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Section A

- a. Diobutanol is a renewable, second-generation alcohol fuel. This kind of fuel has higher energy density than ethanol but does have a lower volatility. Butanol is able to reach a higher mix rate with gasoline compared to ethanol and its energy density is also closer to gasoline, this makes this new fuel more compatible with existing systems. Reversing the on-demand manufacture of a new partition ICE system all together.

Dimethyl ether (DME) is a fuel which is manufactured by converting coal or natural gas into syngas and then into methanol in the presence of a catalyst, this is then dehydrated to form DME. It is used for blending into liquefied petroleum gas (LPG) to improve its burning properties, this will help improve the burn efficiency and to reduce emissions.

- b. Due to butanol ability to be blended with both gasoline ~~with~~ at any ratio up to 100%, and diesel without any engine modification it could be made possible at the pumps meaning minimal impact to the fuel user.

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DME can be injected into the engine either through the air intake or direct injection. Due to the high cetane number this fuel could be used as a diesel replacement; again making it possible for it to be available at the pump. It can also be used in spark ignition engines only if it is used in the form of LPG-DME blend.

C. In the case of butanol, its ability to be used at the pump either as a fuel blend (like E80-E95) or as it's own makes supplying the product to customers easy due to the ability to make use of existing infrastructure. The use of organic components to manufacture butanol through fermentation has shown to not be a sufficient as when using ~~petrochemical~~ petrochemical feedstocks to produce the chemical using chemical methods. The petrochemical feedstocks method is ~~both~~ more cost efficient and production over the use of organic matter, along with this it does not require the use of agricultural land. This gives it advantage over Ethanol as well. In conclusion only the plant for manufacturing this component will need to be produced.

DME again like butanol has the advantage of being used at the pump in relation to diesel and along side LPG for spark ignition, etc due to

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the chemicals being made using coal and Natural gas current system/factors that have the elements in place could be adopted for manufacturing.

Section B.

Question 2.

- a. Ionic Bonding is when atoms transfer electrons between each other, this is done to achieve balance of the atoms outer shells. This bond normally happens between a donor (Metals) and a receiver (Non-metals).

Covalent bonds only share electrons, they don't transfer electrons like ionic bonds. This happens between the same/similar elements, normally non-metals.

Metallic Bonding is when metal atoms shed electrons from their outer shells freely, this creates positively charged ions and delocalised electrons. From this the ions form a closely packed lattice structure where electrons fill in the gaps.

Electronegativity is the ability of an atom to attract electrons. It is measured by how many hydrogen atoms it can bond with.

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b. Face Centred Cubic dimension

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

$$a = 0.362 \text{ nm} = 0.362 \times 10^{-9}$$

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

~~$$R = \frac{0.362 \times 10^{-9}}{2\sqrt{2}}$$~~

~~$$R = 1.2761 \times 10^{-10} \text{ m}$$~~

$$R = \frac{\left(\frac{a}{2}\right)^2}{2} = \frac{\left(\frac{0.362 \times 10^{-9}}{2}\right)^2}{2}$$

$$R = 1.63805 \times 10^{-2}$$

c. Point defects There are three types of defect, those are:

- Vacancy = this is when an atom is missing due to the lattice forming leaving vacancies in the structure allowing for the distortion of surrounding atoms. This is relevant for crystalline structures and is dependent on temperature.

- Self-Interstices = this is when an atom has become placed between the normal lattice

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Structure atoms

- Substitution: this is when an atom is replaced by another foreign atom within the crystalline solid. Unlike interstitial defect, foreign atoms only occupy the lattice site not the interstitial position.

Line Defects are caused by the dislocation in the lattice which is a defect in the structure. This implies that layers are allowed to slip relative to their adjacent layers. When a dislocation happens bonds will break and new bonds form in relation to where atoms rest once dislocation has happened, this will cause permanent plastic deformation of the structure.

Area defects are caused by grain boundaries which cause defects in crystal line structure. The orientation of these crystals will be different depending on a range of factors like heating and cooling. The resulting boundary of these grains can cause strength or weakness. Grain boundaries can help hinder dislocation.

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- d. The 3 Stages of Creep are Primary, Secondary and Tertiary. The Mechanism for the Secondary creep is Dislocation movement. This is when the Crystalline Structure dislocates and moves towards the grain boundaries when under load. Applied stress to the structure causes the dislocation to shift as the crystalline structure settles.

Question 3.

- a. Casting can be used for R&D Manufacturing within the automotive industry due to the ability to use high wearing ~~from~~ and melting point materials to form and make key engine components like crank shafts. The benefits for this manufacturing process are reusable but the process is labour intensive, requires extra machines and up to 10% of used material is lost.

Forging is also used for manufacture of engine parts such as piston heads. This system has high production rate along with minimal waste. The components made also have minimal material losses. This type of manufacture is limited by shape and die wear life, it is also very costly to start and requires multiple second processes.

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Extrusion can be used to manufacture components such as chassis cross members. This system has minimal waste, quick manufacturing times and a large range of shapes available. The downside to this is the limitations on materials suitable for this process along with it being expensive and it also leaves defects.

b. To calculate RPN the 3 stages used of FMEA are:

1. Likelihood of detection, this is how likely is the problem going to be detected before it causes an issue
2. Severity Number, this is a rating between 1 and 10 to give a figure to the severity of the failure
3. Probability of Occurrence, this is how likely the failure will happen within the life time of the product.

To calculate the RPN you multiply 1 by 2 by 3 to give the overall figure. The higher the number the more effort should be applied to resolve the issue.

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C.

$$D = 0.01 \text{ m}$$

$$h = 1.4 \text{ mm} = 1.4 \times 10^{-3} \text{ m}$$

$$r = 5 \times 10^{-4} \text{ m}$$

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

i.

$$\frac{h}{r} = 2.8$$

$$\frac{2h}{D} = 0.28$$

$$0.935 + 1.922 \sqrt{2.8} + 0.004 \times 2.8 = 4.16 \quad C1$$

$$-0.552 - 5.327 \sqrt{2.8} + 0.086 \times 2.8 = -9.22 \quad C2$$

$$0.754 + 6.281 \sqrt{2.8} - 0.121 \times 2.8 = 10.93 \quad C3$$

$$-0.138 - 2.876 \sqrt{2.8} + 0.031 \times 2.8 = -4.86 \quad C4$$

$$K_t = 4.16 + (-9.22 \times 0.28) + (10.93 \times 0.28)^2 + (-4.86 \times 0.28)^3$$

$$K_t = 8.42 \text{ Pa}$$

$$ii. A = \pi D^2 = \pi \times 0.01^2$$

$$A = 3.14 \times 10^{-4}$$

$$3.14 \times 10^{-4} \times 8.42 = 2.64 \times 10^{-3}$$

$$\text{Peak stress} = 2.64 \times 10^{-3}$$

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d. Fracture Toughness

$$K = \sigma \sqrt{\pi a}$$

$$K_{IC} = \sqrt{G_c E}$$

$$a = 3.4 \text{ mm} = 3.4 \times 10^{-3} \text{ m}$$

$$\sigma = 625 \text{ MPa} = 625 \times 10^6 \text{ Pa}$$

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

$$K = 625 \times 10^6 \times \sqrt{\pi \times 3.4 \times 10^{-3}} = 64594332.13$$
$$64.59 \times 10^6$$

$$K_{IC} = \sqrt{G_c E} \iff G_c = \frac{K_{IC}^2}{E}$$

$$G_c = \frac{(64.59 \times 10^6)^2}{200 \times 10^9} = 20859.34$$

$$G_c = 20859.34 \text{ J/m}^2$$