The Materials of Engineering: an Intro to the Ansys Granta EduPack Software








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Learning objectives for this lecture unit

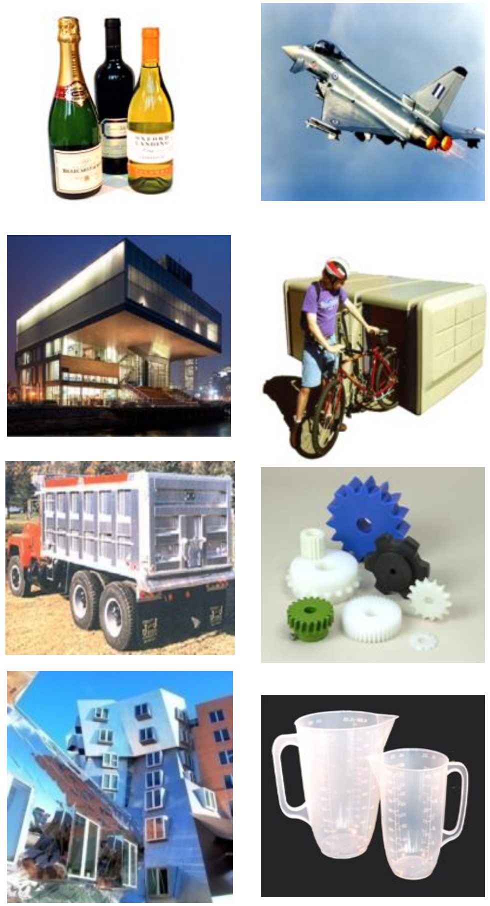
Ansys software mentioned	• Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes	
Knowledge and Understanding	Understanding of what is meant by material and process properties
Skills and Abilities	Ability to find material property data and scientific background to these
Values and Attitudes	Appreciation of the classification and organization of materials information

Resources

- **Text:** "Materials: engineering, science, processing and design" 4th edition by M.F. Ashby, H.R. Shercliff and D. Cebon, Butterworth Heinemann, Oxford, 2019, Chapters 1-2
- **Text:** "Materials Selection in Mechanical Design", 5th edition by M.F. Ashby, Butterworth Heinemann, Oxford, 2016, Chapters 1-2
- **Texts:** Callister, Budinski, Askeland and others – recommended reading in records
- Ansys Granta EduPack software

Lecture Outline



- **Background:** the motivation
- **Materials:** classification and properties
- **Ansys Granta EduPack software:** structure and content

Teaching materials to engineering students

The starting point

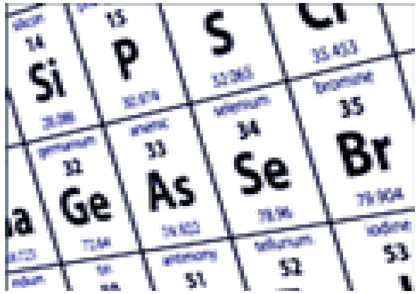
- Engineers make things. They make them out of **materials**, using **processes**.

- What do they need to know?
  - **Perspective** of the world of materials and processes
  - **Understanding** material properties
  - An ability to **select**
  - **Information** and **tools**

- **Ansys Granta EduPack software**: resources to achieve this

- a tool for later profession (like CAD or FE)

Which courses? Campus-wide?



Materials science


General engineering


Polymer engineering


Aerospace engineering


Architecture


Bioengineering


Product design


Environmental engineering

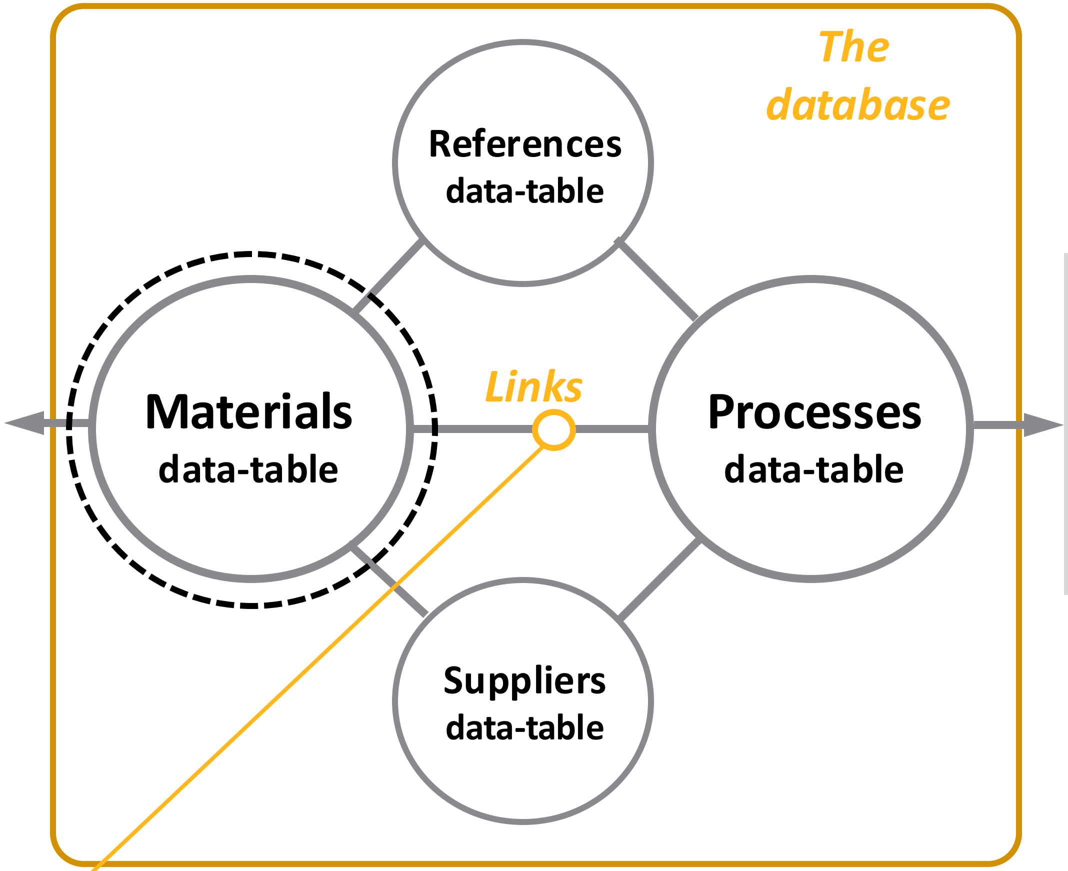

Sustainability assessment

Organizing information

Select on material properties

DATA FOR

- ***Metals & alloys***
- ***Polymers***
- ***Ceramics & glasses***
- ***Hybrids***



