



Material selection:

Translation, screening,
ranking, documentation

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Learning objectives for this lecture unit

Ansys software mentioned

- Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes

Knowledge and Understanding	Knowledge and understanding of the design process using Material Indices
Skills and Abilities	Ability to use the Ansys Granta EduPack software to apply screening and ranking to material properties
Values and Attitudes	Appreciation of design-led decision-making using Ansys Granta EduPack software tools

Resources

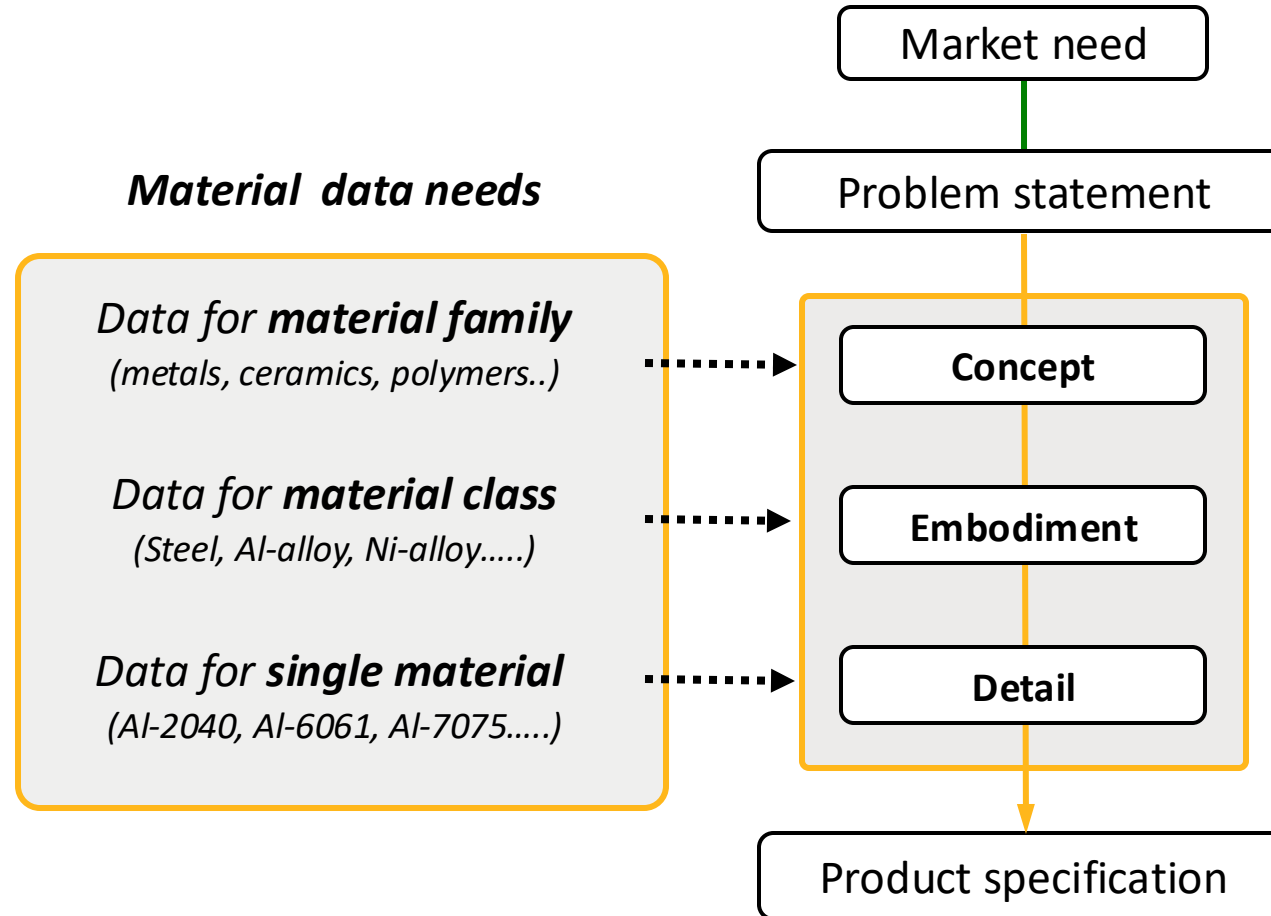
- **Text:** “Materials: engineering, science, processing and design” 4th edition by M.F. Ashby, H.R. Shercliff and D.Cebon, Butterworth Heinemann, Oxford, 2019, Chapter 3, 5 and 7.
- **Text:** “Materials Selection in Mechanical Design”, 5th edition by M.F. Ashby, Butterworth Heinemann, Oxford, 2016, Chapters 4-5

Outline of lecture unit



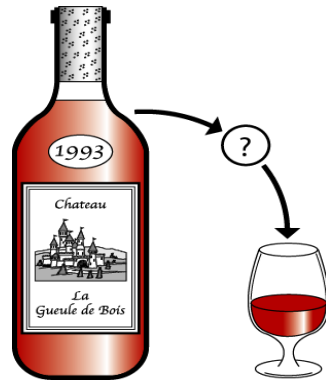
- Linking **materials** to **design**
- The **selection strategy**:
Translation – Screening – Ranking - Documentation
- The **Ansys Granta EduPack software selection toolbox**
 - *Limit stages*
 - *Graph stages*
 - *Tree stages*
- **Material indices** do the job

The design process

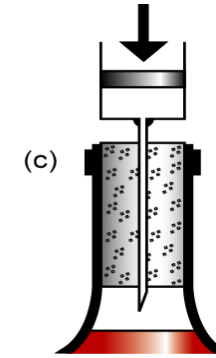
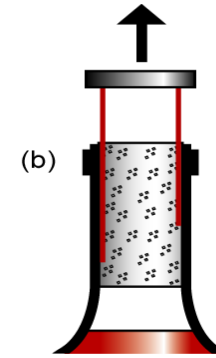
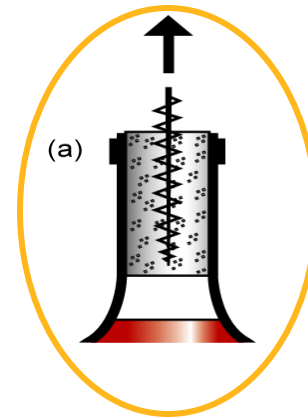


