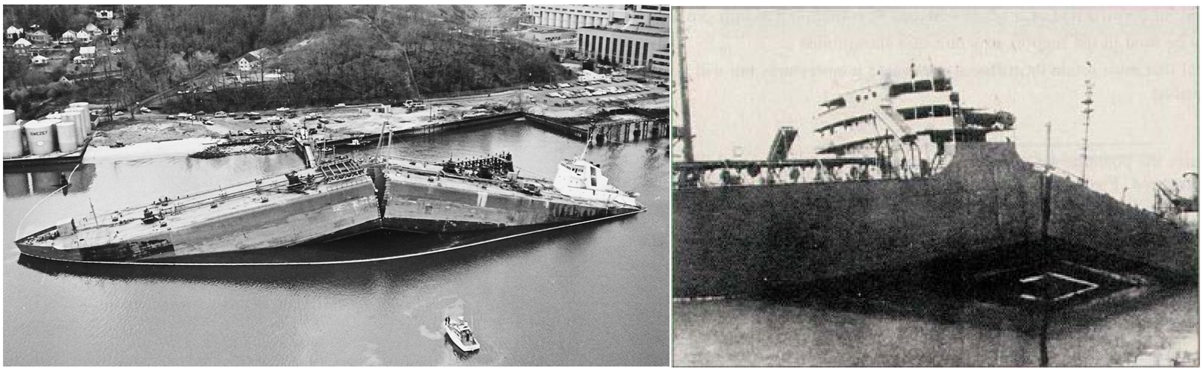
Lesson 12: Failure

Exercise 12.1 Liberty ships

What happened to the ”Liberty” ships? Discuss and search relevant information on the internet. Explain the problem from a materials perspective (take into account defects, cracks, crack propagation, temperature, joining, and design)! Does the same hold for the “Titanic”?



For the production of ”liberty” ships, the wrong steel has been used with a too high ductile to brittle transition temperature (DBTT), cruising the cold Atlantic ocean caused brittle failure. The plates have been welded together which allowed the crack to propagate (with the velocity of sound) around the entire hull where the load has been largest.

Exercise 12.2: Materials selection for an Eco-car (use ANSYS Granta EduPack)
An eco-car maker seeks a material for a *light-weight space frame*. To meet the specifics the material must have a Young’s modulus above 70 GPa, a yield strength above 500 MPa and a fracture toughness above 25 MPa $m^{1/2}$. Which materials could be chosen? Which material should be selected, i.e. which criteria are still missing?

Using the limit function in ANSYS Granta EduPack results in a short list of possible materials:

- Age-hardening wrought Al-alloys
- Brass
- Bronze
- Cast iron, ductile (nodular)
- Commercially pure titanium
- High carbon steel
- Low alloy steel
- Medium carbon steel
- Nickel
- Nickel-based superalloys
- Stainless steel
- Titanium alloys
- Tungsten alloys

The selection can be further restricted by considering mass density (eco-car!) or price.

Exercise 12.3 Select an appropriate polymer
Choose between polyethylene, polypropylene, polyvinylchloride, PET polyester and polycarbonate:
a) which of the polymers shall be used for manufacturing coffee cups?
b) which of the polymers shall be used for ice cube trays?

a) Coffee cups should be a glass when used, i.e. for temperatures up to the boiling temperature of water. The glass transition temperature of the material should be above 100 °C: polycarbonate.
b) Ice cube trays should be rubbery when freezing water in a freezer. The glass transition temperature must be (well) below 0 °C: polyethylene and polypropylene.

Exercise 12.4 Viscoelasticity
Compare the glass transition temperature for a polymer with side chains to one without side chains
a) if both have the same main chains, i.e. same length, same composition?
b) if both have the same molar mass?
What about the melting temperature?

The glass transition temperatures increases when the molar mass is increased or the number of side chains is increased significantly (a small number of side chains actually reduces the glass transition temperature).
In case of (a), both the number of side chains are larger and the molar mass increases, in case of (b) only the number of side chains increases, nevertheless the glass transition temperature is increased in both cases.
The melting temperature increases also when the molar mass is increased, but becomes lower when side chains are introduced due to the introduced defects. In case (b), one can expect that the melting temperature drops, for case (a) both influences are counteracting and they would have to be quantified before drawing a conclusion.

Exercise 12.5 Comparing mechanical properties of metals, ceramics, and polymers
Use ANSYS Granta EduPack or Callister, Rethwisch 10th edition, Appendix

Find and tabulate the following properties for six materials:
a) Cast Al-alloys; b) low carbon steel; c) Aluminium oxide; d) Silicon carbide; e) Polyethylene; f) Teflon
Modulus of Elasticity, E, GPa
Yield strength (elastic limit), σ_y, MPa
Ultimate tensile strength, UTS, MPa
Elongation, %

Sketch the flow curves (qualitatively) in a common stress strain diagram. (A hand-drawing is sufficient. There are no opportunities to draw flow curves in ANSYS Granta EduPack or other graphic programs).

Table with mechanical properties of different materials
a) Al cast alloy; b) Low carbon steel; c) alumina; d) silicon carbide; e) polyethylene; f) teflon.

	Al cast alloy	Low carbon steel	Alumina	Silicon carbide	Polyethylene	Teflon
Young's modulus E/GPa	80,5	207,5	366,5	430	0,7585	0,476
Yield strength σ_y/MPa	190	322,5	465	505	23,45	20
Tensile strength UTS/MPa	225,5	462,5	465	505	32,75	25
Elongation to failure/%	5,2	36,5	0	0	500	300