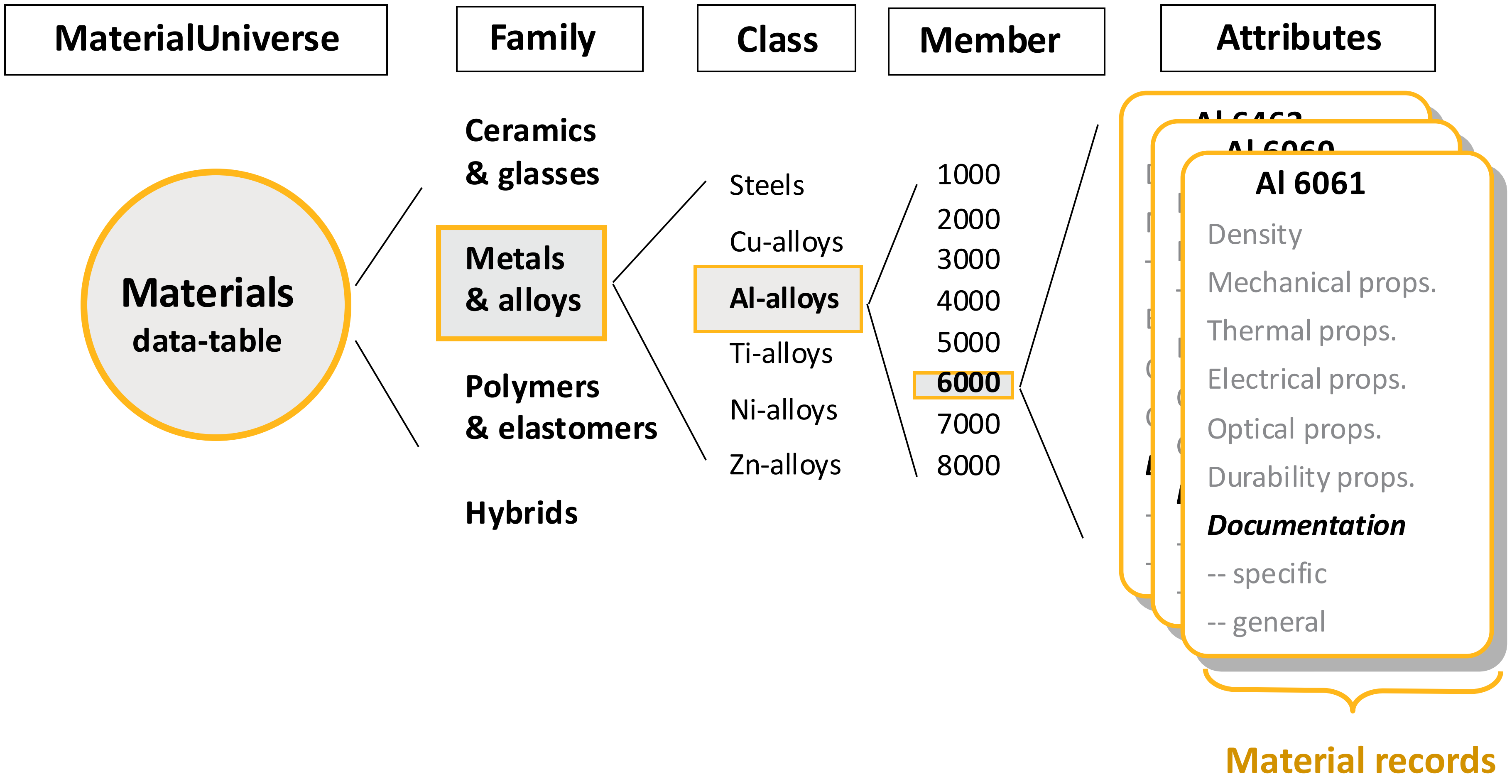
Select on process properties

DATA FOR

- ***Joining***
- ***Shaping***
- ***Surface treatment***

Select on links

Organizing information: the Materials Tree



Structured information for ABS*

Acrylonitrile-butadiene-styrene (ABS)

General properties

Density	1.03e3	-	1.06e3	kg/m^3
Price	* 2.22	-	2.79	USD/kg
Date first used	1937			

Mechanical properties

Young's modulus	2.07	-	2.76	GPa
Shear modulus	* 0.74	-	0.987	GPa
Bulk modulus	* 3.84	-	4.03	GPa
Poisson's ratio	* 0.391	-	0.407	
Yield strength (elastic limit)	34.5	-	49.6	MPa
Tensile strength	37.9	-	51.7	MPa
Compressive strength	* 39.2	-	86.2	MPa
Elongation	5	-	60	% strain
Hardness - Vickers	* 10	-	15	HV
Fatigue strength at 10^7 cycles	* 15.2	-	20.7	MPa
Fracture toughness	* 1.46	-	4.29	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.0145	-	0.0193	

Thermal properties

Glass temperature	102	-	115	°C
Maximum service temperature	62.9	-	76.9	°C
Minimum service temperature	-45.2	-	-35.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	* 0.253	-	0.263	W/m.°C
Specific heat capacity	* 1.69e3	-	1.76e3	J/kg.°C
Thermal expansion coefficient	74	-	123	µstrain/°C

Optical properties

Transparency	Opaque		
Refractive index	1.53	-	1.54

Critical Materials Risk

High critical material risk?	No

Processability

Castability	1	-	2
Moldability	4	-	5
Machinability	3	-	4
Weldability	5		

Geo-economic data for principal component

Annual world production, principal component	8.07e6			tonne/yr
Reserves, principal component	7.13e7	-	7.88e7	tonne

Primary material production: energy, climate change and water

Climate change (CO2-eq), primary production (virgin grade)	* 3.51	-	3.87	kg/kg
Embodied energy, primary production (virgin grade)	* 92.6	-	102	MJ/kg
Water usage	* 167	-	185	l/kg

Links to Processes

*Excerpts from the Ansys Granta EduPack software Level 2 database

Unstructured information for ABS*

Description

Image


Caption

1. ABS pellets. © Shutterstock 2. ABS allows detailed moldings, accepts color well, and is non-toxic and tough enough to survive the worst that children can do to it. © Gettyimages

The material

ABS (Acrylonitrile-butadiene-styrene) is tough, resilient, and easily molded. It is usually opaque, although some grades can now be transparent, and it can be given vivid colors. ABS-PVC alloys are tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

Compositional summary ⓘ

Block terpolymer of acrylonitrile (15-35%), butadiene (5-30%), and styrene (40-60%).

*Excerpts from the Ansys Granta EduPack software Level 2 database

Supporting information

Design guidelines

ABS has the highest impact resistance of all polymers. It takes color well. Integral metallics are possible (as in GE Plastics' Magix.) ABS is UV resistant for outdoor application if stabilizers are added. It is hygroscopic (may need to be oven dried before thermoforming) and can be damaged by petroleum-based machining oils. ASA (acrylic-styrene-acrylonitrile) has very high gloss; its natural color is off-white but others are available. It has good chemical and temperature resistance and high impact resistance at low temperatures. UL-approved grades are available. SAN (styrene-acrylonitrile) has the good processing attributes of polystyrene but greater strength, stiffness, toughness, and chemical and heat resistance. By adding glass fiber the rigidity can be increased dramatically. It is transparent (over 90% in the visible range but less for UV light) and has good color, depending on the amount of acrylonitrile that is added this can vary from water white to pale yellow, but without a protective coating, sunlight causes yellowing and loss of strength, slowed by UV stabilizers. All three can be extruded, compression molded or formed to sheet that is then vacuum thermo-formed. They can be joined by ultrasonic or hot-plate welding, or bonded with polyester, epoxy, isocyanate or nitrile-phenolic adhesives.