Need – Concept – Embodiment

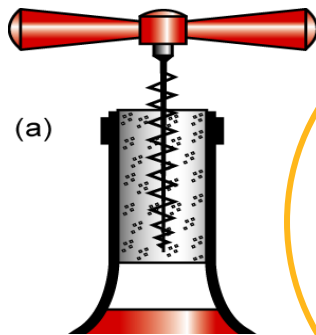
Need



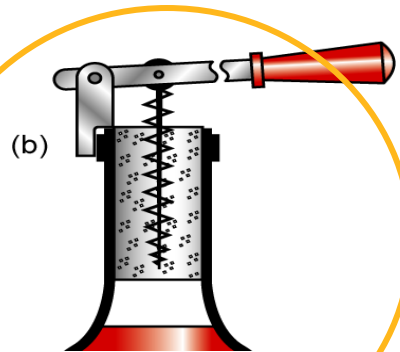
Concepts



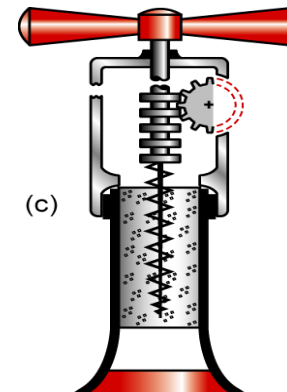
Embodiments



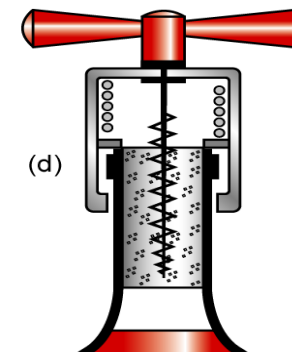
Direct pull



Levered pull



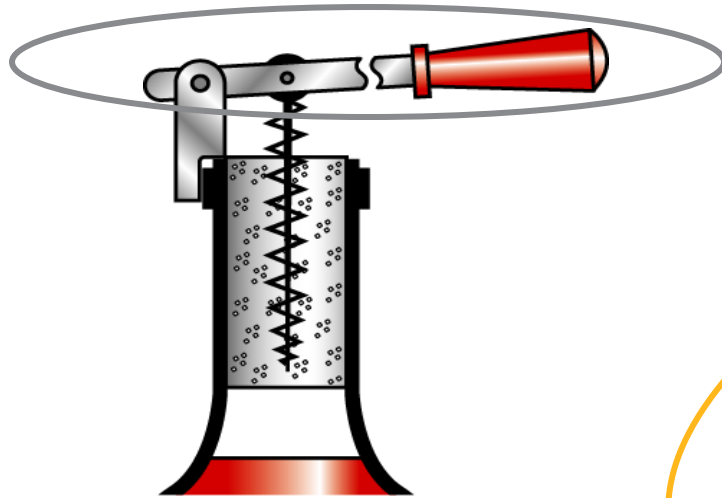
Geared pull



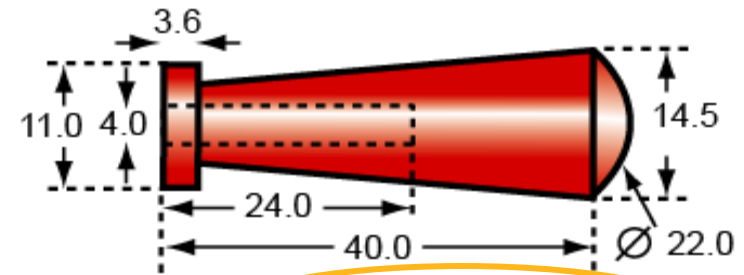
Spring-assisted pull

Embodiment – detail

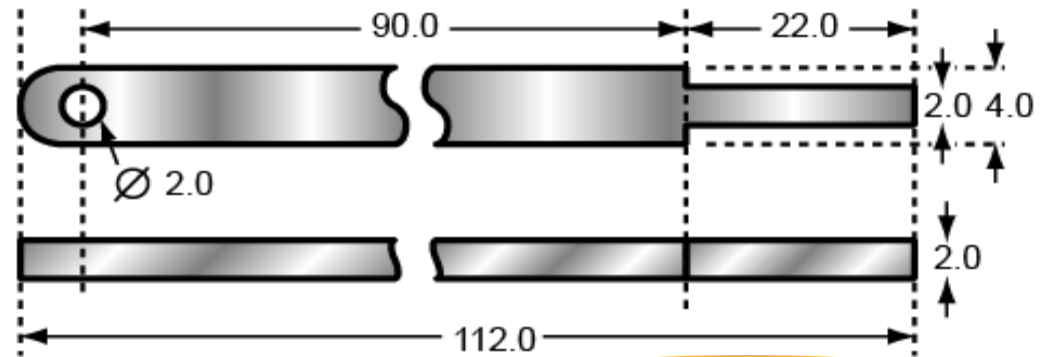
Embodiment



Detail



GRIP Cast phenolic through colored

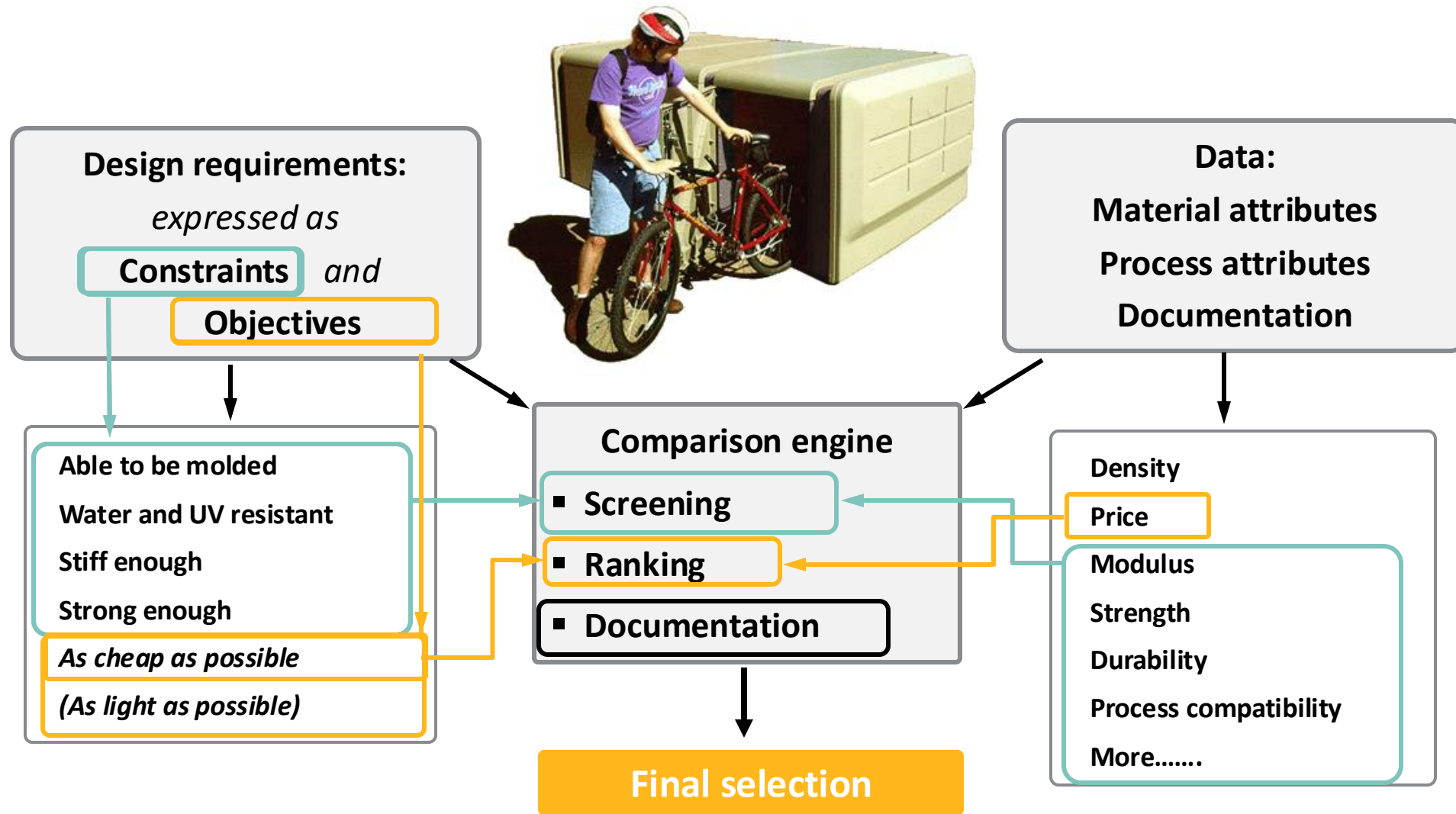


All dimensions mm

ARM Stainless steel type 302 machined from bar stock

How are those choices made?

The selection strategy: materials



Translation is important

Translation: “express design requirements as constraints and objectives”

Design requirements

Typical Constraints

What essential conditions must it meet ?

