Materials and Manufacturing 2 Questions and Answers

2. Bulk Materials Fabrication Processes

2.1 Casting

2.1.1. Why are chills used during casting?

To prevent the occurrence of porosities. The chill cools the material locally, causing it to solidify earlier than the surrounding metal. Ideally solidification should start at one location and should spread toward the risers.

2.1.2. What is the difference between a micro porosity and a hot tear?

When areas further away from the riser have smaller thickness than areas near the riser, the metal further away solidifies first, so the riser serves as storage for liquid metal needed to fill the product. A micro porosity occurs when there is a small thickness near the riser, which is already solidified, while the riser can not supply the extra metal needed for filling the mould cavity with larger thickness behind the small t (so micro porosity occurs).

Hot tearing is a failure mode which might occur during casting. When shrinkage is locally obstructed, it results in high stresses followed by cracking.

2.1.3. A riser resembles most to...

- **overflow**
- **ventilation shaft**
- **buffer risers**

Buffer risers. Buffer risers supply additional metal to the casting as it shrinks during solidification. So a riser serves as a storage for liquid metal needed to fill the product.

2.1.4. Why should a pattern, as applied during sand casting, be tapered?

- **Since otherwise the pattern can not be removed before casting.**
- **Since otherwise the product can not be removed after casting.**
- **Both above answers are correct.**

Both above answers are correct.

2.1.5. What is a shrinkage allowance?

Cooling and thus solidification results in shrinkage of metal alloy. The mould cavity is therefore larger than the product. This is called the shrinkage allowance, which usually ranges from $10mm/m$ to $20mm/m$. In short, it is the extra thickness needed to compensate for shrinkage of the material during casting.

2.1.6. What is a machining allowance?

Stuff produced via casting with expendable moulds often need finishing such as machining. So on top of the shrinkage allowance, a machining allowance is needed. In short, it is the extra thickness needed to compensate for mechanical removal of the material after casting.

2.1.7. From where do the gasses arise during the casting of metals?

Gases dissolve much more in liquid metal than in solid metal, solidification will lead to origination of gases. When thermosetting polymer binder is used in the sand mould (as a binder), the binder will disintegrate into gases which also have to be vented.

2.1.8. Which element causes an aluminum alloy to shrink less? Given is the solidification contraction:

- **Al: 6.6 volume%**
- **Al-4.5%Cu: 6.3 volume%.**
- **Al-12%Si: 3.8 volume%.**

So Silicium causes an Aluminum alloy to shrink less.

2.1.9. What can you state about temperature and pressure during the sand casting process?

Temperature is high (melting temperature) and pressure is low (gravity).

2.1.10. What is the advantage of slow cooling over fast cooling?

Slow, uniform cooling allows the liquid metal to reach every corner of the mould, therefore preventing the forming of micro porosities.

2.1.11. What is the advantage of fast cooling over slow cooling?

The internal grain structure is maintained, and there is less time needed so the costs per product decrease.

2.1.12. There are many variants of the sand casting process. What in the sand casting process can be changed in order to obtain a different process (two main groups)?

Mould materials and pressure during the process are variables in the casting process. Other answers could be the change in driving force of the flow, and the cooling rate.

2.1.13. Which improvements are strived for when changing from sand casting to an other casting process?

- Plaster: better surface quality, increased casting precision.
- Shell-mould: better surface quality. Permanent mould: incorporation of smaller details.
- Other improvements: producing more, increased accuracy, smaller wall thickness, cheaper product (shorter process time, less finishing operations).

2.1.14. How can you get rid of gasses that emerge during the casting process (two possibilities)?

Permeability of the mould, or the use of vents.

2.1.15. Give two advantages of the investment casting?

High accuracy (suitable for complex products with small geometrical tolerance), smooth product surface, cost reduction due to joining of wax parts in a tree, in case wax is used, the mould can be easily removed and reused.

2.1.16. What is so marvelous about the investment casting process?

Suitable for large and small amount of products (no expensive product dependent tools needed), suitable for complex, accurate products and for high melting point metals.

2.1.17. Why is it so difficult to cast tungsten products?

Very high temperatures are needed, making casting difficult. All machines should be suitable for these processing conditions. Large temperature differences (room temp. vs. melting temp.) give a large amount of shrinkage, and thus possibly a lot of trouble.

