**AE4ASM004: Manufacturing of Aerospace Structures & Materials**
**Answers**

**Question 1** [Composite basics]

Carbon/epoxy is the most frequent fibre/resin combination used in aircraft composite structures nowadays. Can you explain why? In these structures, which is the most common reinforcing type (continuous or discontinuous) and why? Is epoxy a thermoplastic or a thermoset resin and why?

**Answer 1**

Owing to performance, low weight, manufacturability and experience. The most common reinforcement type is continuous fibres since it is the one that results in the highest mechanical properties. Epoxy is a thermoset resin, it has a 3D cross-linked molecular structure obtained upon curing.

**Question 2** [CTE's, elastic & plastic deformation]

A flat rectangular laminate made out of two different metals intimately connected to each other is subjected to a certain temperature cycle in an oven. Once the cycle is completed, the originally flat laminate turns into a cylindrical shell. What does this indicate regarding the properties of the two materials and their isotropy? Would you expect the same effect in a composite laminate?

**Answer 2**

The change in shape indicates that the coefficients of thermal expansion of both materials are different. The final cylindrical shape indicates that at least one of the materials is not isotropic (different properties in 0 and 90° directions). If a flat composite laminate (already solid/cured) is placed in an oven, CTE differences may cause shape changes with temperature, however, since composites do not undergo plastic deformation, the laminate will return to its original flat shape upon cooling down.

**Question 3** [Heat capacity/heat transfer]

A certain part is placed in an oven originally at room temperature. Once the oven door is closed, the temperature in the oven is increased by injecting hot air into it. The temperature at a specific location of the part is monitored using a thermocouple. What can you say about the heating rate in the part in relation to its mass? What can you say about the cooling rate if (1) hot water /(2) hot oil are injected in the oven instead of hot air (consider that water, oil and air are at the same temperature)?

**Answer 3**

The heating rate in the part will increase for decreasing mass.
Heat is transferred to the part from the surrounding environment through convection. The convective heat transfer coefficient, and hence the rate at which heat will be transferred to the part, depends on the nature of the fluid inside of the oven. In principle, the convective heat transfer coefficient for gases is lower than for liquids.

**Question 4** [relation between material and structure]

Material properties and structural properties sometimes get the same names although they are not identical. What is the similarity and difference between material stiffness and structural stiffness (both for tensile load)? What parameters influence the structural stiffness?

**Answer 4**

Material stiffness, Young's modulus or E-modulus is a material property and depends on the composition and microstructure of the material. The material stiffness is independent of the shape of the test specimen. Structural stiffness depends on (1) material stiffness and (2) shape/geometry of the structural element. So, the structural stiffness can be manipulated not only by changing the material, but often more effectively by changing the shape/dimensions of the component/part.

**Question 5** [understanding of mechanical behaviour of metals]

During testing metal alloys show elastic and plastic behaviour. Describe both behaviours briefly. Does a metal alloy deform exclusively plastically beyond its yield point? What parameters of a stress strain curve are important for the evaluation of the formability of a metal alloy? How can you change the formability of a metal alloy (increase or decrease)?

**Answer 5**

Elastic behaviour can be understood by a "rubberlike" behaviour of the material: when the load increases, the deformation increases too, but upon unloading the original shape of the specimen is fully recovered. Plastic deformation is irreversible: once the material is deforming plastically, displacements in the microstructure cause permanent deformation. Plastic deformation occurs once a limit stress is exceeded (so-called yield stress). Beyond the yield stress however, the elastic deformations still increase, although limited. A metal alloy has a good formability if the applicable deformations are large (large failure strain) and the required loads to deform the alloy plastically are low (low yield stress). The formability of a metal alloy can be changed by heat treatments: both increasing and decreasing of its formability are feasible – depending on the type of alloy.

**Question 6** [manufacturing processes & trade-off]

What processes are available to manufacture a thin-walled 3D product (rough outer dimensions 0.25 x 0.25 x 0.25 meter)? What are the basic principles of each of the processes you mentioned? What criteria would you choose (and why) when you have to select the best process?

**Answer 6**

For metal alloys: all kind of sheet forming processes like deep drawing, press forming, etc., (Casting, machining an forging processes are not feasible). For composites typical processes are lay-up techniques, resin injection techniques (like vacuum infusion, RTM), compression moulding (for long fibres) and injection moulding (for short fibres). The criteria to select the process stems from the material that has to be processed (performance of the product), the required quality and the required product series (quantity).