- **Be strong enough**
- **Conduct electricity**
- **Tolerate 250°C**
- **Be able to be cast**

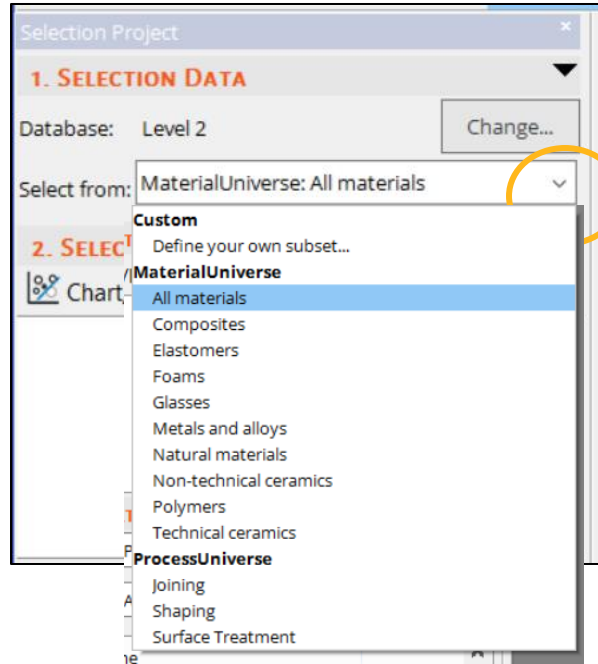
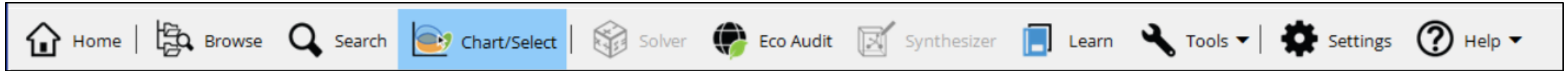
Typical Objectives

What measure of performance is to be maximized or minimized ?

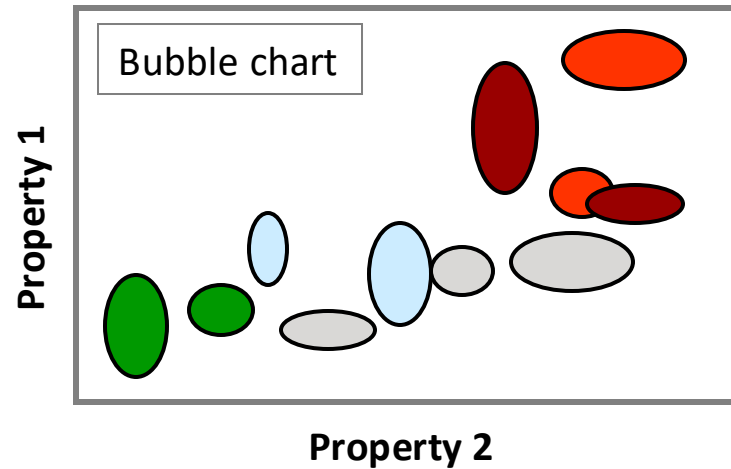
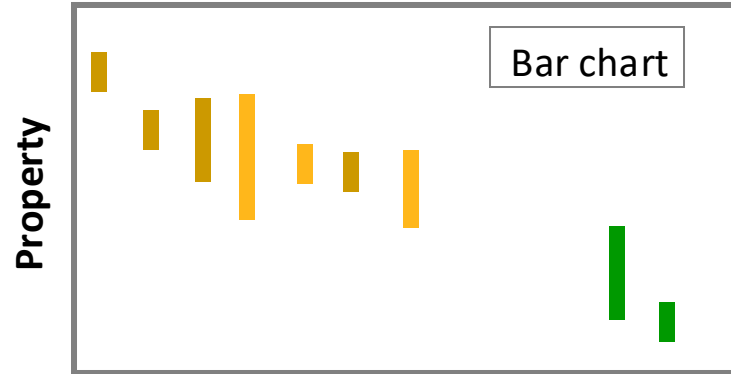
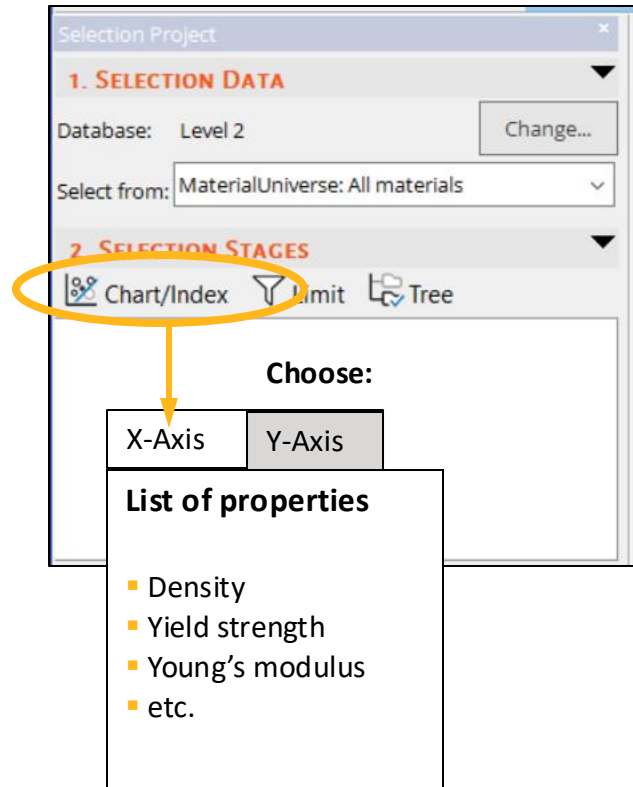
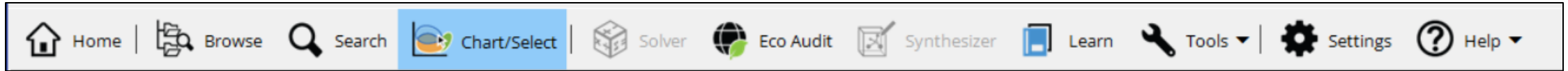
- **Mass**
- **Volume**
- **Eco-impact**
- **Cost**

Screening: “use constraints to eliminate materials that can’t do the job”