2.1.18. Why are the pressure die casting and injection moulding in principle only suitable for large series of products?

It is an economical reason: The moulds are product dependent and because of the high pressures and increased temperature the mould will be expensive. The costs of the moulds need to be divided over many products to get an acceptable cost per product.

2.1.19. Which casting process is suitable for the casting of high melting point metal alloys?

Investment casting, and processes with ceramic (sand, clay) moulds.

2.1.20. Why is the occurrence of gasses less a problem for pressure die casting than for permanent mould casting?

The liquid metal is pressurized (by hydraulics or pneumatics) and fed into the cavity of the permanent moulds. The increased pressure during pressure die casting ($50Mpa = 500Bar$) causes compression of the gasses, so they will have less influence on the product.

2.1.21. What can cause you to dislike performing certification tests?

Certification tests are very cost increasing activities since a lot of testing needs to be performed when proving the fitness of a structural part.

2.1.22. Which casting factor do you like to apply for loaded non critical structural parts?

Factor 2

2.2 Lay-Up

2.2.1. Orientation errors have an influence on the mechanical properties of composites. Do you expect differences between thin laminates (mm) and thick laminates (cm)?

Yes, when one layer is misplaced, the influence on thick laminates is less than on thin laminates.

No, when a percentage of the layers is misplaced, the influence on thick and thin layers is the same.

2.2.2. What is the first layer applied to a mould during lay-up processes?

A release layer (film, spray).

2.2.3. Why are hardly ever carbon fibers applied during the spray-up process? (Glass fibers are applied.)

Glass fibers are much cheaper than carbon fibers AND the time needed for production of a part is short, so the material cost has a large influence on the product costs.

2.3 Resin Transfer Moulding

2.3.1. What is the difference between porosity and permeability?

Porosity states something about the percentage void (emptiness). Permeability states something about the easiness of flow.

2.3.2. A runner channel is a production error during Vacuum infusion. Why is such a runner channel not predictable via computer software?

A runner channel can be created when the foil is applied during Vacuum infusion. The foil shows in such cases a fold. Since the foil is applied by hand, it is crafts work, and that can not be simulated by software. The possible variation when applying the foil is very large, so predictions can not be made.

2.3.3. Why are RTM products limited in size and VI products not?

During RTM external pressures are applied, so presses are needed. These are limiting factors for product size. During VI only vacuum is applied, no presses are needed, only tables, moulds and foil. These three are not limiting the size of the product.

2.3.4. The fill time of an RTM product is a function of porosity, permeability (fibres), viscosity (resin), pressure difference (inlet-outlet) and flow length. Which of the mentioned influences are placed in the numerator and which in the denominator of the expression for the fill time? (Fill time $= \frac{a\,b\,c}{d\,e\,f}$**.)**

Viscosity, porosity and flow length are placed in the numerator, the larger the value the longer it takes. Permeability and pressure difference are placed in the denominator, the larger the value the quicker it goes.

2.3.5. Why is a (double) curved shell structure easier to produce in composites than in metals?

A composite is created during the production. Before production composites have a textile appearance and thus easy to shape in many forms. Metals are often preshaped (sheet, plate) and need force (and often temperature) to change shape.

2.3.6. When you compare the properties of composites with metal, it appears that the properties of composites show much more scatter. Give a reason why this increase in scatter occurs.

Since composites are created during the production the properties are created as well. All possible variation that can occur during the process influence the values of properties. Metal products are often shaped from semi-manufactured parts. The properties are already fixed and the manufacturing process has less influence.

2.4 Filament Winding

2.4.1. If you compare driving a car from Amsterdam to Paris and geodesical winding of a sphere, what can you tell about the steering of the car?

You don't need to steer, a geodesical path is the shortest so a "straight" line.

2.4.2. When a cone-like shape is wound by the filament winding process, the orientation differs from cross-section to cross-section according to the law of Clairaut. At cross-section $A - A$ the radius is $R = 100mm$ and the winding angle is 45 degrees. At cross-section $B - B$ the radius is $R = 80mm$.

