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(2a) Ionic bonding is when atoms are ~~electronically~~ ^{electrostatically} attracted to each other by their ^{permanent} oppositely charged ions. These bonds are formed by the transfer of outer shell electrons from one atom to another. This ~~is because~~ happens as atoms want to be balanced by having complete outer shells of electrons. Electron donors are typically metals, receivers are non-metals normally.

Covalent bonding is similar to ionic due to the bond caused by sharing of electrons. However, they are not transferred between atoms permanently. This bonding is a result of sharing of an electron pair between atoms and normally happens between atoms of the same element.

Metallic bonding is different in that metal atoms release electrons from their outer shell freely, making a sea of free delocalised electrons, and the metal atoms become positively charged ions. This forms a tight lattice structure between ions where electrons fill the gaps.

The valency of an atom is the property of an ^{element} ~~element~~ that determines how many other atoms it ~~can~~ can bond with.

(2b) Face centred cubic as has 4 atoms per unit cell.

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

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

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

$$R = 1.28 \times 10^{-10} \text{ m} = 12.8 \text{ nm}$$

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(2c)

A crystalline material is one in which the atoms are situated in a repeating/periodic display over large atomic distances. Conditions that affect the ~~display~~ of structural composition are considered defects.

Point defects caused by vacancies of an atom are when there are missing ~~of~~ atoms within the structure, resulting in vacancies or spaces in which distortion of surrounding atoms are caused. Another point defect is when defects occur when other atoms intrude within the lattice structure causing distortion, which is known as self-interstitial defects.

Finally, another point defect is when an original atom within the structure is replaced by a different atom occupying the original's position ~~also~~ within the structure, also known as a substitutional defect.

A line defect ~~is~~ ^{caused} ~~when~~ by a dislocation ~~at~~ within the lattice structure where layers of the lattice move or 'slip' in relation to the other layers. This causes bonds to break and be remade in a different position after the dislocation of the layer.

~~At~~ Grain boundaries cause Area defects in a ~~can~~ crystalline structure.

These are boundaries between crystals within a material that cause changes in the bonding structure.

(2d)

Creep is the deformation of a metal at ~~an~~ elevated temperatures while under constant loading. Dislocation movement is the failure mechanism that controls the speed of the creep in the second stage. Defects within the crystalline structure will move towards grain boundaries when under load. While under stress, the dislocations shift as the structure 'settles'.

Triple points are when three grain boundaries intersect. They tend to be the weakest points ~~at~~ within the structure and so dislocations will move there.

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3a Casting is an example of a manufacturing process within the industry. It is the process of pouring liquid metal into a mould, then cooled and extracted. Many components are cast but it is an old and labour intensive technique that provides a poor surface finish and gives poor dimensional control. Can be used for steel and aluminium.

Forging is when a combination of pressure and heat are used to transform a billet into a desired shape. However, it results in ~~the~~ high initial costs and requires large productions in order to be viable. ~~A wide~~ Steel, aluminium and iron can be used in this process.

Extrusion is when material is pushed through a shape to form a desired alternative shape. Wide variety of materials can be used in process such as polymers and metals. However, it can produce defects and requires low melting point alloys.

3b The first stage of FMEA used to determine RPN is stage 2, the likelihood of detection. This is how likely a failure is likely to be detected before a catastrophic issue is caused. It is ranked between 1 and 10, where 1 is absolute certainty, and 10 is unlikely. ~~The second~~ Secondly, the severity number is used. This is ranking the severity of the potential failure from 1 to 10, where 10 is the worst possible. Finally, probability of occurrence is when for each failure mode, the probability of the failure happening in the product's lifetime being identified. Again ranked between 1 and 10, where 1 is very unlikely and 10 is unavoidable. These rankings are then multiplied together to give the RPN.

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(3c)

$$D = 10 \text{ mm}$$

$$h = 1.8 \text{ mm}$$

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

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

$$h/r = 3.6$$

$$\sqrt{h/r} = 1.897$$

$$\frac{2h}{D} = \frac{2(1.8)}{10} = \cancel{0.28} 0.36$$

$$(i) \quad C_1 = 0.935 + 1.922\sqrt{h/r} + 0.004h/r$$

$$= 4.595$$

$$C_2 = -0.552 - 5.327\sqrt{h/r} + 0.086h/r$$

$$= -10.348$$

$$C_3 = 0.754 + 6.281\sqrt{h/r} - 0.121h/r$$

$$= 12.233$$

$$C_4 = -0.138 - 2.876\sqrt{h/r} + 0.031h/r$$

$$= -5.482$$

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

$$= 4.595 + (-10.348)(0.36) + \overset{12.233}{\cancel{12.233}} (\overset{0.36^2}{\cancel{0.36}}) + (-5.482) (\overset{0.36^3}{\cancel{0.36}})$$

$$= \cancel{2.199} \underline{2.199}$$

$$(ii) \quad \sigma = F/A$$

$$\sigma = \frac{55}{4.637 \times 10^{-5}} = \underline{1.186 \text{ MPa}}$$

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(3d)

$$a = 3.8 \text{ mm} = 0.0038 \text{ m}$$

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

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

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

$$K = 625 \times 10^6 \times \sqrt{\pi \times 0.0038}$$

$$K = 68.288 \times 10^6$$

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

$$G_c = \frac{K_c^2}{E} = \frac{(68.288 \times 10^6)^2}{200 \times 10^9}$$

$$G_c = 23.32 \text{ kPa m}$$

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- ① Biofuels are an alternative types of fuel that can be used to help present road vehicles meet the future regulations. Bio ethanol and Biobutanol are examples of these.

Biobutanol's energy content is high among other gasoline alternatives. But, however its energy density is much lower by around 10-20% than that of gasoline.

When compared to ethanol, biobutanol has a lower vapor pressure and so is less volatile.

Biobutanol can be produced through fermentation process of corn. Also produces, byproducts such as solvents to help the producer's economic performance.

Also ^{environmentally} ~~economically~~ friendly as it produces fewer emissions than petroleum fuels like petrol and diesel. And the growing of corn to produce the biofuel captures carbon dioxide, therefore reducing greenhouse gas emissions.