Technical notes

ABS is a terpolymer - one made by copolymerizing 3 monomers: acrylonitrile, butadiene and styrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, the butadiene component (which gives poor UV resistance) is replaced by an acrylic ester. Without the addition of butyl, ABS becomes, SAN - a similar material with lower impact resistance or toughness. It is the stiffest of the thermoplastics and has excellent resistance to acids, alkalis, salts and many solvents.

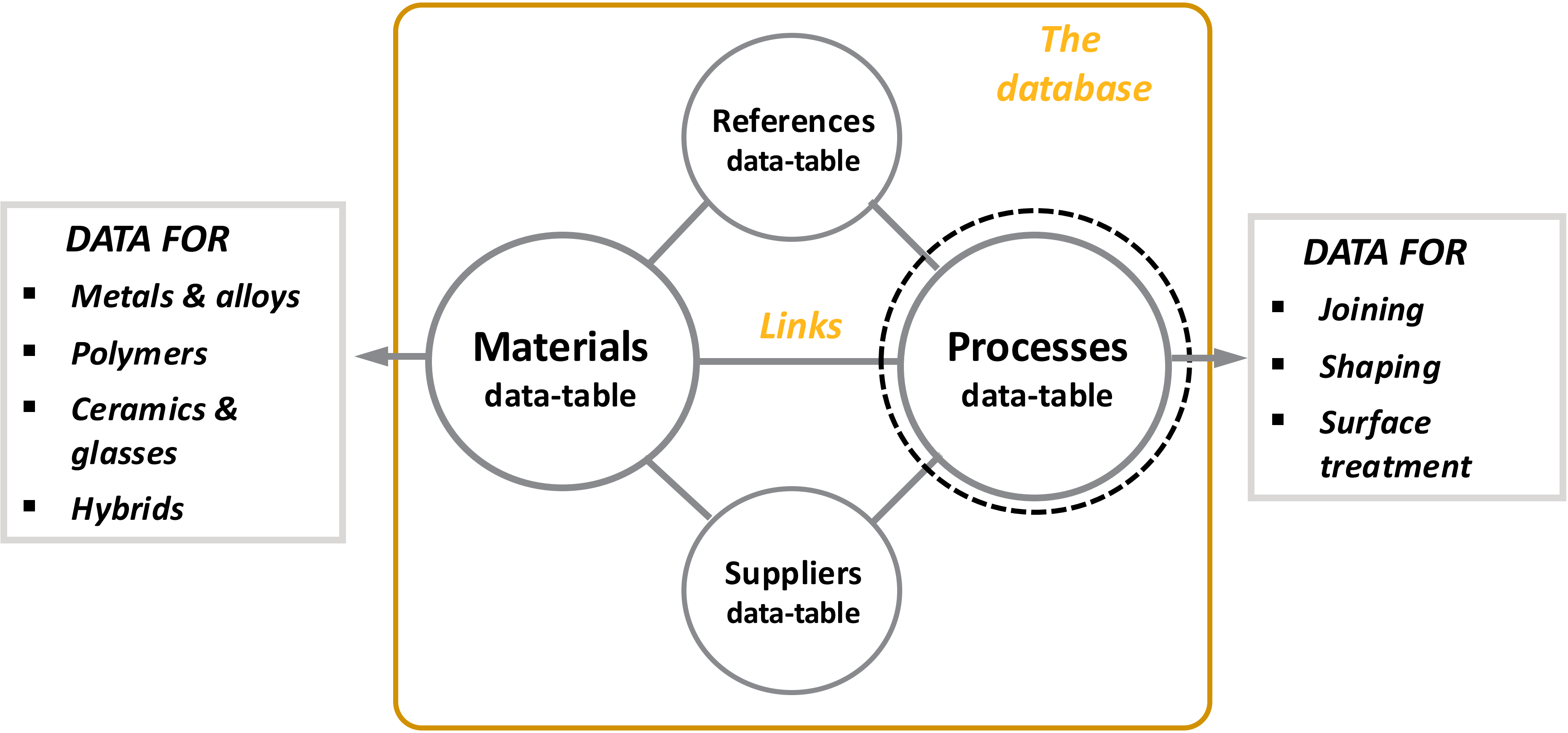
Typical uses

Safety helmets, camper tops, automotive instrument panels and other interior components, pipe fittings, home-security devices and housings for small appliances, communications equipment, business machines, plumbing hardware, automobile grilles, wheel covers, mirror housings, refrigerator liners, luggage shells, tote trays, mower shrouds, boat hulls, large components for recreational vehicles, weather seals, glass beading, refrigerator breaker strips, conduit, pipe for drain-waste-vent (DWV) systems.

Tradenames

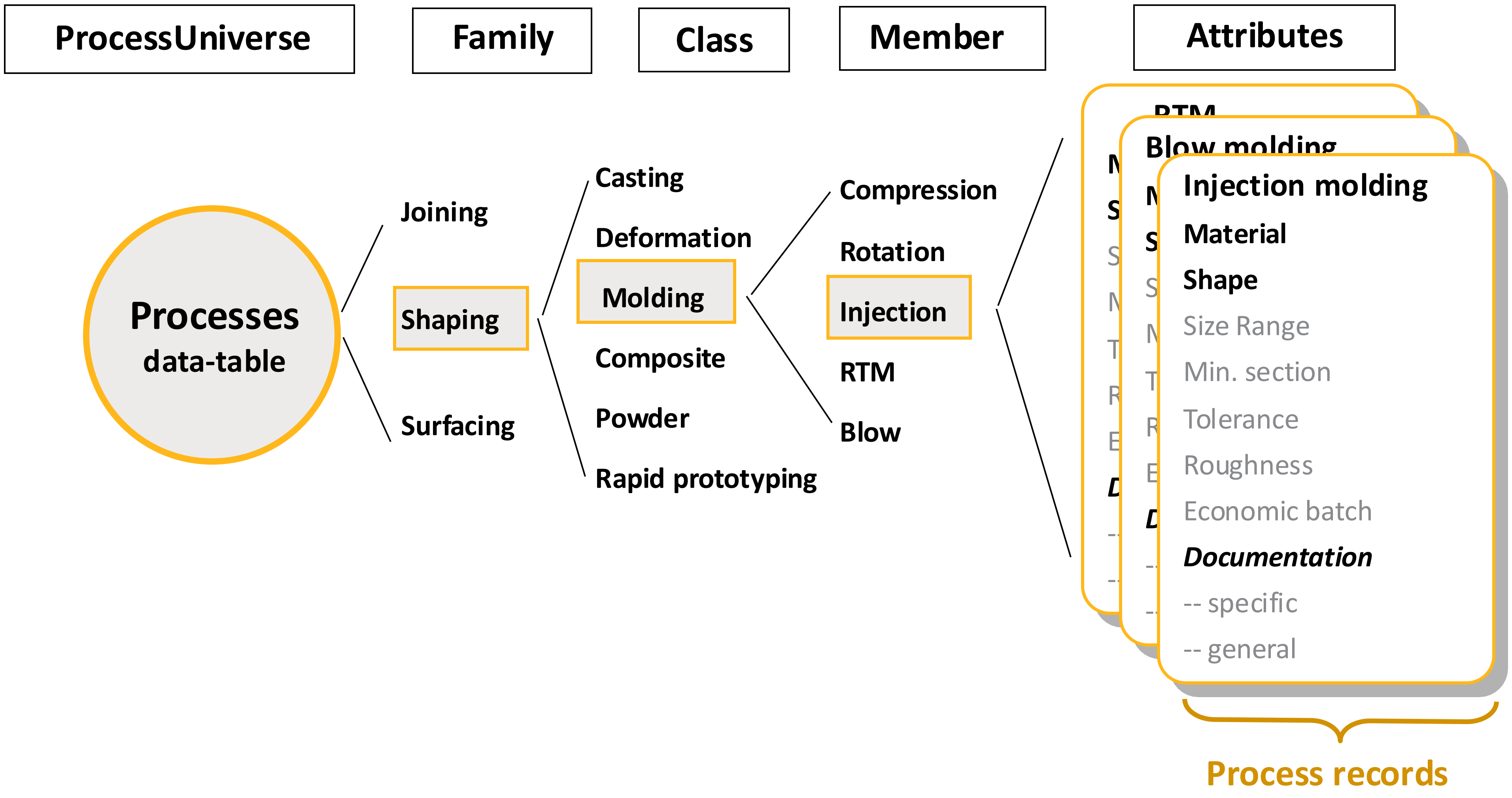
Claradex, Comalloy, Cycogel, Cycolac, Hanalac, Lastilac, Lupos, Lustran ABS, Magnum, Multibase, Novodur, Polyfabs, Polylac, Porene, Ronfalin, Sinkral, Terluran, Toyolac, Tufrex, Ultrastyr