- **What is the expected winding angle at cross-section $B - B$?**
- **How many windings are needed to fully cover section A-A when the width of the tape is 11.2 mm?**
- **Will section B-B become fully covered as well when applying the same amount of windings?**

- The winding angle at $B - B$ is

$$\arcsin\left(\frac{100}{80}\sin 45\right) = 62.11^\circ. \tag{2.4.1}$$

- The width in cross section $A - A$ is

$$\frac{11.2}{\cos 45} = 15.84mm. \tag{2.4.2}$$

  The perimeter is $2\pi R = 628.32mm$. The number of windings needed therefore is

$$\frac{628.32}{15.84} = 39.66. \tag{2.4.3}$$

  So 40 windings are needed.
- Yes, almost twice! $\left(\frac{502.65}{23.94} = 20.99\right)$

2.4.3. If you compare driving a car from Amsterdam to Paris and non-geodesical winding of a sphere, what can you tell about the steering of the car?

You need to steer according to the way the non-geodesical path you follow. Every corner in the road to Paris is thus a nongeodesical change of the path.

2.4.4. What is an isotensoid structure?

An isotensiod structure is a structure in which all structural members are loaded equally. i.e. all fibres have the same tension in a composite product.

2.4.5. What is an advantage of an isotensoid structure over a non isotensiod structure?

Since everything is stressed equally, the lightest solution for the materials applied is achieved.

2.4.6. What is a disadvantage of an isotensiod structure over a non isotensiod structure?

The shape of the structure is often prescribed leaving little room for design of the shape.

2.4.7. Give two reasons why it becomes possible for (isotensoid) LPG pressure vessels of carbon fibre to be cheaper than (isotensoid) LPG pressure vessels of glass fibre?

Amount of fibres needed is less, since the properties of carbon fibre are better. The time needed for winding is thus less, shortening the process time and lowering costs to a large extent.

2.5 Forging

2.5.1. Why is forging not a suitable process for short fiber reinforced thermoplastics?

Short fibre reinforced polymers do not possess strain hardening which is essential for forging.

2.5.2. Why is a temperature increase needed during hot forging?

Material properties change with temperature. The right yield stress, strain hardening and max strain are often only available at elevated temperatures.

2.5.3. Which three functions could be fulfilled by lubricant during forging?

- Lowering friction, thus reducing wear of the mould.
- To work as thermal barrier between hot workpiece and relatively cool dies (slowing workpiece cooling rate and improving metal flow).
- Preventing workpiece from sticking to the dies and help its release from the die.

2.5.4. What makes the mechanical properties of a forging better than those of a casting?

The grains are better shaped and oriented than after casting. Strain hardening is present.

2.5.5. What do you expect of the internal stresses at the middle and near the outside of a forged flat plate after cooling?

At the middle tension will be present, while near the outside compression will be present. Due to the quicker cooling of the outside, the outside is relative larger than the inside. So the inside tries to make the outside smaller (compression), and vice versa.

2.5.6. Is this favorable for fatigue loaded structures or not? Explain your answer.

Yes, compression at the outside lowers the average stress during fatigue which leads to lower crack growth (and delayed crack initiation).

2.5.7. Give two different type of processes in which a shrinkage allowance is applied.

Casting and forging (processes which have a large difference between process temperature and usage temperature).

2.6 Extrusion & Pultrusion

2.6.1. Name three differences between extruding metal alloys and thermoplastic polymers?

- Temperature is higher for metal.
- Transportation of material to the die: for metal, a plunger is used while for polymers a screw is used.
- Small amounts of material can easily be fed into the screw, so the thermoplastic extrusion has a continuous nature, contrary to the metal variant.
- Thermoplastics swell when they exit the extruder due to low stiffness (elastic springback).

2.6.2. Why is the extrusion of aluminum so popular when compared to extrusion of steel (two important reasons)?

Aluminum is softer, so the tools are not as highly loaded as during steel extrusions. Secondly, aluminum alloys are the only materials which show good welding properties during extrusion. Also the temperature and pressure are lower.

2.6.3. What does the shape factor of an extrusion express?

The shape factor equals the perimeter divided by the cross sectional area. It is (among others) a measure for the complexity of the product.