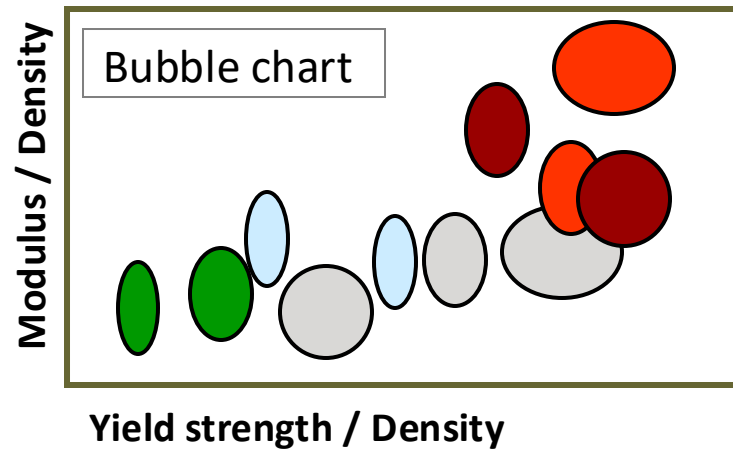
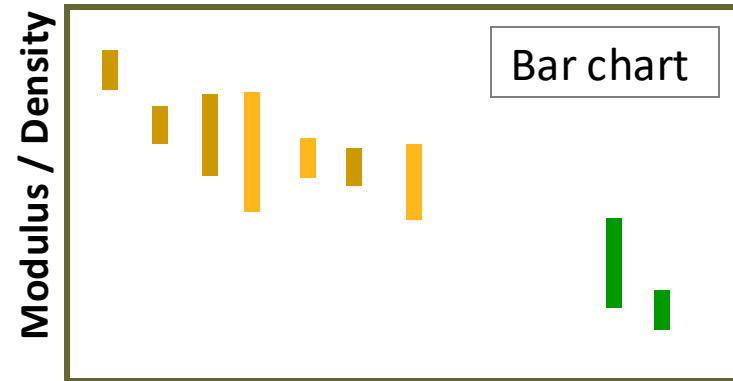
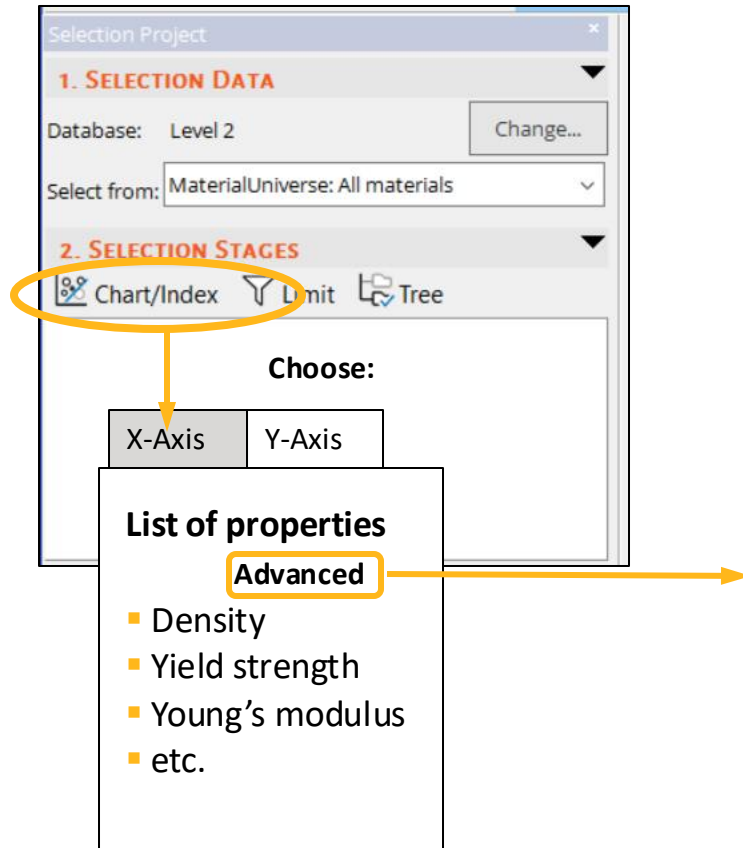
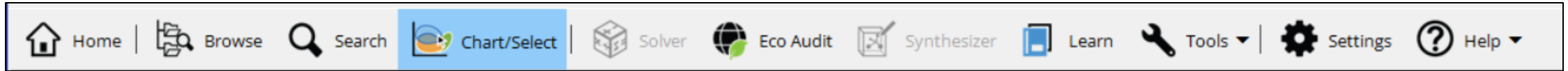
Creating Charts – choosing materials to plot



Creating Charts – single property charts



Creating Charts – advanced property charts

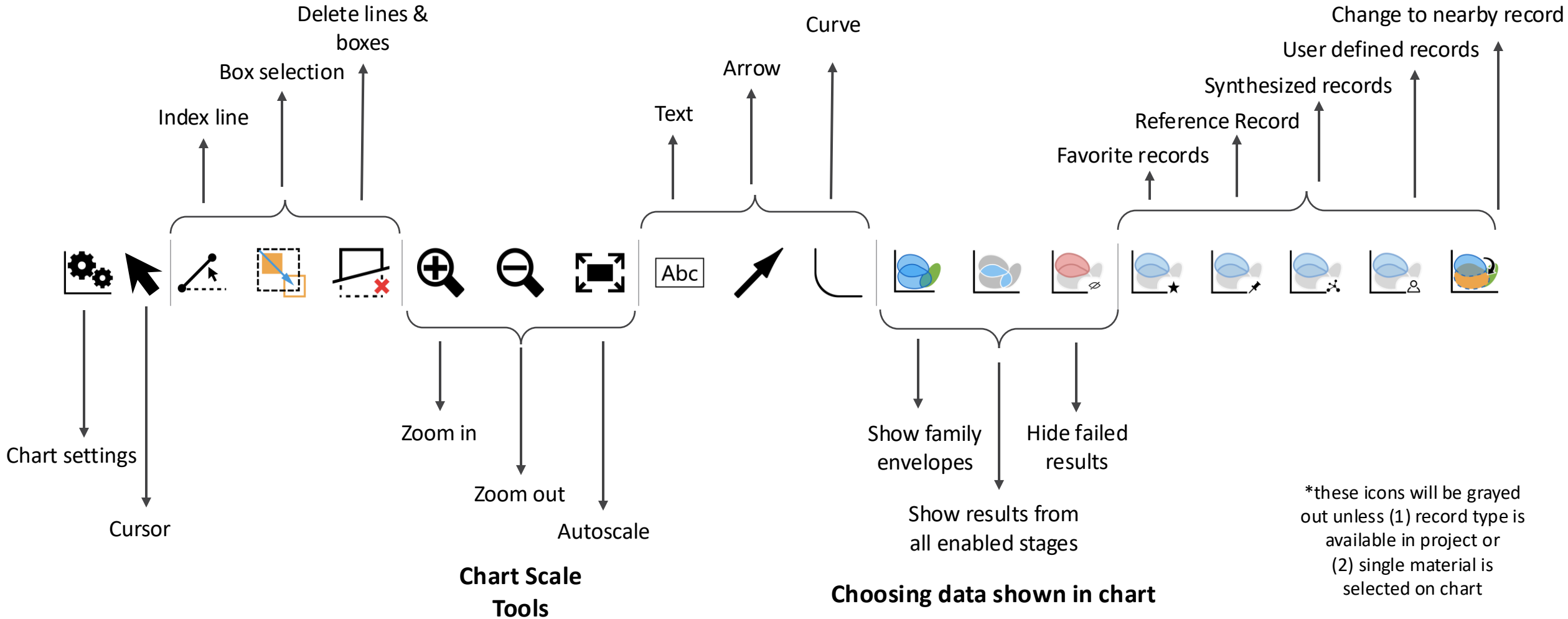


The Chart tool bar

Materials Selection Tools

Chart Annotation Tools

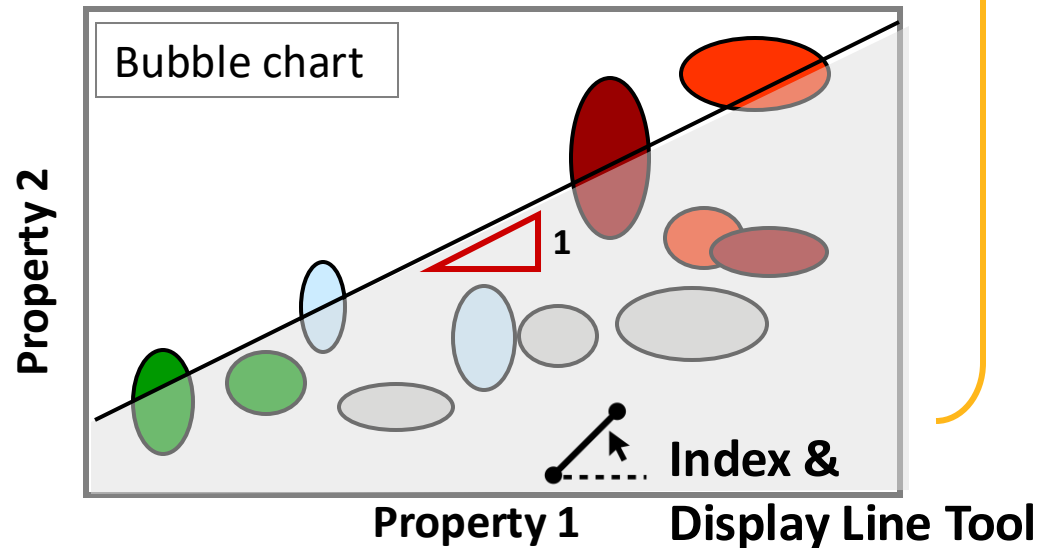
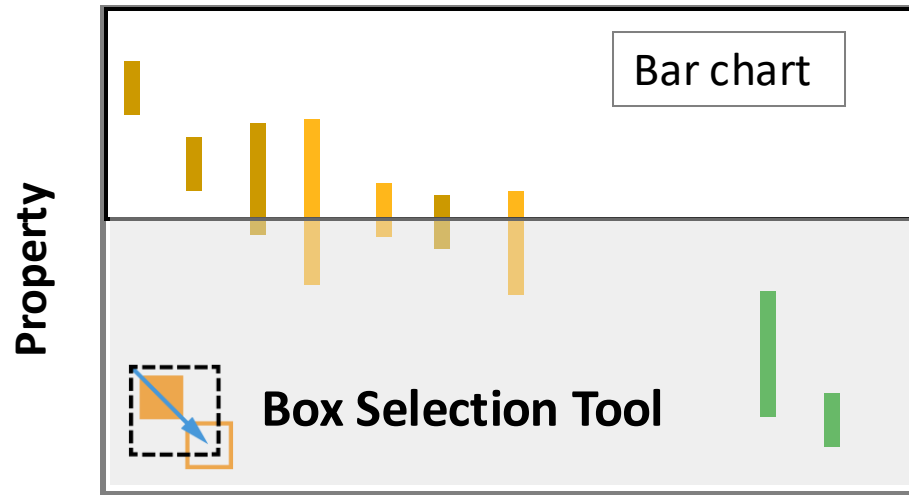
Data highlight tools*



