sealants/adhesives-sealants-overview/adhesive-technologies/chemically-curing

2.5.3 Snap Fits

By following the link in the URL below, you can see a report by BAYER MaterialScience on different snap joints.

http://fab.cba.mit.edu/classes/S62.12/people/vernelle.noel/Plastic_Snap_fit_design.pdf

2.5.4 Interference Fits

Interference fits use friction between two parts as a method of fastening. This is typically done by making the male connection larger than the female connection. Interference fits can be split into press fits and shrink fits.

Press Fits

Press fits is just the application of force to fasten the two parts together.

Shrink fits

Shrink fits will apply heat to the female connection and make it expand, the male connection is kept cool and inserted into the female. Once the female connection cools it will shrink and fit around the male, keeping it fastened.

2.5.5 Mechanical Assemblies

The types of joining techniques discussed so far all create static bodies, the purpose of mechanical assemblies is to create dynamic systems. Mounting a door to the frame is a mechanical assembly, the joint being the hinge.

Axles