Basic Systematic Materials Selection

Homework Solutions

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Questions originally from resources created by Mike Ashby, University of Cambridge

Section 1: Translating Design Requirements

Product	Function	Constraints	Objectives	Free Design Parameter
Car headlight lens	Protect bulb and focus light	• Optical quality material • Mold-able material • Good durability for fresh water, salt water, UV radiation	• Minimize cost • Maximize hardness (abrasion resistance)	Shape
Radial turbine blade for aerospace applications	Aids in energy generation via turbine for powering airplanes, *etc.*	• Fatigue strength at 10^7 cycles > 360 MPa • Maximum service temperature > 900°C	• Maximize fracture toughness (crack propagation resistance) • Maximize yield strength	Angular velocity of blade
Aircraft cargo door	The door to load and unload freight or luggage in an aircraft. The door can be assumed to be a panel in bending.	• Yield strength > 359 MPa • Service temperature range -50 to 120 °C • Excellent resistance to fresh and salt water • Excellent resistance to UV radiation	• Minimize mass • Minimize CO_2 footprint	Material choice
Recycling bin	Hold recycling from a household	• Resistant to water, food waste (citric acid (10%)), wine, ethanol, and vegetable oils • Good resistance to UV radiation • Manufactured by injection molding	• Minimize mass • Minimize cost	Material shape and choice

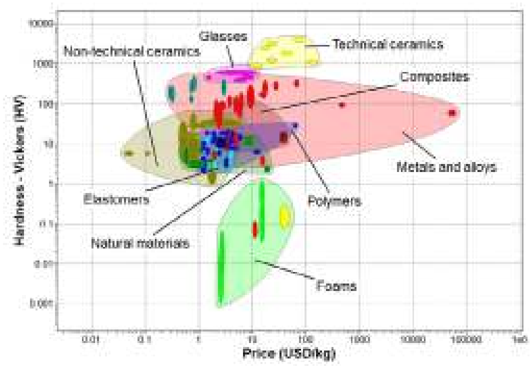
Section 2: Applying Constraints and Objectives with Granta EduPack

All answers were generated using the Level 2 database of the 2022R1 Granta EduPack

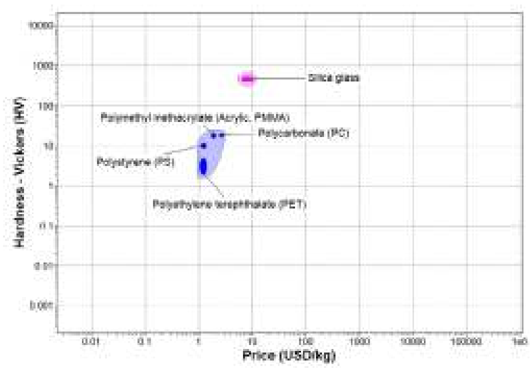
Car headlight lens

**To demonstrate how the constraints limit our material choices, we will start by plotting our objectives and apply our constraints one at a time*

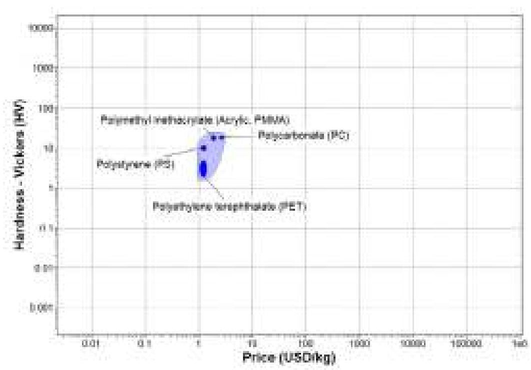
Here is the chart for Hardness-Vickers vs. Price, with material families shown and labeled.



