

Automotive Materials and Sustainability

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Section B

Question 3

a) Forging: Combination of heat and pressure to transform a billet into the desired shape. Dies are used to form the component shape.

Adv. - Variety of component can be made.

- Grain structure aligns which leads to better strength properties.

- High production rate possible.

- Minimal material wastage.

Disadv. - High initial cost required.

- Needs large production run.

- Dies wear out, require replacement.

- Limited shape forming.

- Multiple secondary processes needed.

Forging is applied in production for industrial and hand tools, automotive parts, machinery components, etc.

Metals used in forging are alloy steel, stainless steel, titanium and others.

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

Adv. - Complex shapes can be achieved.

- Virtually no material wastage

- Very rapid production process.

Disadv. - Only low melting point alloys required.

- Extrusion can leave defects.

- Complex and expensive tooling.

- Brittle materials struggle to be used.

Extrusion is widely used to produce plastic objects such as tubes, hollow pipes, frames, etc.

The material used ^{is} in a form of plastic filament or aluminium.

Powder Metallurgy: Metal powder is compacted into shapes at very high pressure and temperature environment.

Adv. - Complex shapes achieved.

- Excellent material yield.

- High melting point alloys can also be used.

- Great mechanical properties.

Disadv. - Powder cost up to 3 times more than the wrought material.

- Potential contamination.

- poor surface finish, hence further finishing process required.

Powder melting find application in the automotive industries, for example babbit bearings, oil pump gears, turbines, etc.

Powder melting uses materials such as stainless steel, copper alloys, aluminium alloys, titanium alloys, and others.

e) ~~Stages: Detection of Failure Mode~~

FMEA consists of 6 stages which are required to assess and determine where a failure may occur and the severity of the potential risk.

RPN helps to identify which failure require the most attention. The higher the RPN, the more effort should be put into resolving the issue.

$$RPN = D \times S \times P$$

Probability of Detection Severity Probability of Occurance

First, analyse an assembly line process in an automotive engineering plant.

=> Specifically looking into a certain process.

=> This process was assessed for potential failures.

=> Then the severity, probability of occurrence and probability of detection was scored. (3)

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c) U-shape notch

$$D = 10 \text{ mm} \quad h = 1,7 \text{ mm} \quad r = 0,5 \text{ mm} \quad M = 55 \text{ N}$$

i) $k_T = ?$, bending

$$\frac{h}{r} = \frac{1,7}{0,5} = 3,4$$

$$\Rightarrow c_1 = 0,935 + 1,922 \sqrt{3,4} + 0,004 \times 3,4 = 4,493$$

$$c_2 = -0,552 - 5,327 \sqrt{3,4} + 0,086 \times 3,4 = -10,082$$

$$c_3 = 0,754 + 6,281 \sqrt{3,4} - 0,121 \times 3,4 = 11,924$$

$$c_4 = -0,138 - 2,876 \sqrt{3,4} + 0,031 \times 3,4 = -5,336$$

$$k_T = c_1 + c_2 \left(\frac{2h}{D} \right) + c_3 \left(\frac{2h}{D} \right)^2 + c_4 \left(\frac{2h}{D} \right)^3$$

$$k_T = 4,493 - 10,082 \left(\frac{2 \times 1,7}{10} \right) + 11,924 \left(\frac{2 \times 1,7}{10} \right)^2 - 5,336 \left(\frac{2 \times 1,7}{10} \right)^3$$

$$k_T = 2,234 //$$

ii) $\sigma_{\max} = ?$

$$\sigma_{\max} = k_T \frac{M}{\pi (D - 2h)^3} = 2,234 \times \frac{32 \times 55}{\pi (10 \times 10^{-3} - 2 \times 1,7 \times 10^{-3})^3}$$

$$\sigma_{\max} = 4,353 \text{ GPa} //$$

d) crack = $3,7 \text{ mm} = a = 0,0037 \text{ m}$

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

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

$$G_c = ?$$

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$$k = \delta \sqrt{\pi a} = 625 \times 10^6 \times \sqrt{\pi \times 0,0037} = 67,384 \times 10^6$$

$$G_c = \frac{k^2}{E} = \frac{(67,384 \times 10^6)^2}{200 \times 10^9} = 3,369 \times 10^{-4} \text{ Pa m}$$

Question 4

a) i) 7XXX Aluminium

The main alloying element is Zinc. It gets into the Heat-Treatable alloy category. Usually, 7XXX Aluminium finds application in the aircraft industry.