Screening with a CHART STAGE

2. SELECTION STAGES

Chart/Index Limit Tree

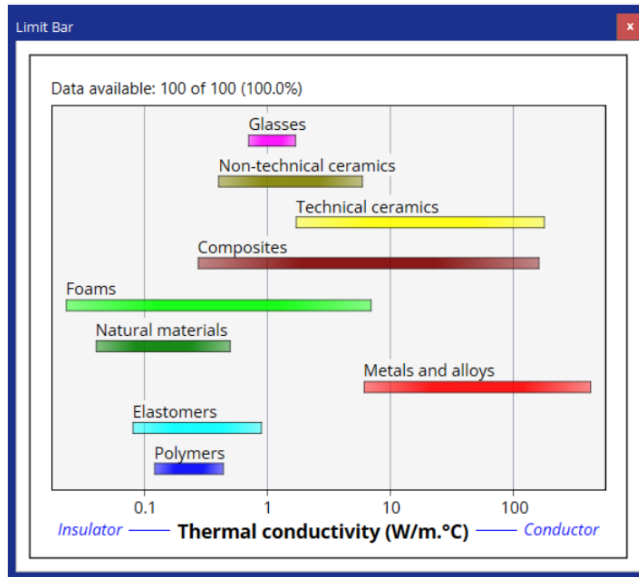


	Results		Ranking	
	<i>X out of 100 pass</i>		<i>Prop 1</i>	<i>Prop 2</i>
Material 1	2230	113		
Material 2	2100	300		
Material 3	1950	5.6		
etc...				

Screening with a LIMIT STAGE

2. SELECTION STAGES

Chart/Index **Limit** Tree



Limit

Settings Apply Clear Logic between attributes for this stage: AND ?

Can't find the property you are looking for?

- General properties
- Mechanical properties
 - Young's modulus: Minimum 2, Maximum [] GPa
 - Shear modulus: Minimum [], Maximum [] GPa
 - Bulk modulus: Minimum [], Maximum [] GPa
 - Poisson's ratio: Minimum [], Maximum []
 - Yield strength (elastic limit): Minimum 10, Maximum [] MPa
 - Tensile strength: Minimum [], Maximum [] MPa
 - Compressive strength: Minimum [], Maximum [] MPa
 - Elongation: Minimum [], Maximum [] % strain
 - Hardness - Vickers: Minimum [], Maximum [] HV
 - Fatigue strength at 10⁷ cycles: Minimum [], Maximum [] MPa
 - Fracture toughness: Minimum 5, Maximum [] MPa.m^{0.5}
 - Mechanical loss coefficient (tan delta): Minimum [], Maximum []
- Thermal properties
 - Melting point: Minimum [], Maximum [] °C
 - Glass temperature: Minimum [], Maximum [] °C
 - Maximum service temperature: Minimum [], Maximum [] °C
 - Minimum service temperature: Minimum [], Maximum [] °C
 - Thermal conductor or insulator?: Good insulator
 - Thermal conductivity: Minimum 1, Maximum [] W/m.°C
 - Specific heat capacity: Minimum [], Maximum [] J/kg.°C
 - Thermal expansion coefficient: Minimum [], Maximum [] µstrain/°C

Results	Ranking	
	X out of 100 pass	Prop 1 Prop 2
Material 1	2230	113
Material 2	2100	300
Material 3	1950	5.6
etc...		

Screening with a TREE STAGE

2. SELECTION STAGES

Chart/Index Limit **Tree**

Title: [Video Tutorials](#)

Notes:

[How to use a tree stage](#)

Trees

ProcessUniverse

- ProcessUniverse
 - Joining
 - Shaping
 - Additive manufacturing
 - Casting
 - Die casting processes
 - Investment casting processes
 - Sand casting processes
 - Composite forming
 - Deformation
 - Machining

Preview

Insert

Choose and insert records from the ProcessUniverse tree.
MaterialUniverse records linked to these records will pass the selection.

Selected records:

[ProcessUniverse\Shaping\Casting\Die casting processes]