Organizing information: the ProcessUniverse



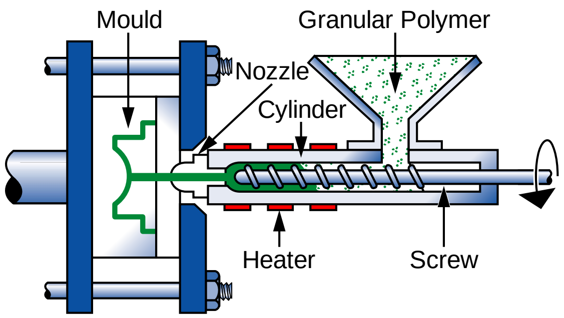
Ansys / GRANTA EDUPACK

Organizing information: the Process Tree



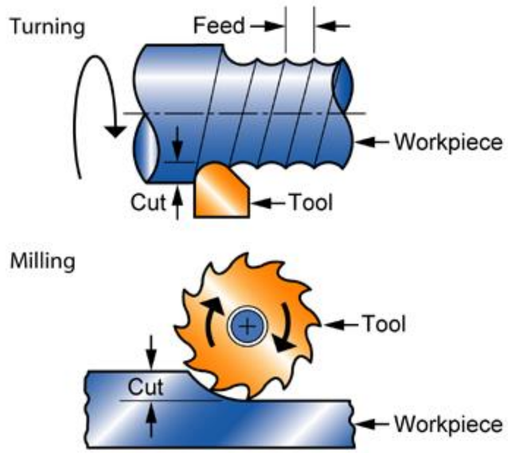
Organizing info: manufacturing processes

Primary shaping



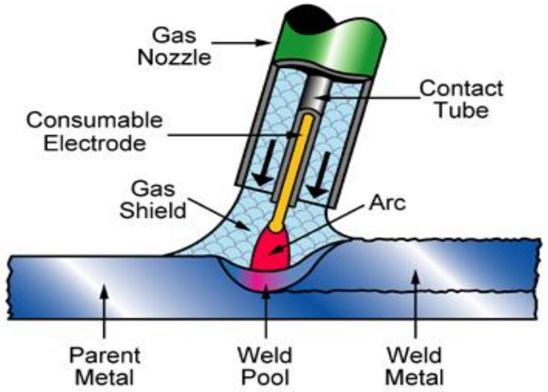
Injection moulding

Secondary shaping



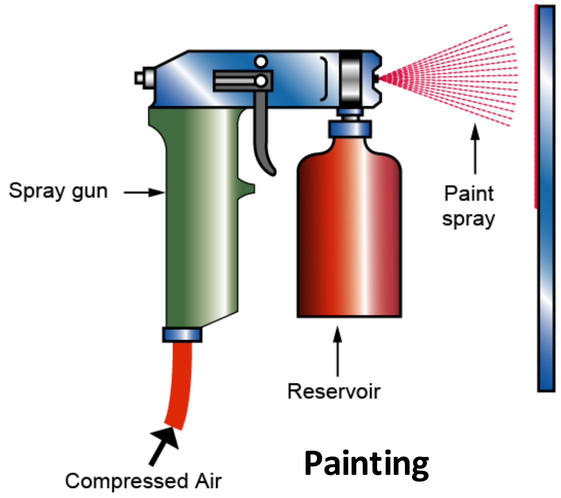
Machining

Joining



Welding

Surface treating

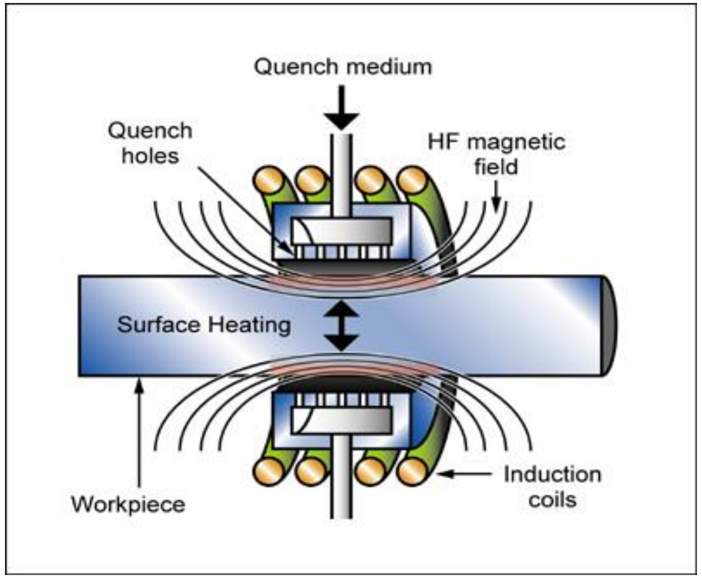


Painting

A surface-treatment record*

The process

Induction hardening allows the surface of carbon steels to be hardened with minimum distortion or oxidation. A high frequency (up to 50kHz) electromagnetic field induces eddy-currents in the surface of the work-piece; these currents heat the surface into the austenitic phase-region, from which it is rapidly cooled from a gas or liquid jet, giving a martensitic surface layer. The depth of hardening depends on the frequency of the electromagnetic field. In flame hardening, heat is applied instead by means of one or more high-temperature gas burners, followed, as before, by rapid cooling. Both processes are versatile and can be applied to work pieces that cannot readily be furnace treated or case hardened in the normal way. Induction and flame hardening allow selective hardening of particular areas of the work piece. Both give a surface layer with a hardness that is lower than that of diffusion-based processes like carburizing and nitriding, but the depth is greater. The hardened surface layer carries internal stresses that can lead to micro cracking if the process conditions are incorrect.