Adv: Heat-treatable for increased strength.

~~Disadv~~

Disadv: The alloy becomes very brittle. Rarely used alone.

ii) Steel 1045

First digit, 1, identifies that the steel type is carbon.

Third digit, 4 and 5, show that there is 0,45% carbon content in this steel material.

b)

Composites

Particle-reinforced

Fibre-reinforced

Structural

Large Particle
Dispersion strengthened

Continuous
Discontinuous

Laminates
Sandwich panels
(5)

Particle reinforced: small particles of reinforcing material $\approx 0,01 - 0,1$ microns.

Smaller particles form ~~the~~ bonds on atomic or molecular levels to surrounding matrix.

$\Rightarrow$ restricts plastic deformation

ex: concrete

For best effectiveness the particles should be small and evenly distributed and of constant size.

Fibre-reinforced: design goals are high strength and stiffness to on weight basis.

Characteristics are expressed in terms of specific strength and specific modulus. Most heavily used are Fibreglass and Carbon Fibre.

Orientation of these fibres play crucial role to its strength properties:

Aligned Fibres - highly effective along fibre direction

Random Fibres - less strength but easier and cheaper to produce

Woven Fibres - very high strength but expensive to produce

Structural: ~~can~~ made of composite and homogeneous materials where combined together and composite have the properties from both materials.

ex: multi-ply carbon fibre or Aluminium Honeycomb

The direction and orientation of the sheets are tailored to provide the overall composite the desired properties.

~~can~~ Find great application in F1, for example, where components experience forces in both directions. ~~But not~~ 6

$$c) E_f = 65 \times 10^9 \text{ Pa}$$

$$\text{fibre } V = 45\%$$

$$E_m = 3,2 \times 10^9 \text{ Pa}$$

$$\text{matrix } V = 55\%$$

$$A = 300 \times 10^{-6} \text{ m}^2$$

$$\sigma = 30 \times 10^6 \text{ N}$$

$$E_c = E_f \times V_f + E_m \times V_m$$

$$E_c = (65 \times 10^9 \times 0,45) + (3,2 \times 10^9 \times 0,55)$$

$$E_c = 31,01 \text{ GPa} //$$

$$\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m} = \frac{65 \times 10^9 \times 0,45}{3,2 \times 10^9 \times 0,55} = 16,619$$

$$\Rightarrow F_f = 16,619 \times F_m$$

$$F_c = \sigma A_c = 30 \times 10^6 \times 300 \times 10^{-6} = 9000 \text{ N} //$$

$$F_c = F_f + F_m$$

$$9000 = 16,619 \times F_m + F_m$$

$$F_m = \frac{9000}{17,619} = 510,812 \text{ N} //$$

$$F_f = 16,619 \times F_m = 16,619 \times 510,812 = 8489,185 \text{ N} //$$

Section A

Question 1

Bioethanol and Hydrogen fuels are alternative fuels which can help the industry to meet the 2025 emission standards.

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a) Hydrogen is stored in water, H_2O . ^{A combination} ~~water~~ of high-temperature steam with natural gas is required to extract hydrogen. It can also be produced ~~by~~ from water through electrolysis.

Hydrogen can power fuel cells coupled with electric motor vehicles and ICE. Hydrogen is around 3 times more efficient than ICE operating on gasoline. in terms of pipe emissions.

Bioethanol is produced from renewable resources, usually plants such as corn, straw, wood, etc. Since the end product is a type of alcohol it contains high amounts of ethanol. The production of bioethanol releases some emissions but the tail-pipe emissions in ICE are reduced by approximately 40%.

b) Hydrogen is difficult to be stored. ^{since it has to be compressed.} Special tanks must be installed in vehicles and the filling process is limited. Hydrogen has a low-volumetric energy density, there is not enough space in the combustion chamber to produce the same power output ~~by~~, comparing hydrogen to gasoline in ICE.

Bioethanol has less ^a energy than gasoline hence the fuel economy has decreased. However, hydrogen has a high octane number which would produce more power in an ICE.