2.6.4. Why is pultrusion not suitable to produce metal alloy profiles?

There is a soft phase present when forming the metal, so pulling at the metal will only result in breakage.

2.6.5. Why can splitting be a problem for a pultruded product?

The composite as present in pultruded profiles is highly anisotropic. Mechanical properties in pultrusion direction are very good, contrary to properties perpendicular to this direction. UD reinforcement is sensitive to splitting because the strength perpendicular to the fibers is low (resin dominated).

2.6.6. Compare the temperature and pressure of the extrusion and pultrusion process?

Temperature in the extrusion process should be high enough to preheat the metal billet and for heat treatment. Pressure has to be very high so that the material is forced to deform through the die. In the pultrusion process an appropriate temperature is used to cure the resin. A pulling machine needs only low forces to pull the profile through the mould. In short, temperature and pressure are much higher during extrusion.

2.6.7. With which process, extrusion or pultrusion, can you make the largest product considering only the cross section area? Explain your answer.

The size of pultruded profiles can be larger than those produced via extrusion, in terms of CCD (Circumscribing Circle Diameter). This is caused by the low forces during the pultrusion process. The forces and temperatures are much lower, so machines (and dies) do not have to be that stiff and strong and can be scaled up easily.

2.6.8. What is the difference between the mould used during extrusion and the mould used during pultrusion?

An extrusion mould ('die') only shapes the product. Pultrusion moulds have to support the loose impregnated rovings, and curing should take place as well. So the moulds also have to be much longer.

2.7 Compression Moulding

2.7.1. Why could you expect that compression moulding is the most applied process for reinforced products?

The cycle time is short, it can be automated, it reproduces very well, it has a large freedom in design.

3. Fabrication Process with Sheet Materials

3.1 Sheet Forming

3.1.1. The stress-strain relation can be made visible using a tension test.

- **What areas can be distinguished in such a curve for a metal?**
- **What is the relationship/formula between the stress and strain in the elastic area?**

- Elastic area, uniform deformation, (diffuse) necking area, local necking up to failure.
- Hooke's law/E-modulus: $\sigma = E\varepsilon$.

3.1.2. For the plastic area there is no unambiguous relationship. Why not?

The deformations are a combination of elastic and plastic deformation. Continued deformation is performed at decreasing forces (instability).

3.1.3. What is a stress state? What is a strain state? Try to give some examples.

The ratios of stresses and strains in different directions. Stress & strain states have a dimension, for example the strain state of a tensile test is one-dimensional, while its strain state is three-dimensional!

3.1.4. What stress and strain states are active (in the plastic area) during a tensile test of an isotropic metal?

The stress-state in axial direction is active (the 2 directions perpendicular to the pulling axis are free to contract, so no stress is present there). The strain states in all 3 directions are active. The strain in both directions perpendicular to the axial direction is equal.

3.1.5. What stress and strain states are active (in the plastic area) during biaxial testing of an isotropic metal?

Only 2D in-plane stress, again 3D strain.

3.1.6. "A tensile test has one maximum strain; sheet forming often has different combinations of maximum strains". Could you explain this statement?

A tensile test has one maximum strain in axial direction, while a sheet is stressed in multiple directions so it can fail in multiple ways.

3.1.7. What is a Forming Limit Curve?

When the forming limits (as function of strain in direction 1 and direction 2) for in-plane stress are represented by a line, it is called an FLC. The FLC for a tensile test has one failure limit for a linear stress situation, so it is a point.

3.1.8. Mention two reasons for the application of heat treatments (for metals).

At first, to improve the formability of the material. When the product has been formed, other heat treatments may improve the mechanical properties (at the cost of its formability).

3.2 Bending

3.2.1. Mention at least two different processes to manufacture profiles.

Bending or extrusion.

3.2.2. Mention at least three different bending methods for the manufacture of stringers.

Press brake bending, wipe bending, guided bending or roll bending.

3.2.3. What is a spring back angle?

The angle over which a material bends back after deformation, which is due to elastic deformation.

3.2.4. What causes spring back?

Elastic deformation. Spring back is elimination of this deformation when the loads are released.

3.2.5. Why has spring back a negative influence on the production?

Tools and dies should have a geometry different from the product geometry to compensate for the geometrical changes after spring back.

