

SECTION A.

Question :1

(a) ① Hydrogen

a. Hydrogen is considered an ideal energy source because its only emission at low combustion temperatures is water vapour. $2H_2 + O_2 \rightarrow 2H_2O$. At higher combustion temperatures it will produce a certain amount of nitrogen oxides. This can also help with reducing NOx along with water injection. Hydrogen can be used only in the electrolysis process of fuel cells but also in the spark ignition of internal combustion engines.

b. However, hydrogen is extremely volatile at room temperature and can ignite or explode at the slightest spark, making it very dangerous. This is why the general public considered this quality to be dangerous and did not want to use it as alternative fuel.

c. However, very few petrol stations are equipped with tools to replenish hydrogen and have ability to refill it, as opposed to filling stations. Hydrogen as an alternative energy source is ~~stored~~ stored in a liquid state.

So there we need more hydrogen refuelling and safer and more efficient ways of preserving hydrogen

② Bio-butanol.

Bio-butanol is a renewable second generation alcohol fuel that is ~~transparent~~ colourless, and has a higher energy density and lower volatility compared ethanol. When looking at its safety and simplicity of use butanol will outperform ethanol, biodiesel ~~and~~ as a gasoline alternative. ~~Bio~~ Bio-butanol has promising applications due to its good water insolubility/hygroscopicity, low vapour pressure, high calorific value, low flammability. Butanol is more environmentally friendly than petroleum-refined fuels, thus reducing the greenhouse gas emission from petrol refining process.

However, since bio-butanol is not as easy to produce as it is at present, it may be an additional burden for users.

In order to produce bio-butanol, more crops and plants are needed. As UK does not have many indigenous, given the conversion efficiency it may be necessary to import large quantities.

Question 2.

(a) Ionic Bonding is when atoms transfer electrons between each other. When an atom donates an electron, it becomes positively charged. When receiving an electron, the opposite happens, and the atom becomes negatively.

Covalent Bonding is when atoms share electrons but don't permanently transfer them. Mostly happen with non-metals and happens with atoms of the same element or elements close to each other on the periodic table.

Metallic Bonding — Metal atoms are free to fling electrons from the shell instead of sharing electrons directly. This is therefore creates a sea of positively charged ions and "free" electrons. And it is be named delocalised electrons. Ions form a tight lattice structure and their electrons fill in the empty parts of it. The valence of an element is number of electrons it gains or loses when atoms combine each other.

(b). 4 atoms per unit cell = FCC

$$a = 2\sqrt{2}R \quad a = 0.362 \text{ nm} = 0.362 \times 10^{-9} \text{ m}$$

$$a = 2\sqrt{2}R$$

$$R = \frac{a}{2\sqrt{2}} = \frac{0.362 \times 10^{-9}}{2\sqrt{2}} = 0.128 \times 10^{-9} \text{ m} = 0.128 \text{ nm}$$

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(c) Conditions that impact the 'ideal' alignment of the lattice structure of a crystalline material are considered defects.

Crystalline structures suffer from 3 main types of defects

① Point Defects.

There are in turn three different categories of point defects themselves.

1) Vacancies.

During lattice formation, the missing atoms leave vacancies in the lattice structure so that the atoms around them will move towards the vacancies and eventually deform, forming defects.

2) Self-Interstitials

Autogap defects occur when an atom becomes positioned between atoms of the normal lattice structure, but this position appears in the wrong place and is not in order.

3) Substitutional.

Substitution defects occur when the original atom at a lattice site of a crystalline solid is replaced by a different type of atom. But substitution defects are different from interstitial defects. This is because the foreign atoms should only occupy lattice sites and not interstitial positions.

d) Secondary phase

Secondary phase is the predictable stage of creep. Because it shows the material deformation stabilise and act in a linear manner. And secondary creep is a relatively slow and predictable stage of the failure mechanism. After the initial grain rotation, the dislocations with the structure begin to move to the applied loading. The dislocation will move towards the grain boundaries as the crystalline structure realigns. These dislocations will tend to coalesce at the nodal triple points, where multiple grain boundaries intersect.

a) ① Casting

Casting is an ancient technique that has been refined over time. It is a process in which liquid metal is poured into a mould, cooled and then extracted. Many automotive parts are cast. Use steel or aluminium.

Casting has lots of Advantages. Casting allows the production of large and complex shapes, such as chassis for cars, engine parts. It also has a short production cycle and can be produced in large quantities with just one grinder. Moreover, this mould can be reused once it has been manufactured. As the process involves melting the metal and then cooling it to shape, many high melting point metals can be used for casting.

But it still has some disadvantages. As it is melted and cooled to form the required parts. It is not possible to control the dimensions precisely. The liquid is also fluid, so the surface finish of the part is poor. Also, heating the metal requires a lot of energy, so it is very labour and energy intensive. Once cast, the parts cannot be used directly, ~~which can be stated as~~ and require additional processing, which can result in material losses of up to 10%.