Material compatibility

Metals - ferrous	ⓘ	✓

Function of treatment

Hardness	ⓘ	✓
Wear resistance	ⓘ	✓
Fatigue resistance	ⓘ	✓
Friction control	ⓘ	✓

Economic compatibility

Relative tooling cost	ⓘ	low
Relative equipment cost	ⓘ	medium
Labor intensity	ⓘ	low

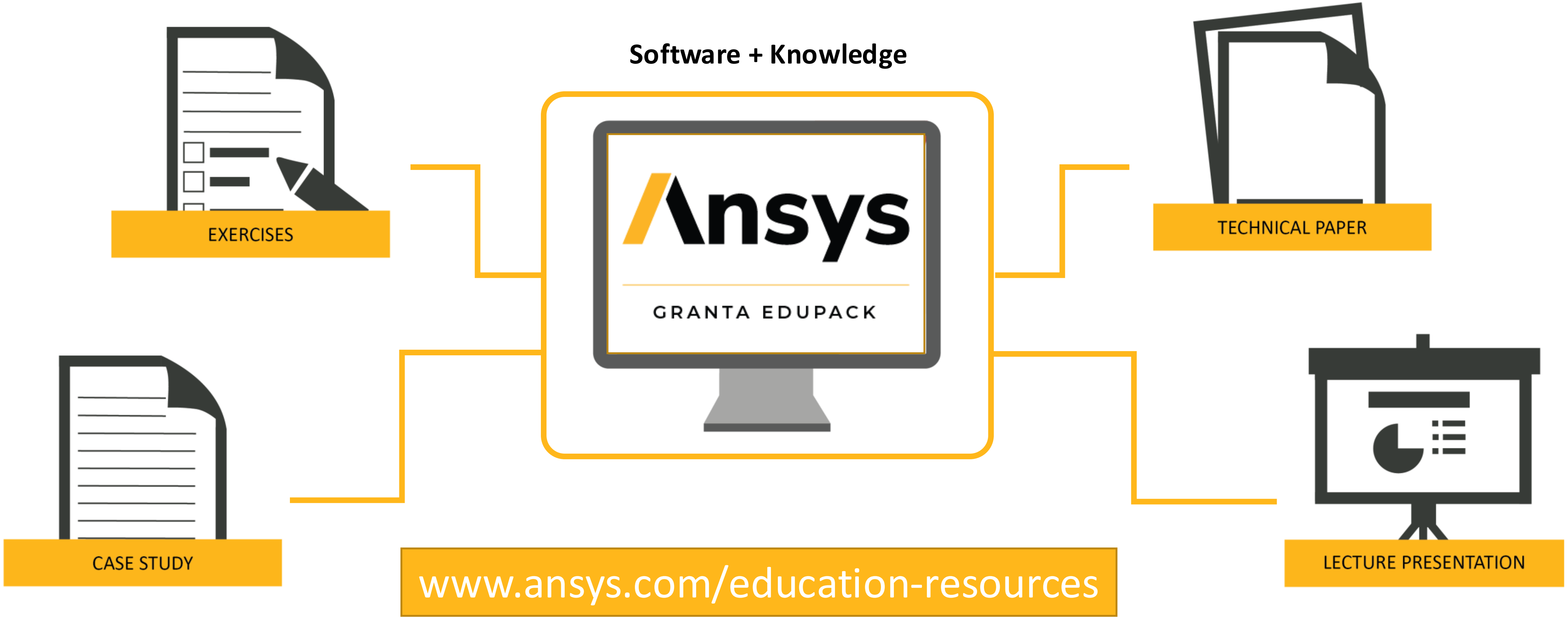
Typical uses

The processes are used to harden gear teeth, splines, crankshafts, connecting rods, camshafts, sprockets and gears, shear blades and bearing surfaces.

Links to Materials

*Excerpts from the Ansys Granta EduPack software Level 2 database

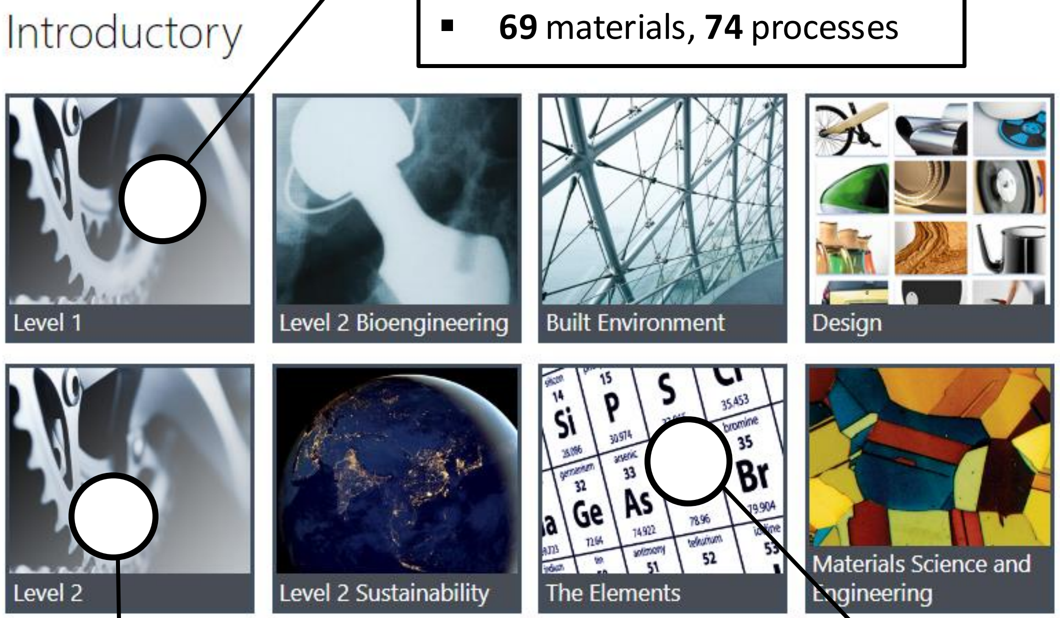
Ansys Granta EduPack software and education resources



Ansys Granta EduPack software 2025R1

Level 1, general

- Schools, 1^{st} **year** college
- **69** materials, **74** processes



Level 2, general

- **1^{st}-3^{rd} year** students of Engineering, Materials Science and Design
- **100** materials, **116** processes