3.2.6. What parameters have an influence on spring back?

Spring back is related to ratio of elastic energy stored in the material during bending, and total energy required for bending. The total energy is the area under the stress-strain curve up to the applied strain. The elastic energy is a portion of this area. Plastic energy + elastic energy = total energy. So the spring back angle is influenced by material properties, bend radius, sheet thickness and bend angle.

3.2.7. What parameters can be manipulated to reduce spring back? How?

E-modulus E up $\Rightarrow$ spring back angle down (reduction of ratio elastic/total energy); yield strength up $\Rightarrow$ spring back angle up; bend ratio r/t up $\Rightarrow$ spring back angle up; bend angle up $\Rightarrow$ spring back angle up.

3.2.8. What is the relationship between spring back and residual stresses?

Both are related to the elastic deformations. e.g. when spring back is small, residual stress is high and vice versa.

3.2.9. What is the most important problem in roll bending and why?

The control and/or prediction of spring back, because elastic energy is relatively large with respect to total applied energy.

3.2.10. Why is roll forming only applied for large product series?

Expensive tooling (rolls are more or less product related, large number of different rolls needed), so large series required to reduce tooling cost per product.

3.3 Stretch forming

3.3.1. For what parts is stretch forming applied?

Large and slightly double curved shells for instance in the front and aft sections of the aircraft fuselage.

3.3.2. Is stretch forming a pure bending process?

No, bending and stretching are combined in one process, so in-plane stress occurs.

3.3.3. The visible spring back of stretch forming is eliminated. Explain how.

Material on both inside and outside surface springs back in same direction. The elastic strains in both cases are nearly the same. so the spring back perpendicular to surface which increases sheet radiuses is negligible. In-plane, there is however some spring back. So in short, by changing out-of-plane spring back into in-plane spring back, spring back is reduced.

3.3.4. What is the major advantage of minimizing this spring back?

Elimination or reduction of residual stress.

3.3.5. The maximum applicable strain in stretch forming is limited to 6-8%, even when the failure strain is much larger. Why?

By forming you 'consume' some plasticity and toughness is reduced, after forming the material is more brittle.

3.3.6. Such a limit is not applied for bending. Why not?

Stretch forming applies global deformations (over the entire surface - also in loading directions); bending applied local deformation in transverse direction.

3.4 Deep drawing

3.4.1. Give a brief description of "deep drawing".

Deep drawing uses rigid dies. A metal sheet is drawn through a die opening, then punched so it is transformed into a cup with a bottom and vertical walls. The material at the part's bottom is stretched in two directions (biaxial stretching); the material in the flange of the product is deformed by in-plane shear.

3.4.2. Which tools of the deep drawing process are product related?

The punch, it provides the shape to the part.

3.4.3. What stress and strain states occur in the flange of a deep drawn part?

Shear mode: Tangential deformations are compressive, radial deformations are in tension.

3.4.4. What is the function of the blank holder?

Prevention of wrinkling: by the inwards movement of the material, the tangential distances reduce, compressive stresses will occur, so there is danger of buckling.

3.4.5. Explain that, when in the wall of a cylindrical cup plain strain occurs, the stress in tangential direction is non-zero.

The material can not deform in tangential direction because it is wrapped around the die. But it is being deformed. Therefore there exists tensile stress.

3.4.6. Matched die forming is applied in the automotive industry but not in the aircraft industry. Why?

It is too expensive for the aerospace industry. The product series are too small to invest in such costly tooling.

3.5 Rubber forming

3.5.1. Rubber forming is a process highly suitable for the aircraft industry. Why?

Low tooling costs (so low production costs); for the manufacture of a part only one product related tool is required, the other tool is the flexible rubber die. Secondly, the rubber forming press is a universal piece of equipment; wide variety of parts can be press formed on the same press.

3.5.2. What is the most dominant product shape in the rubber forming process?

Flanged parts, like wing ribs. Often these flanges are curved, because straight flanges can better be made without special dies, by bending.

3.5.3. What different rubber forming processes can you mention?

Regular or Fluid cell.

