FINAL ASSESSMENT COVER PAGE - 2022/23

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Date: 22/05/2023

2 MQ2

2.1 i

2.1.1 a

α is HCP β is BCC

Alloy 1 is α Alloy 2 is α Alloy 3 is $\alpha + \beta$ Alloy 4 is β

2.1.2 b

Alloy 1 has solid solution strengthening from small amounts of dissolved O. Alloy 2 also has solid solution strengthening from Al and O. Alloy 3 has laths of α in β, leading to a basketweave structure. The precipitates alone also lead to more hardening. Alloy 4 has solid solution as well as precipitate hardening.

2.1.3 c

Solid solution comes about through annealing because the high heat allows for O and other atoms to diffuse through the microstructure, leading to stresses from the different sized elements. Annealing also leads to grain boundary refinement during recrystalisation and grain growth. Precipitates are also allowed to form.

Ageing leads to even more of these mechanisms

2.1.4 d

Alloy 1 is corrosion resistant. The relatively low yield stress means that in most cases with high structural loads, other alloys are better. In addition, the density is slightly higher than others.

Alloy 2 is useful for higher temperature applications. The higher yield strength is also a benefit.

Alloy 3 has a very good strength to weight ratio, so can be used for structural elements.

Alloy 4 is good for high tensile strength structural members. It is the densest compared, so will not be used where alloy 3 could be used instead. It is also the ideal high-temperature alloy.

2.2 ii

Alloy 2 has good creep resistance, but this is not relevant as creep only starts at $0.4T_m$, or around $660°$ so is not relevant in this application. The other alloys have service temperatures below $500°$, meaning that alloy 4 is the obvious choice. In addition, it has better tensile strength.

2.3 iii

For carbon fibre, $V_m = 0.8$ gives $E_c = 1.42 \times 10^{11}$ and $S_c = 1.32 \times 10^9$, which are both within specification.

$V_f \times \rho_f = \frac{2}{5}$

For SiC, $V_m = 0.95$ gives $E_c = 1.24 \times 10^{11}$ and $S_c = 1.29 \times 10^9$, which are within specification.

$V_f \times \rho_f = \frac{3}{20}$. This means that the carbon fibre saves more weight for similar material properties, so should be used instead.

2.4 iv

The demands of a turbine mean that high strength will be needed to make the turbine spin. Also, good surface finish is ideal. Lower weight means lower loads, which is also ideal.

Martensite is extremely hard, but also brittle. Tempering it makes it less brittle and more suitable for the use case. It becomes less hard because the carbon trapped in the martensite is allowed to leave. Stainless steel is generally harder than mild steels. The higher hardness makes it more suited to the task. Through tempering, fine carbides have been formed, making the stainless steel even harder.

It also has better high-temperature strength than mild steel.

The corrosion resistance is also important, because if any steam condenses, the mild steel could begin to rust. The chromium oxide layer means that is not an issue with stainless steel.

In addition to this, stainless steel is relatively cheaper.

2.5 v

2.5.1 a

The Larsen Miller Parameter is given by $LMP = T(C + \log(t))$, where t is the time to failure. Clearly, changing T will have a non-linear effect on t.

2.5.2 b

Find C with the Larsen Miller Parameter:

$$450(C + \log(2034967)) = 700(C + \log(69558))$$

$C \approx -2.2032$ $LMP \approx 1860$

Find life used at $625°C$:

$$1860 = 625(-2.2032 + log(t))$$

$t = 151078$ $L_{625} = \frac{85000}{151078} = 0.5626$

Find how many hours at $680°C$:

$$1860 = 680(-2.2032 + \log(t))$$

$t = 86795$ $\frac{t_{680}}{86795} = 1 - 0.5626$ $t_{680} = 37964hr$

Applying a safety factor of 1.5 gives a value of 25309 hours.