The Elements Database

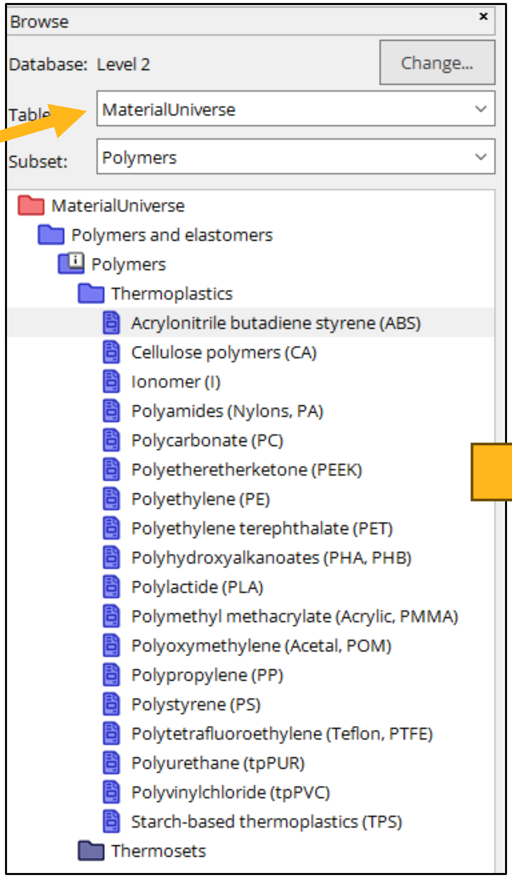
- Schools-University students
- **149** records, periodic table

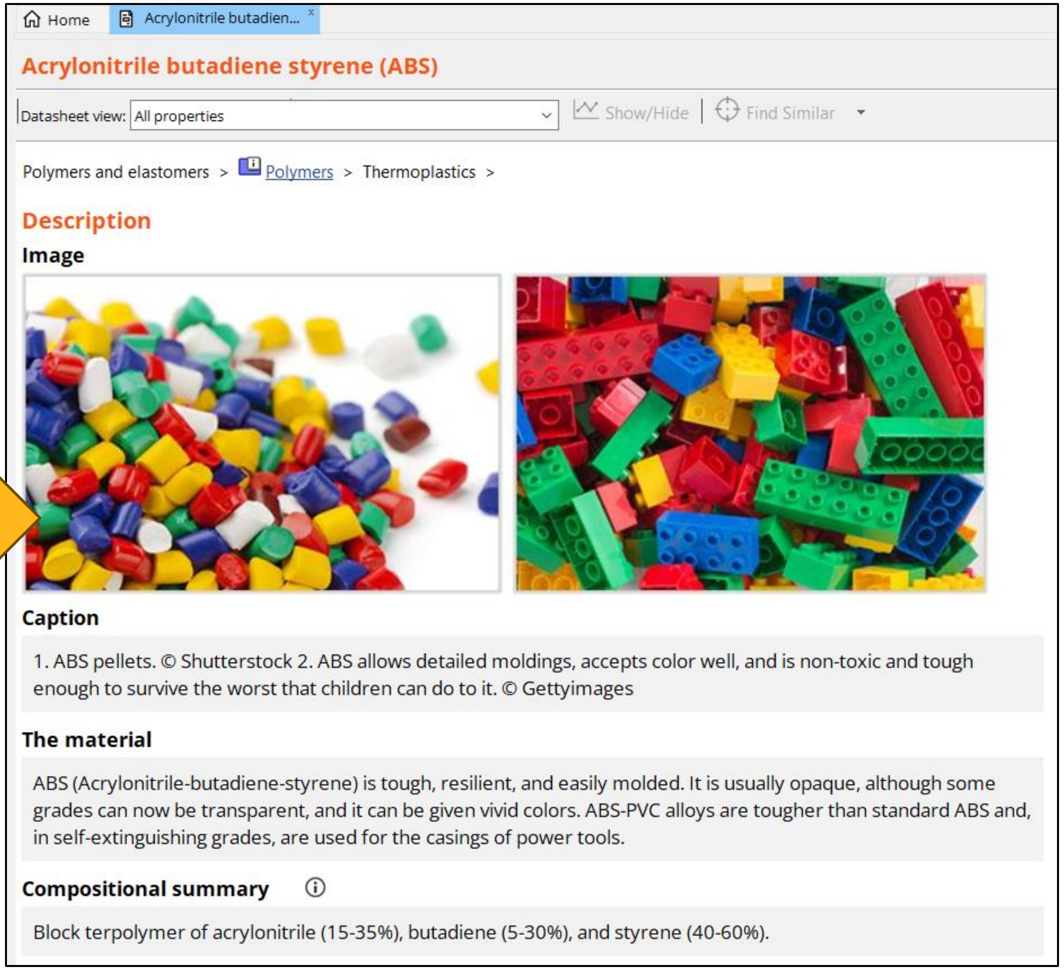
Level 3, general

- **3^{rd}-4^{th} year**, **masters** and **research**
- **4000+** materials, **225+** processes

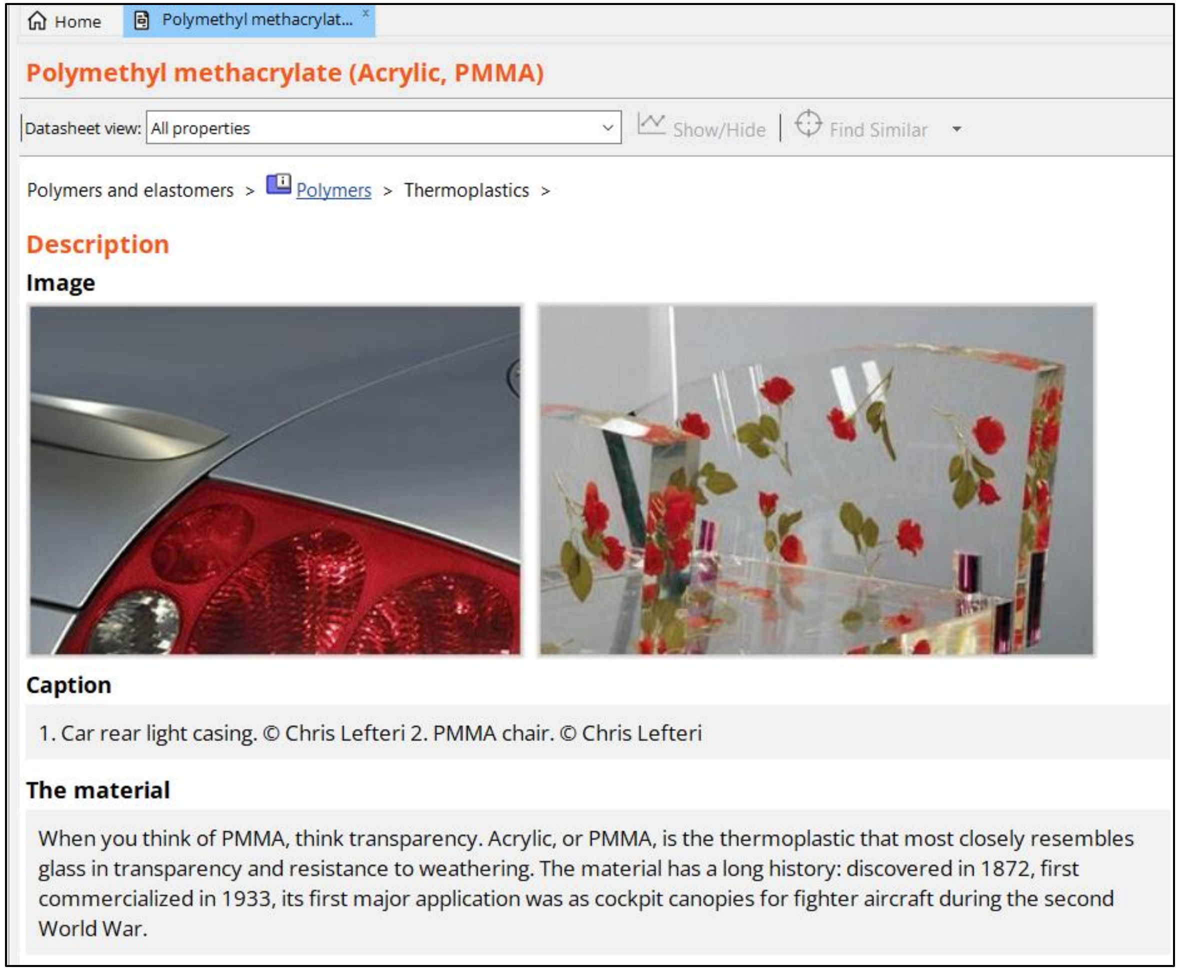
Tools to find information- Browse function