3.5.4. The complexity (height/diameter ratio) of hollow, deep drawn like shapes, made by rubber forming is much smaller than for deep drawing. Explain.

The rubber pad is not flexible enough to go very deep, while the rest of the pad should also cover the sides of the material and die. The punch in deep drawing does not have to be flexible.

3.5.5. What is the strain state in a stretch flange?

The same as in a tensile test: tension in flange direction, free contraction in height and thickness directions.

3.6 Superplastic Forming

3.6.1. What is the most important feature of superplastic forming?

It can lead to large deformations, so complex parts can be made in one process cycle. With increasing part complexity, the number of parts can be reduced so the number of tools-assembly costs-number of joints-weight and therefore eventually cost is reduced.

3.6.2. Superplastic forming has a special deformation mechanism. Which?

No dislocation movement occurs such as during plastic forming of metal alloy crystals. Instead, the crystals are not deformed but slide along each other.

3.6.3. What are the prerequisites for the process/material in order to apply superplastic forming?

High temperature ($500-900^{\circ}$, depending on material), special equipment to withstand that temperature, inert atmosphere (in case of titanium alloy). Stable crystal structure, particular strain rates. Small grains with dimensions equal in all directions, high strain rate sensitivity at a particular range of strain rates.

3.6.4. During superplastic forming the flow stresses are very low. What is the advantage of this fact?

Gas pressure is sufficient to stretch form the material into a die cavity.

3.6.5. What is diffusion welding/bonding?

The creation of a bond between two metal surfaces squeezed at high pressures and temperatures by means of atomic diffusion and migration.

3.7 Forming of Fibre Reinforced Thermoplastics

3.7.1. Often, thermoplastic composites (continuous fibers) can be formed similar to metal sheets. However, there are two important differences. Which?

The presence of a heating unit during forming. Also matching dies (constant gap width) are not used due to the Trellis-effect (thickness of FRTP laminate may change considerably over the surface). If they were, the composite part will be damaged.

3.7.2. Does the type of fabric have an impact on the "formability" of the composite?

Yes, different types of fabric have other fiber orientation.

3.7.3. "Compression moulding" is applied for composites having small/long fibers, not for composites with continuous fibers. Explain.

Smaller fibers flow with the resin. Continuous fibers will not.

3.7.4. What processes for thermoplastic composites are suitable for the manufacture of: stringers/profiles, double-curved shells, deep drawn like parts?

Rubber forming, deep drawing, etcetera.

3.8 General forming questions

3.8.1. What is a universal process?

A process that is applicable to a wide range of different parts.

3.8.2. What is the benefit of universal processes?

Lower tooling costs, as they do not have to be made specifically for every product series.

3.8.3. Why are universal processes important for aerospace production?

Huge diversities of products and limited product series are possible.

4. Fabrication Processes by Separating

4.2 Separation by Removal

4.2.1. What is the difference between punching and blanking?

In punching the slug is discarded (scrap), while in blanking the slug is the product.

4.2.2. Is a perforator a punch or a blanking process? Clarify your answer.

Punch: the slug is discarded.

4.2.3. Why is fine blanking not suitable as a punching process?

During fine blanking the clamping of the sheet is such that an indentation is made in the sheet. With punching this would mean that the product has a dent, and that is not what you want.

4.2.4. What is the importance of a right clearance during the shearing process?

A right clearance causes the material to shear the way that you want.

4.2.5. What can happen when the clearance during shearing is much too large?

The sheet will start to rotate when it is not properly clamped, or bend when the clamping prevents the rotation.

4.2.6. Why is a cutting angle of zero degrees never applied during the shearing process?

A cutting angle of zero degrees implies that the sheet is cut over the full width at the same time. This would need a very large force, leading to expensive equipment and thus raising costs.

4.2.7. Why is nesting so important during shearing processes such as blanking?

By nesting properly the lost material (scrap) is minimized.

4.2.8. Why is it almost impossible to apply shearing, punching or blanking processes to composites (continuous fiber reinforced polymers)?

During these processes the material separation is caused by shearing material. When composites are subjected to these kind of forces, edge damage such as delamination will occur, which is not acceptable.

4.2.9. Explain what happens with the metal work piece material during punching.

Just after contact of the punch and metal sheet the sheet will be dented locally. At a certain depth a crack caused by shearing will occur, separating the slug.