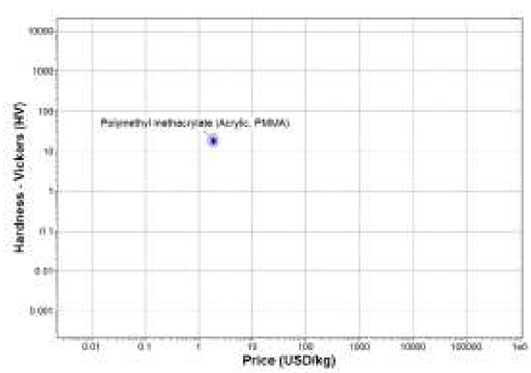
Here is the plot again after we apply the limit for Optical Quality Transparency, with non-passing records removed. Notice how we have dropped from all material families to just two: glasses and polymers.



After applying a limit for Moldability 4-5, only the four polymer options remain. The chart remains the same after applying the limits Acceptable and Excellent for fresh water and salt water. We use both Acceptable and Excellent to avoid eliminating too many candidates.

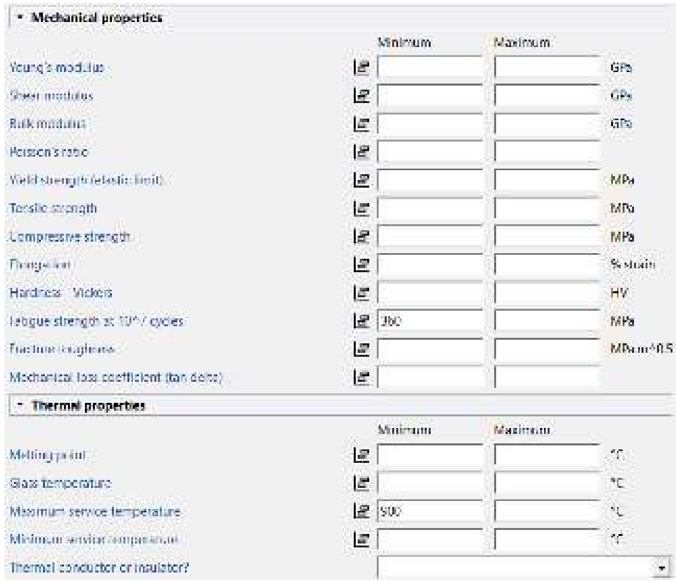


After applying the limit for acceptable and excellent "UV radiation", only one material remains: PMMA, which is used for car tail lights.