Change datatable of interest here





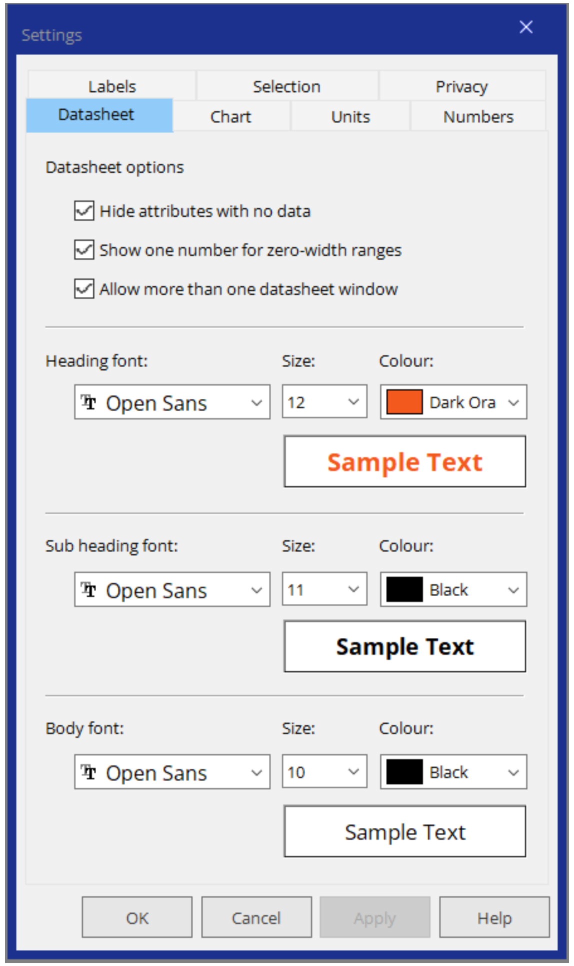
Tools to find information- Search function

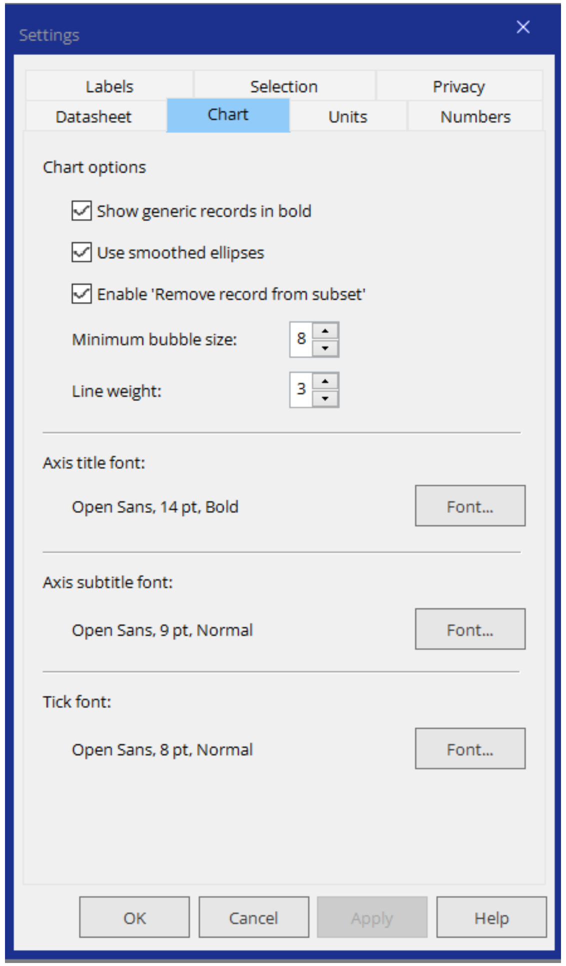


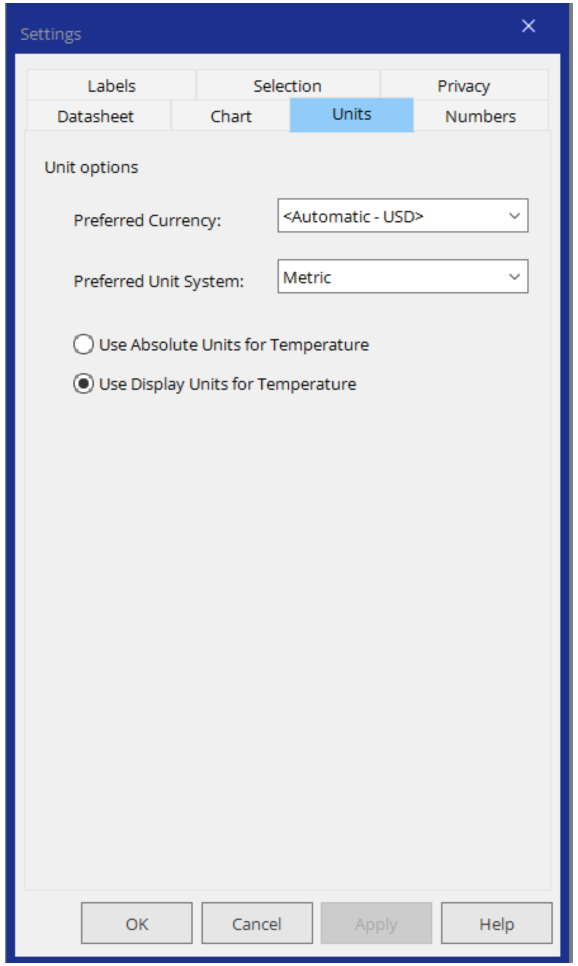
About the search function:

- Not sensitive to CASE but to spelling
- Searches all data-tables
- Operators AND, OR, NOT, * ...
- Categorizes all results
- Highlights search term in datasheet

Changing the data settings (units etc.)