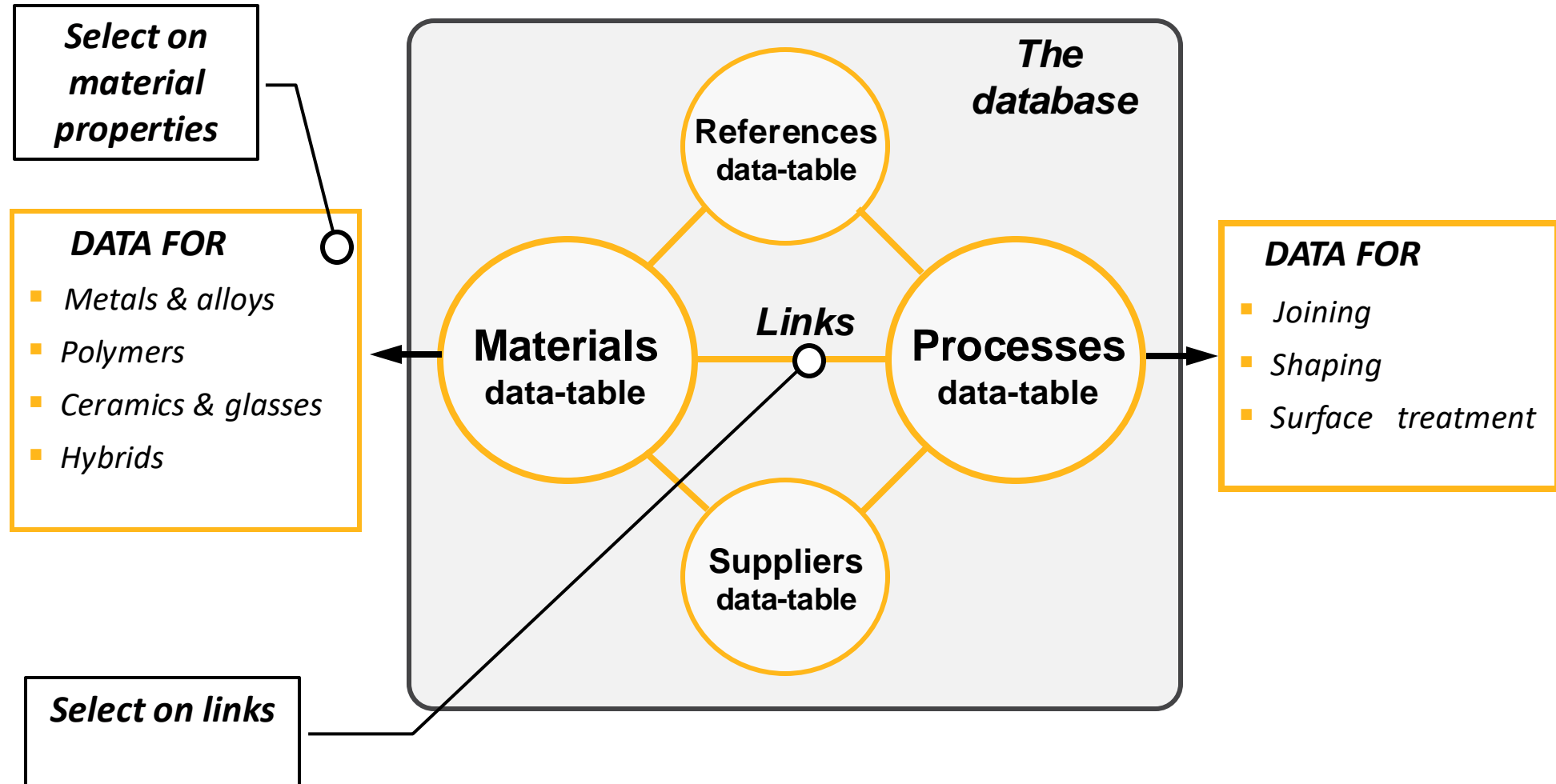
OK Cancel Help

*Materials that
can be die-cast*

Results
X out of 100 pass

Material 1
Material 2
Material 3
etc...

Selection on links



What is a “material index”?

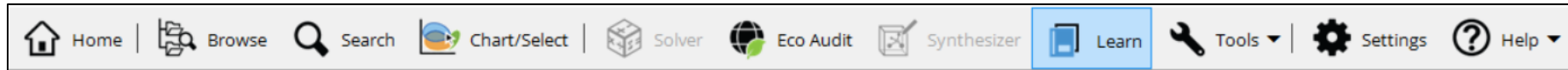
Component performance is limited by either:

- a single material property e.g. tensile strength,
- a material property group, e.g. modulus / density,



To maximize performance:

- First apply all **constraints**
- Then select materials with the **biggest or smallest index**



Materials Selection

Ansys Innovation Courses

Follow this link to the free Materials Selection courses to learn about this methodology's principles.

[LEARN MORE →](#)

Materials Selection White Paper

Learn the core steps of the materials selection methodology and grasp a basic understanding of performance indices.

[LEARN MORE →](#)

Performance Indices Booklet

This interactive booklet provides pre-derived performance indices for a variety of conditions.

[LEARN MORE →](#)

Performance Indices Reference Booklet

Katlin Tyler and Harriet Parnell
Ansys Academic Development Team

Booklet Contents

Use the interactive table below to explore different performance indices by type. References shown in the table can be found under the [References](#) section.

The symbols list can be found by [clicking here](#).

	Mass	Cost	Embodied Energy	Carbon Footprint
Stiffness-limited Design	kg	\$	H _m	CO ₂
Strength-limited Design	kg	\$	H _m	CO ₂

Vibration-limited Design

Damage-tolerant Design

Abrasion-resistant Design

Thermo-mechanical Design

Electro-mechanical Design

Vapor barrier Design

Strength-limited design to optimize performance

Simple one-property indices



Protective visor
for motorcyclists

Design requirement

Constraints

- Transparent - of optical quality
- Able to be molded

Objective

- As tough as possible –
maximize fracture toughness K_{1c}

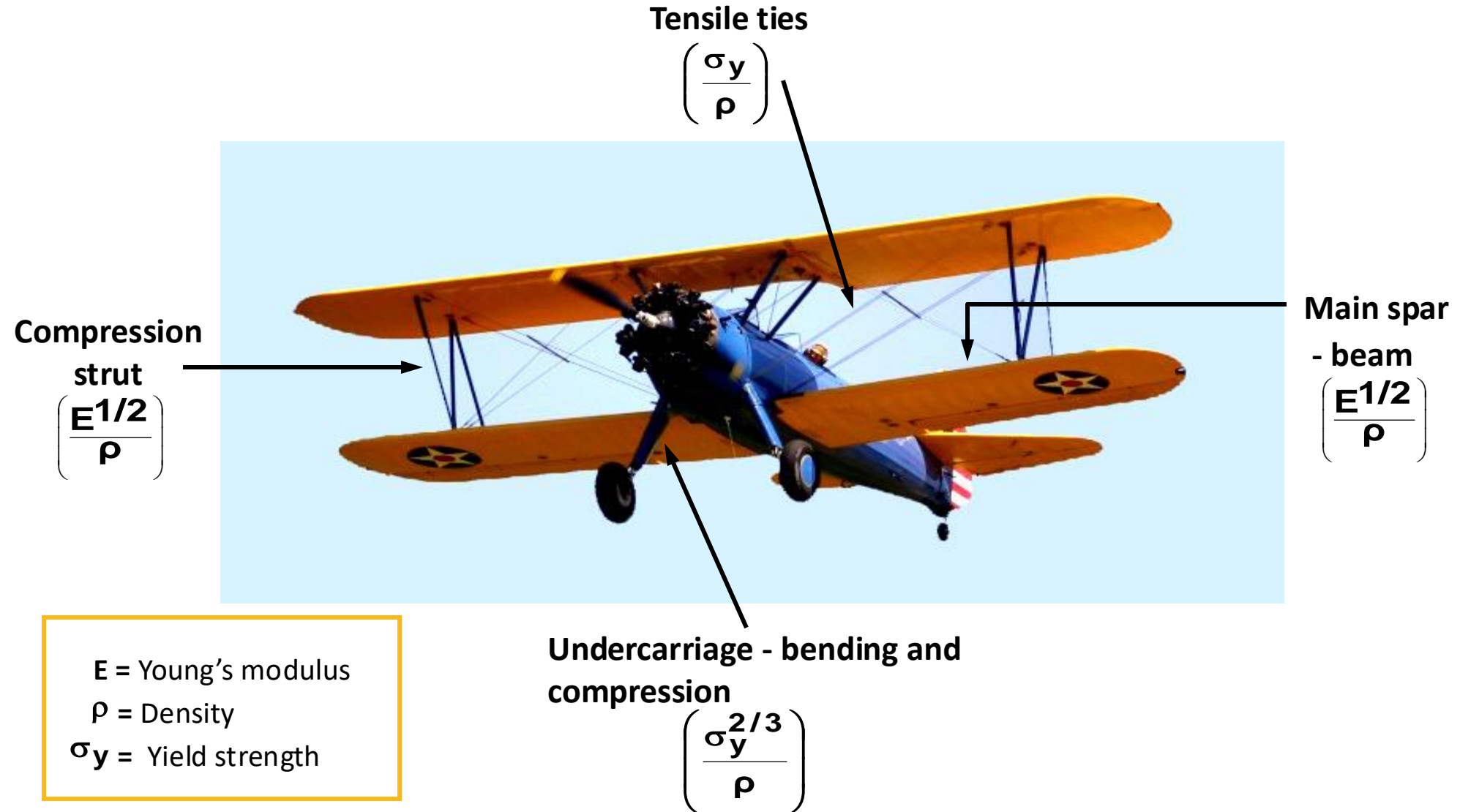
The material index: choose material with largest K_{1c}