② Forging.

Forging is combination of heat and pressure to transform a billet into the desired shape. The mould is used to form the shape of the part and it can produce a stronger final part.

Advantages.

Variety of components can be made. And Grain structure aligns so it can lead to better strength properties. And Forging has high production rate and it has minimal material wastage.

Disadvantages.

① Forging initial costs is too high and it need large production run to be viable. At the same time, the moulds subject to wear and tear, and limited shape forming. Various secondary process required.

③ Extrusion

Material is pushed through a shape form to produce the desired profile

Advantage -

Extrusion can ~~compete~~ make complex shape. And ~~structural~~ structural members is very excellent. Virtually no material and very rapid production process.

Disadvantage.

Requires low melting point alloys. And extrusion process can leave defects. And the tooling is very complex and expensive. Brittle materials struggle to be extruded.

② Line Defects.

Dislocations.

Line defects are caused by dislocation in the lattice, which are a defect in the structure. As these regions move, bonds between atoms break, and once the sliding motion is complete, new bonds are formed.

③ Area Defects.

Grain boundaries create regional defects in the crystal structure. This is because grain boundaries are between crystals in a material and this leads to change in the bonding structure. Regional defects can lead to different orientations of the crystals. But grain boundaries can help to prevent dislocations from occurring.

Defects have a significant impact on physical properties and can greatly affect the thermal, electrical, optical, and mechanical properties of the material, greatly affecting various performance indicators such as strength and plasticity.

b) ① stage 2 - likelihood of Detection (D).

How likely is it that the failure will be detected before it causes a catastrophic issue. Ranged 1-10, where 1 = absolute certainty of detecting the failure.
10 = unlikely to detect the problem.

Where would the identifier be before a fault occurs? Certain mechanisms need to be in place to identify problems before they are presented to the consumer.

② stage 3 - Severity Number (S)

Ranking the severity of the potential failure on a numeric scale 1-10.
10 - worst, can be a business case (process). Or can be risk to life/injury
(component failure)

③ stage 4 - probability of Occurrence (P)

For each failure mode, identify the probability of the failure happening in the lifetime of the ~~product~~ product.

ie: How likely is it that this identified failure will occur.
ranked 1-10. 10 = unavoidable occurrence.

$RPN = D \times S \times P$. The higher the RPN the more effort should be put into resolving the issue.

$$c) (i) D = 10 \text{ mm} = 0.01 \text{ m}$$

$$h = 1.5 \text{ mm} = 0.0015 \text{ m}$$

$$r = 0.5 \text{ mm} = 0.0005 \text{ m}$$

$$\frac{h}{r} = \frac{1.5}{0.5} = 3 > 2$$

$$\sqrt{\frac{h}{r}} = 1.73$$

$$P = 55 \text{ N} = M$$

For Bending, $C_1 = 0.935 + 1.922 \times 1.73 + 0.004 \times 3$

$$= 4.272$$

$$C_2 = -0.552 - 5.327 \times 1.73 + 0.086 \times 3$$

$$= -9.51$$

$$C_3 = 0.754 + 6.281 \times 1.73 - 0.121 \times 3$$

$$= 11.757$$

$$C_4 = -0.138 - 2.876 \times 1.73 + 0.031 \times 3$$

$$= -5.02$$

$$K_t = C_1 + C_2 \left(\frac{2h}{D} \right) + C_3 \left(\frac{2h}{D} \right)^2 + C_4 \left(\frac{2h}{D} \right)^3$$

$$\frac{2h}{D} = \frac{2 \times 1.5}{10} = 0.3$$

$$= 4.272 + (-9.51 \times 0.3) + 11.757 \times (0.3)^2 + (-5.02 \times 0.3)^3$$

$$= 2.297$$

$$(ii) G_{max} = K_t \times \frac{32M}{\pi(D-2h)^3} = 2.297 \times \frac{32 \times 55}{\pi(10-2 \times 0.0015)^3} = 3.752 \times 10^9 \text{ Pa}$$

$$(d) K = G \sqrt{\pi a}$$

$$K = K_c \Rightarrow G \sqrt{\pi a} = \sqrt{G_c E}$$

$$K_c = \sqrt{G_c E}$$

$$\Rightarrow G_c E = G^2 \cdot \pi \cdot a$$

$$a = 3.5 \text{ mm} = 3.5 \times 10^{-3} \text{ m}$$

$$E = 200 \text{ GPa} = 200 \times 10^9 \text{ Pa}$$

$$G = 67.5 \text{ MPa}$$

$$= 67.5 \times 10^6 \text{ Pa}$$

$$G_c = \frac{G^2 \cdot \pi \cdot a}{E} = \frac{(67.5 \times 10^6)^2 \times \pi \times 3.5 \times 10^{-3}}{200 \times 10^9}$$

$$= 2.148 \times 10^4 \text{ Pa.m}$$