Creep Failure Resistance

Comparison of Materials

The materials engineer can devise microstructural modifications to make materials creep resistant. Some of these will be identified in the next section, but an obvious first criterion is to select materials with a high melting or softening temperature. The following table summarizes the approximate ranges of the materials classes.

Melting or Softening Temperature (K)

3500–4000	METALS		CERAMICS	
3000–3500	METALS		CERAMICS	
2500–3000	METALS		CERAMICS	
2000–2500	METALS		CERAMICS	
1500–2000	METALS			
1000–1500	METALS			
500–1000	METALS	PLASTICS	glasses	COMPOSITES

Among familiar metals, three alloy systems melt low enough that creep is a concern at room temperature:

Tin alloys	T/T_m = 0.6–0.7
Lead alloys	T/T_m = 0.5–0.7
Zinc alloys	T/T_m = 0.4–0.5

Aluminum and magnesium alloys with (T/T_m = 0.3–0.4) are creep resistant at room temperature but cannot be heated very much. Room temperature creep is not a concern with steels (T/T_m = ~0.2). The common metals with the highest melting point are tungsten alloys (T/T_m = ~0.1).

Engineering composites soften in the same range as plastics because the matrix of the composites is usually a polymer. The glass or graphite fibers are much stronger.

Note: For the above ranges, room temperature was assumed to be 295 K (22 ºC, 72 ºF).

Creep-Resistant Materials

In addition to a high melting or softening temperature, we look at one additional structural feature desired for creep resistance. Metals and ceramics solidify into *polycrystalline solids*. When examined under a microscope, individual grains packed together are observed. X-ray analysis shows that each grain is a region of atoms arranged on a symmetrical geometrical lattice. Interestingly, the desired grain size for creep resistance is the opposite of the desired grain size for maximum yield strength.

Cold forming – plastic deformation below creep temperatures – is treated in section 4.2.1, where a mechanism of dislocation movement is identified. Relevant here is that grain boundaries form an impediment to dislocation movement, so a material with small grains and many grain boundaries is desired for increased yield stress.

Creep deformations involve diffusion of atoms within the solid. Diffusion rates follow the Arrhenius law, which is the source of the temperature dependence of the steady-state creep rate. Grain boundaries constitute an easier path for atom transport than diffusion through the interior of grains. Therefore, for creep resistance, we desire to minimize the amount of grain boundaries. That is, we desire a material with large grains. A limiting application of this is found in jet engine turbine blades that are sometimes specially solidified to be single crystals with no grain boundaries at all.