Alternative objective

- As cheap as possible –
minimize material cost C_m

The material index: choose material with smallest C_m

Minimum weight design - indices

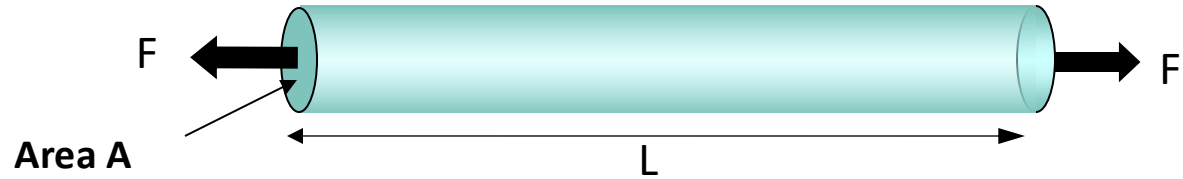


Index for a strong, light tie-rod

Function

Tie-rod

Strong tie of length L and minimum mass



Constraints

- *Length L is specified*
- *Must not fail under load F*

Equation for constraint on A:

$$F/A < \sigma_y$$

Objective

Minimize mass m :

$$m = A L \rho$$

m = mass
 A = area
 L = length
 ρ = density
 σ_y = yield strength

Performance metric

$$m = F L \left(\frac{\rho}{\sigma_y} \right)$$

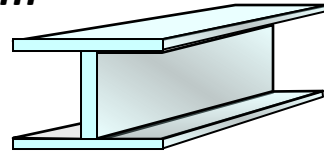
Chose materials with largest

$$M = \left(\frac{\sigma_y}{\rho} \right)$$

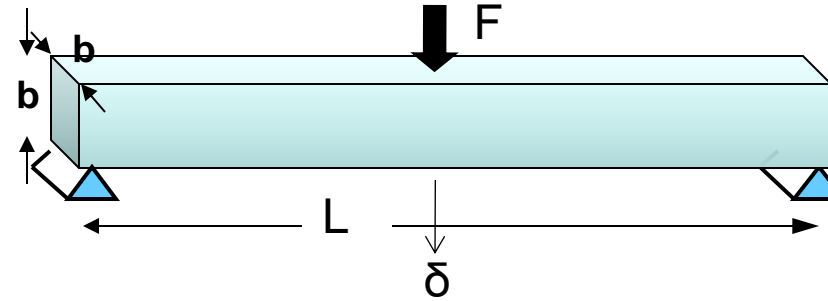
Index for a stiff, light beam

Function

Beam



Stiff beam of length L and minimum mass



Square section, area $A = b^2$

Constraints

- Length L is specified
- Must have bending stiffness $> S^*$

Equation for constraint on A:

$$S = \frac{F}{\delta} = \frac{CEI}{L^3} = \frac{CEA^2}{12L^3}$$

Objective

Minimize mass m :

$$m = AL\rho$$

m = mass
 A = area
 L = length
 ρ = density
 S = stiffness (F/δ)
 This beam: $\delta = FL^3/CEI$
 C = constant (here, 48)
 E = Young's modulus
 I = second moment of area
 $(I = b^4/12 = A^2/12)$

Performance metric

$$m = \left(\frac{12L^5 S^*}{C} \right)^{1/2} \left(\frac{\rho}{E^{1/2}} \right)$$

Chose materials with largest

$$M = \left(\frac{E^{1/2}}{\rho} \right)$$

Ranking, using charts

Light stiff beam:

Index $M = \frac{E^{1/2}}{\rho}$

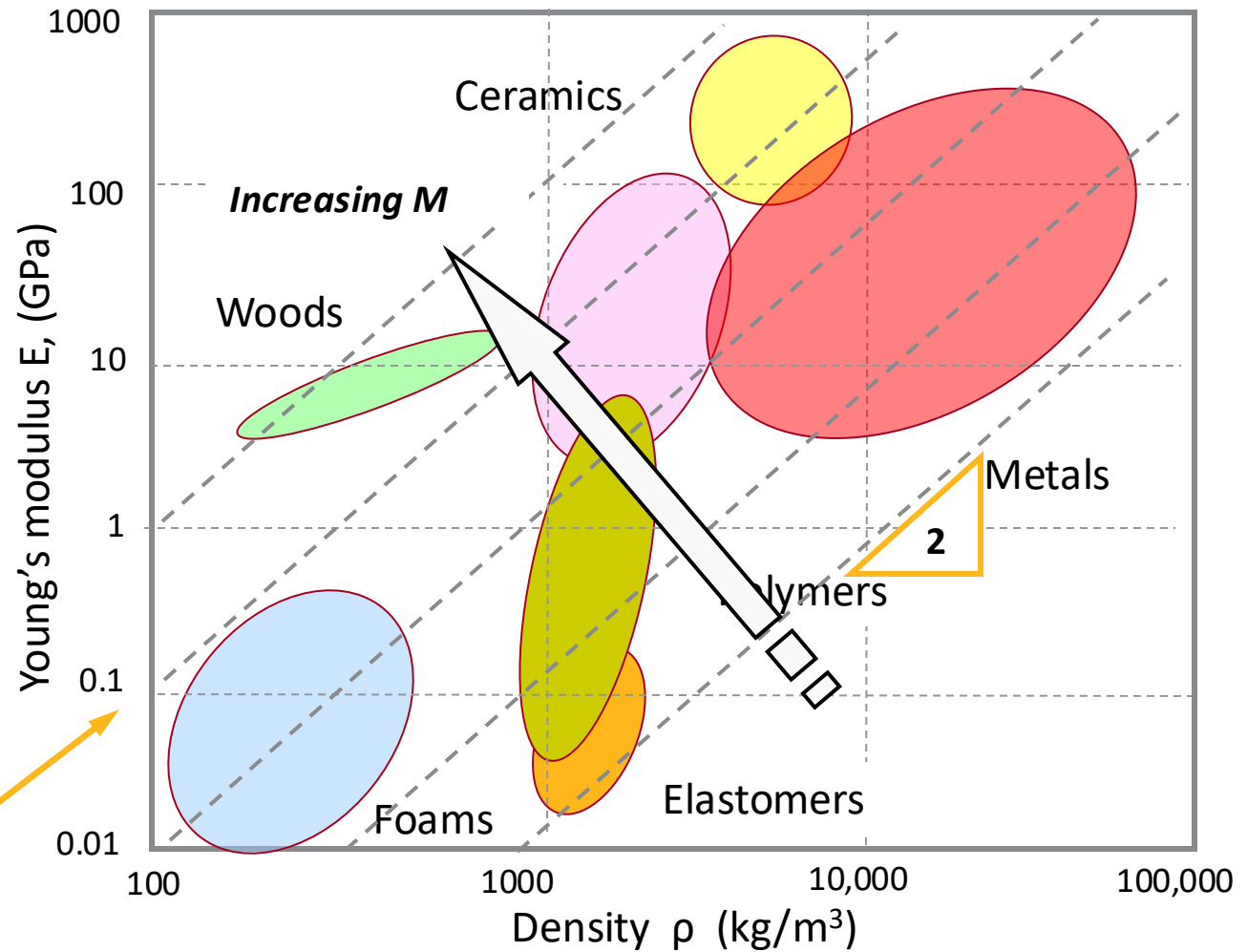
Rearrange:

$$E = \rho^2 M^2$$

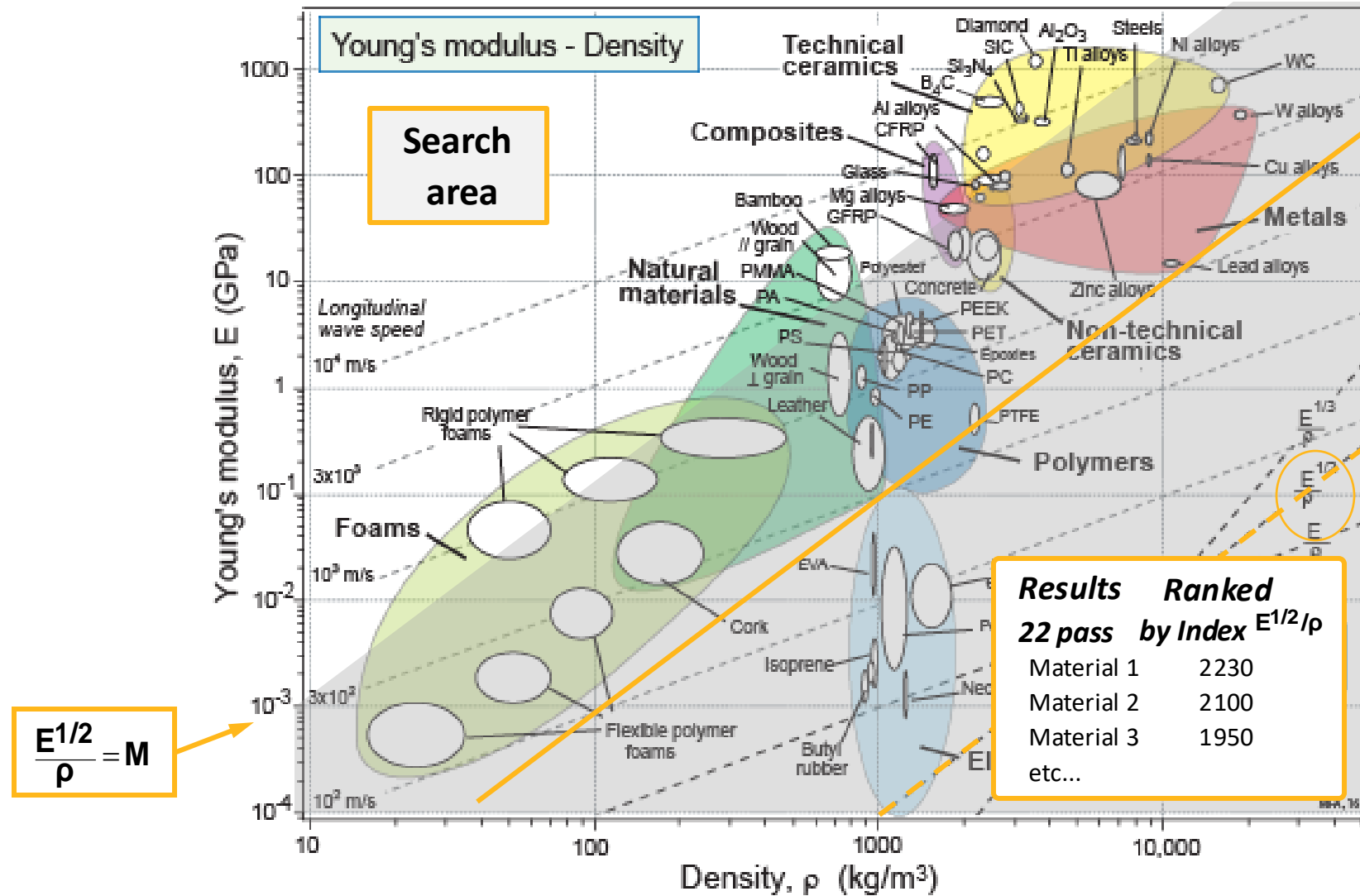
Take logs:

$$\text{Log } E = 2 \text{ log } \rho + 2 \text{ log } M$$

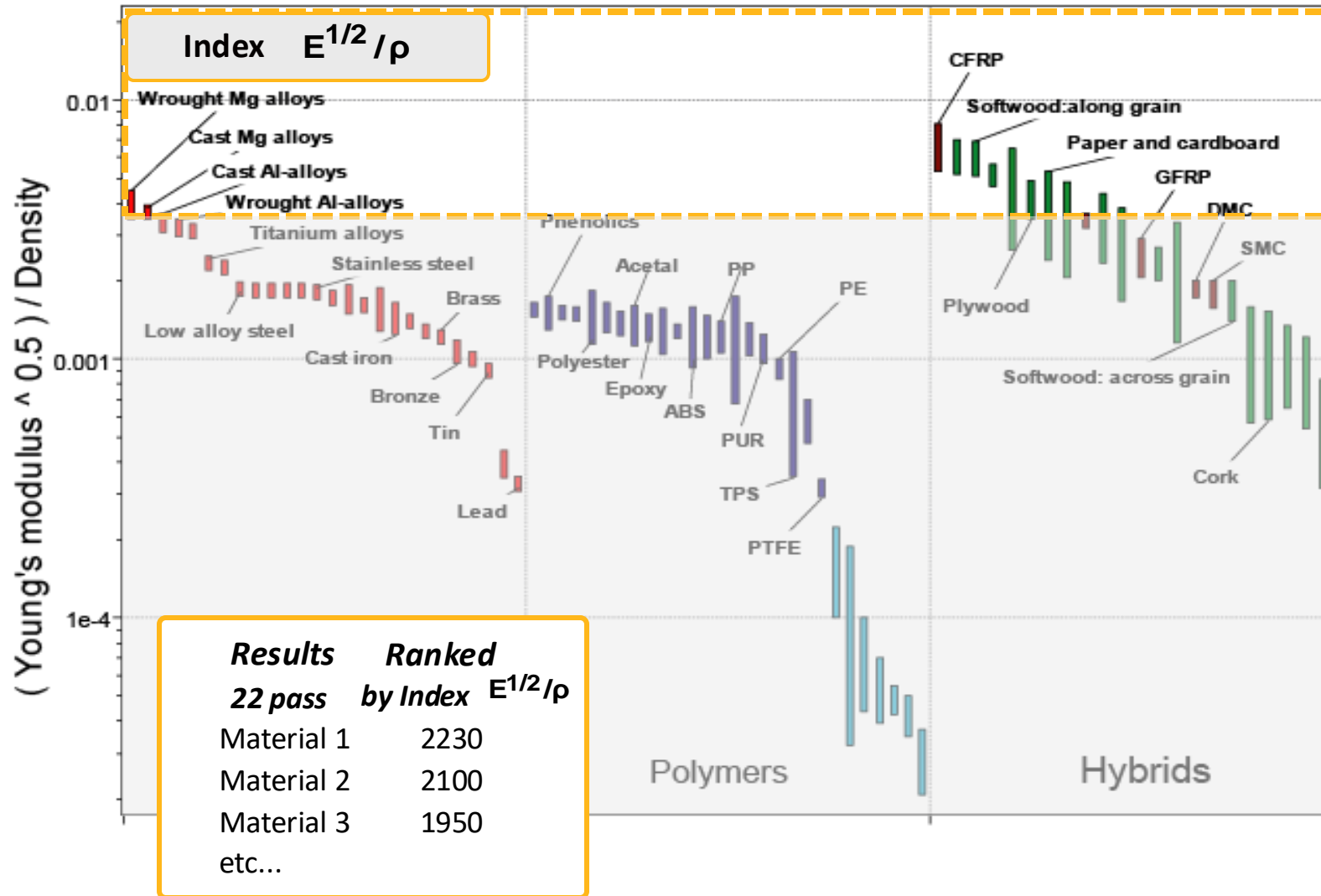
Function	Index	Slope
Tie	E/ρ	1
Beam	$E^{1/2}/\rho$	2
Panel	$E^{1/3}/\rho$	3



Selection using index in a bubble chart



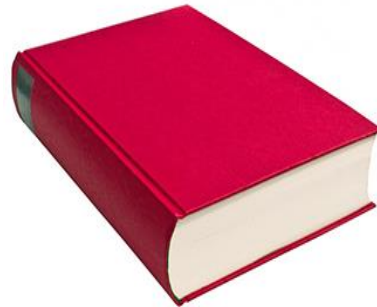
Selection using index directly on chart axis



Documentation: the pedigree

Documentation: “now the number of candidates is small, explore their character in depth”

Handbooks



**Specialized
databases**



**Suppliers'
data sheets**



The Internet

Summary

- **The selection strategy:**

Translate - Screen - Rank - Documentation

- The Granta EduPack software allows Screening using '**Limit – Chart – Tree stages**' in any number and sequence

- The progression:



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