4.2.10. State three processes that can produce a curved cutting line in a flat sheet.

Nibbling, laser beam cutting, plasma arc cutting, electrical discharge wire cutting, water jet cutting.

4.2.11. Why is it not possible to apply electrical discharge machining to composites (continues fibre reinforced polymers)?

The material to be processed during electrical discharge machining needs to be electrically conductive. Polymers based composites are however insulators.

4.2.12. Why is it almost impossible to apply laser-beam cutting to composites (continues fibre reinforced polymers)?

During laser beam cutting heat is transferred to the material of the workpiece. For polymer based composites this means that the edges can become degenerated (burned), which is not acceptable.

4.2.13. What is the most important requirement for the cutting process when the workpiece is a composite material?

The most important requirement is that the edges are not damaged. Burning or delaminations can easily occur as a result (consequence) of a separation process.

4.2.14. When plasma arc and laser beam based separating processes are compared, what is an advantage of plasma arc over laser beam, and what is an advantage of laser beam over plasma arc?

Costs are lower for plasma arc cutting. Laser beam cutting is more accurate.

4.2.15. What is the difference between water jet cutting and abrasive jet cutting (process and material)?

During water jet cutting the water itself is cutting, while during abrasive jet cutting the to the water added hard particles are cutting. Also the workpiece materials for water jet cutting are much softer than those for abrasive jet cutting.

4.2.16. Explain what jetlag is.

Jetlag is the bending of the water beam as a result of the movement of the beam itself.

4.2.17. Why does jetlag occur during water jet cutting and not during laser beam cutting?

During water jet cutting material is mechanically removed. The force exerted on the workpiece is also exerted on the beam (action=reaction). Since the beam has no bending stiffness, the beam will always be bend as soon as there is movement. During laser beam cutting material is thermally removed

4.2.18. Why are lubricants applied during shearing processes?

Lubricants are applied to reduce friction. Thus less heat is generated and wear is also less.

4.2.19. State two processes that can process the result of a punch or blanking process?

Rubber pressing, deep drawing, bending processes.

4.2.20. Which processes can be applied to produce the product shown below left? Metal, so e.g. Shearing to obtain the outer contour. Punching or drilling to obtain the holes. Rubber pressing to bend the sheet and to create the bosses/beats (stiffening elements).

4.2.21. Which processes can be applied to produce the product shown in figure 4.1?

The product is made out of metal. So for example shearing can be used to obtain the outer contour, punching or drilling to obtain the holes and rubber pressing to bend the sheet and to create the bosses/beats (stiffening elements).

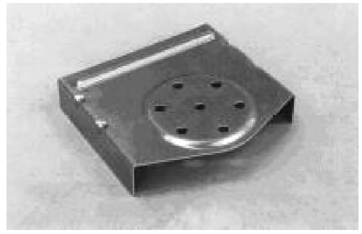

Figure 4.1: Example of a product.

4.2.22. Which processes can be applied to produce the product (continuous fibre reinforced thermoplastic) shown in figure 4.2?

The product is made out of a thermoplastic material. So for example lay-up of thermoplastic prepregs, abrasive jet cutting for cut outs and rubber forming (matched die) for the bending.

4.2.23. Which processes can be applied to produce the product (continuous fibre reinforced thermoset) shown in figure 4.2?

The product is made out of a thermoset material. So for example cut it from a role, lay-up of dry fibre material or vacuum injection (impregnation and curing). Cut outs in the final product can be made by sawing (diamant) or abrasive jet cutting.

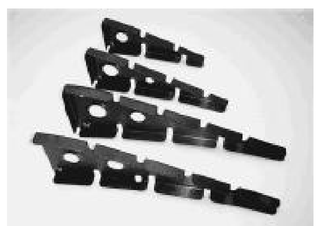

Figure 4.2: Example of a product.

4.3 Machining

4.3.1. Sketch a chisel in two dimensions and name the three angles of the chisel.

See the summary, figure 4.1.

4.3.2. The force of a chisel on a workpiece can be split into three. Which are those three forces?

Cutting force, Feed force and Thrust force.