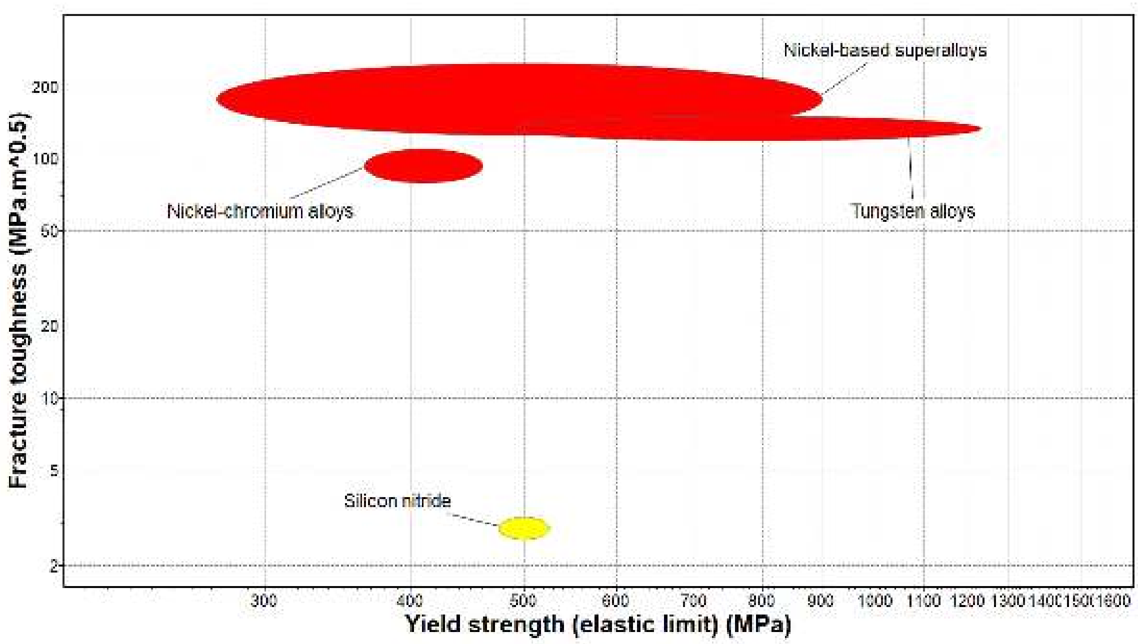


Radial turbine blades

After applying our two constraints (see below), we are left with four materials: Nickel-based super alloys, Nickel-chromium alloys, Silicon nitride, and Tungsten alloys.



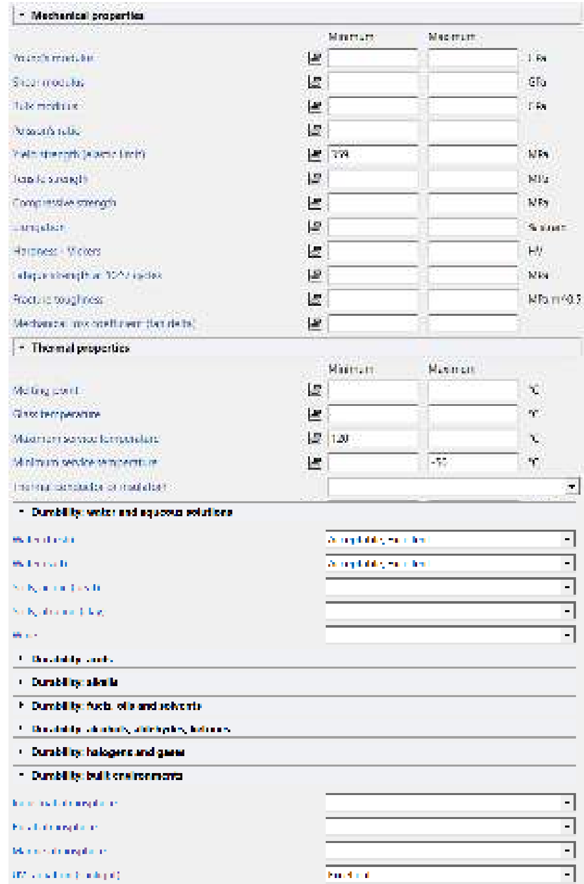
Plotting our objectives of fracture toughness and yield strength, we can see that both nickel-based superalloys and tungsten alloys are good candidates, which makes sense considering what real-life turbine blades are made of.



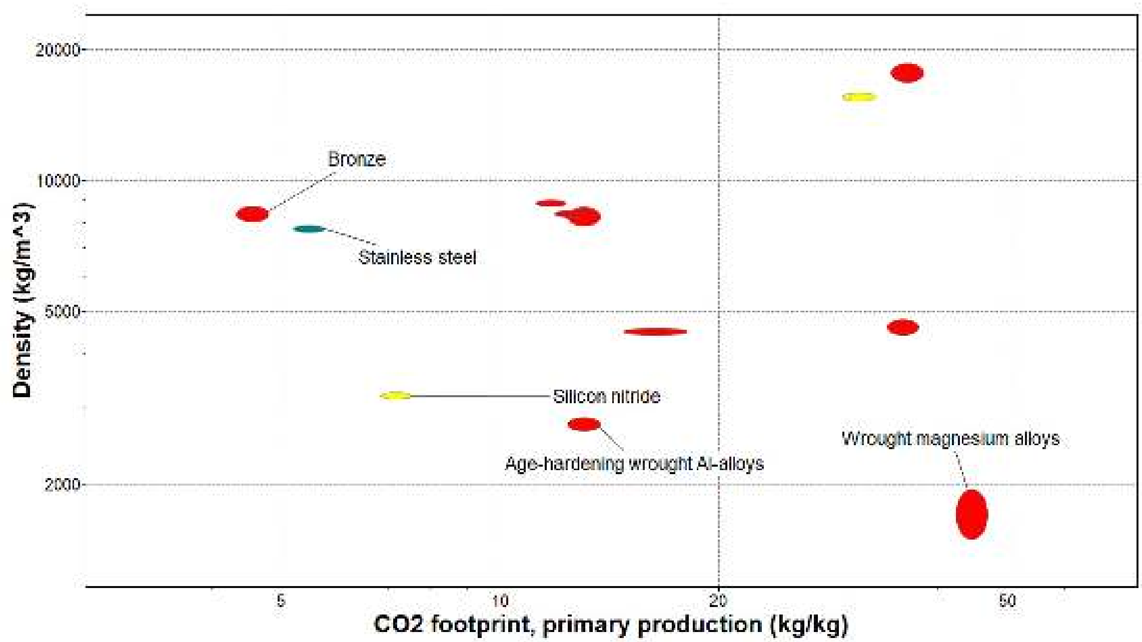
Aircraft cargo door

After applying our constraints via a limit stage, we are left with 12 materials:

1. Age-hardening wrought Al-alloys
2. Bronze
3. Commercially pure titanium
4. Nickel
5. Nickel-based superalloys
6. Nickel-chromium alloys
7. Silicon nitride
8. Stainless steel
9. Titanium alloys
10. Tungsten alloys
11. Tungsten carbide
12. Wrought magnesium alloys

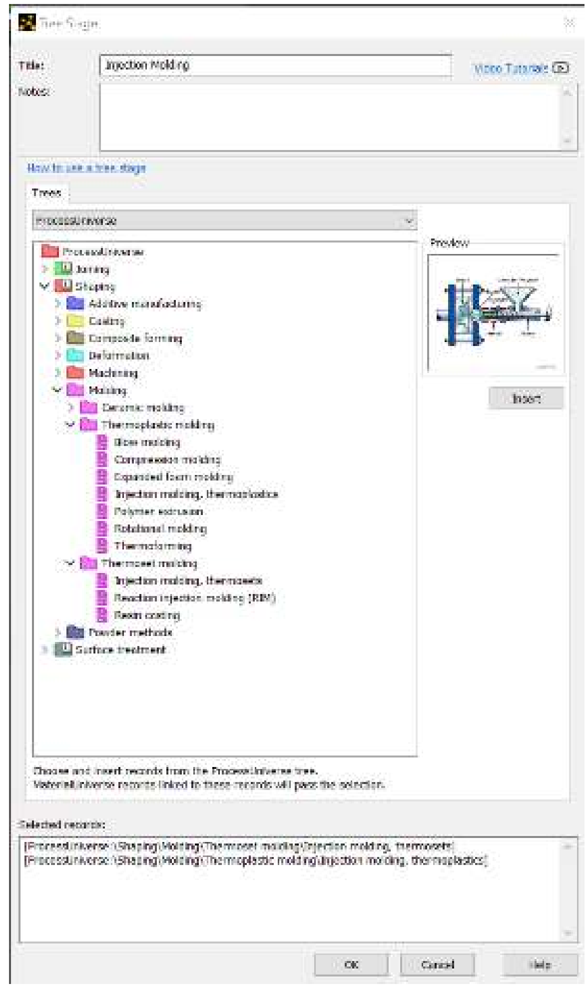


Our chart show many materials with low density and CO_2 footprint for primary production, with age-hardened aluminum and silicon nitride at the top.



Recycling containers

This problem has a unique constraint for a specific processing technique. This can be achieved using Granta EduPack, but requires a Tree Stage, which was not covered in the lecture. The tutorial for the tree stage can be found here.



All of the durability constraints can be applied using a limit stage, while selecting the options for both “Acceptable” and “Excellent”. After this step, 42/100 materials remain.

Using a Tree Stage with the ProcessUniverse, we can select injection molding for both thermosets and thermoplastics. After applying this stage, five materials are left: cement, phenolics, polyetheretherketone (PEEK), high density rigid polymer foam, and medium density rigid polymer foam.

In our chart, phenolics and PEEK are the most likely candidates. While the foams are much lighter weight, using our intuition we can determine this isn’t the best choice.