4.3.3. Give two ways in which the life span of a chisel can be expressed.

Life time (hours,minutes), life length (meters) and life amount (number of products).

4.3.4. Explain how wear of the rake face occurs.

The rake face is the side where the chip makes contact. Due to rubbing of the curved chip on the rake face the rake face will wear, showing a typical crater.

4.3.5. Why does wear occur at the flank of a cutting tool?

Since forces are applied at the workpiece, the workpiece deforms. After cutting spring back will occur, which is the reason for the workpiece touching the chisel at the flank, causing wear to occur.

4.3.6. In what type of energy is the energy needed to cut material transformed?

The energy is transformed into "deformation" energy and heat.

4.3.7. Which two causes exist for the occurrence of heat during cutting?

In the shear zone heat is generated as well as at the places of friction (rake face and flank).

4.3.8. What do you prefer: a continuous chip or a discontinuous chip during machining. Why?

A discontinuous chip, since it can not become entangled with the cutting tool and workpiece.

4.3.9. How can one change the chip shape?

Change the chisel geometry. Use for example a chip break grove, or a chip breaker. You can also change the process parameters, like the feed and the cutting speed.

4.3.10. Which two functions are performed by the cutting fluid?

Lubrication, giving less friction, less wear and thus less heat development. Also cooling, absorbing heat. The cutting fluid can also remove chips.

4.3.11. Give two material aspects (properties) which are important for cutting tools.

(Hot) hardness, yielding point, stiffness, brittleness, toughness, wear resistance.

4.3.12. Although tool steel is harder than high speed steel, high speed steel is preferred as cutting material. Why?

At elevated temperature tool steel shows a drop in hardness, while HSS has a different behaviour.

4.3.13. Why is diamond not used as cutting material for steel and cast iron?

Steel and cast iron absorb the carbon from the diamond, and the carbon content is very important for the properties of the steel and cast iron. (More carbon, more defects, less toughness and thus more brittle.)

4.3.14. Explain the cutting speed influence on the cost per product.

Higher speed means more products per time. So lower labour/machine costs per product. However, more products per time means more tool wear, and thus more tool costs and tool change costs.

4.3.15. What influence does the stiffness of the workpiece material have on the obtained accuracy?

The lower the stiffness, the easier (less force needed) the workpiece deforms, and thus the lower the accuracy. Think of cutting rubber.

4.3.16. Explain the difference of conventional milling and climb milling.

In conventional milling the cutting movement is in opposite direction of the product movement. In climb milling the cutting movement is in same direction as the product movement.

4.3.17. Explain that the middle section of a drill cuts more difficult than the outer section.

In the middle of a drill the rake angle of the drill is negative. This makes cutting difficult. In the outer section the rake angle is positive. This makes cutting easier.

4.3.18. Why is the end of life of a cutting tools (e.g. a tap) not breakage?

Breakage means that the tool might get stuck, which ruins the workpiece. Before it occurs, the wear of the tool will compromise the needed accuracy.

4.3.19. Why is grinding not fit to remove large parts of workpiece materials?

Since grinding is done with a negative rake angle of the cutting parts, less material can be removed per time, which means that more time is needed and thus that it is likely that with some other tools the work could be done faster/cheaper.

4.3.20. Why is a side and face cutter not made from the same material as that of an insert (titanium carbide)?

The shape of a side and face cutter is very complex for creation from materials such as titanium carbide. A coating can be applied however.

4.3.21. Why is a coating of ceramic cutting material preferred over a full ceramic cutting material?

Ceramic cutting materials are very hard but also brittle. A tool from only ceramic would be to brittle to sustain the mechanical shocks as present during cutting. (Next to that, it is also (too) expensive.) The outside of a cutting tool is needed for cutting and the inside for toughness.

4.3.22. Give some possible reasons why fuselage frames for fighter aircraft are milled?

Complex shape, amount of products, accuracy, etcetera.

4.3.23. What are two important aspects for the fixture of inserts considering a face mill?

For a face mill, roundness and flatness accuracy are important. In general, position control is important.

4.3.24. Why do you prefer to machine a product by only clamping it once (and not twice)?

The accuracy is becoming more difficult (or impossible) with multiple clamping stages.