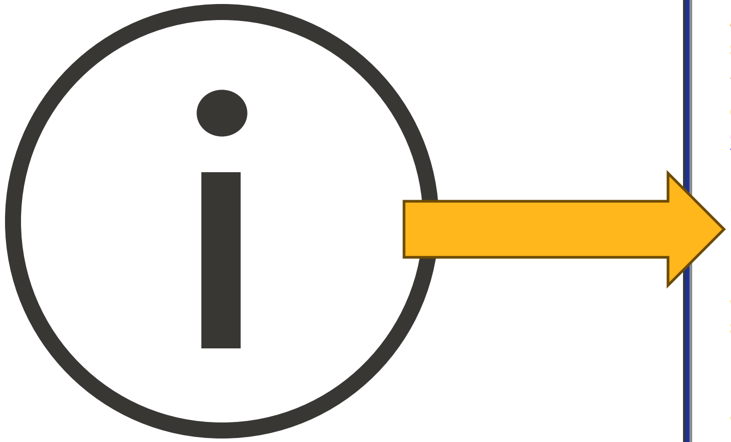






Adding the science

Click the “i” icon next to any attribute



Science Note

Back Forward Copy Print

Young's modulus, shear modulus, bulk modulus and Poisson's ratio

[Definition and measurement.](#)
[Drilling down: the origins of moduli.](#)
[Further reading.](#)

Definition and measurement. Figure 1 shows a typical tensile stress-strain curve. The initial part, up to the yield strength σ_y or elastic limit σ_{el}, defined under *Yield strength (elastic limit)*, is linear (Hooke's law), and it is elastic, meaning that the strain is recoverable - the material returns to its original shape when the stress is removed. Stresses above the elastic limit cause permanent deformation or fracture (see notes for ***Yield strength (elastic limit)*** and ***Fracture toughness***).

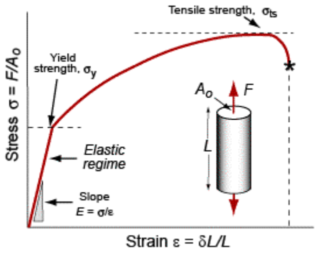


Figure 1. A tensile stress-strain curve.

Within the linear elastic regime, strain is proportional to stress, but stress can be applied in more than one way (Figure 2). The tensile stress σ produces a proportional tensile strain ε:

$$\sigma = E\,\varepsilon$$

and the same is true in compression. The constant of proportionality, *E*, is called Young's modulus. Similarly, a shear stress σ_s causes a proportional shear strain γ

$$\sigma_s = G\,\gamma$$

and a pressure *p* results in a proportional fractional volume change (or "dilatation") Δ:

$$p = K\,\Delta$$

where G is the shear modulus and *K* the bulk modulus. All three of these moduli have the same dimensions as stress, that of force per unit area (N/m^2 or Pa). It is convenient to use a larger unit, that of 10^9 Pa, Giga-Pascals, or GPa.

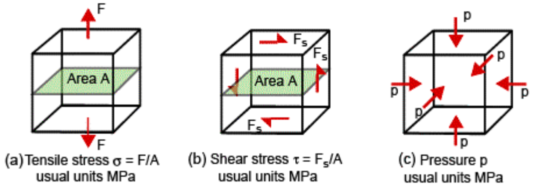
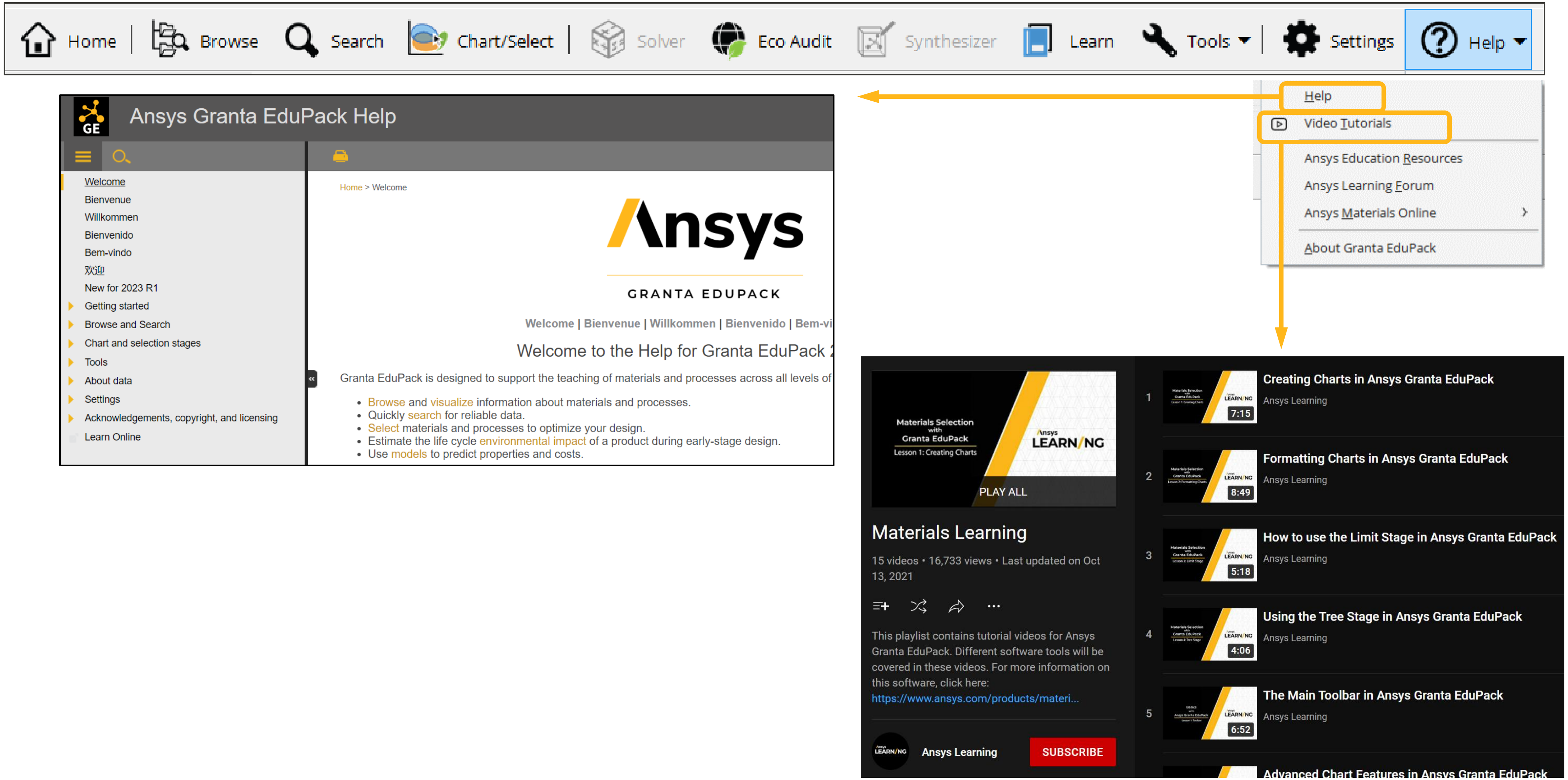


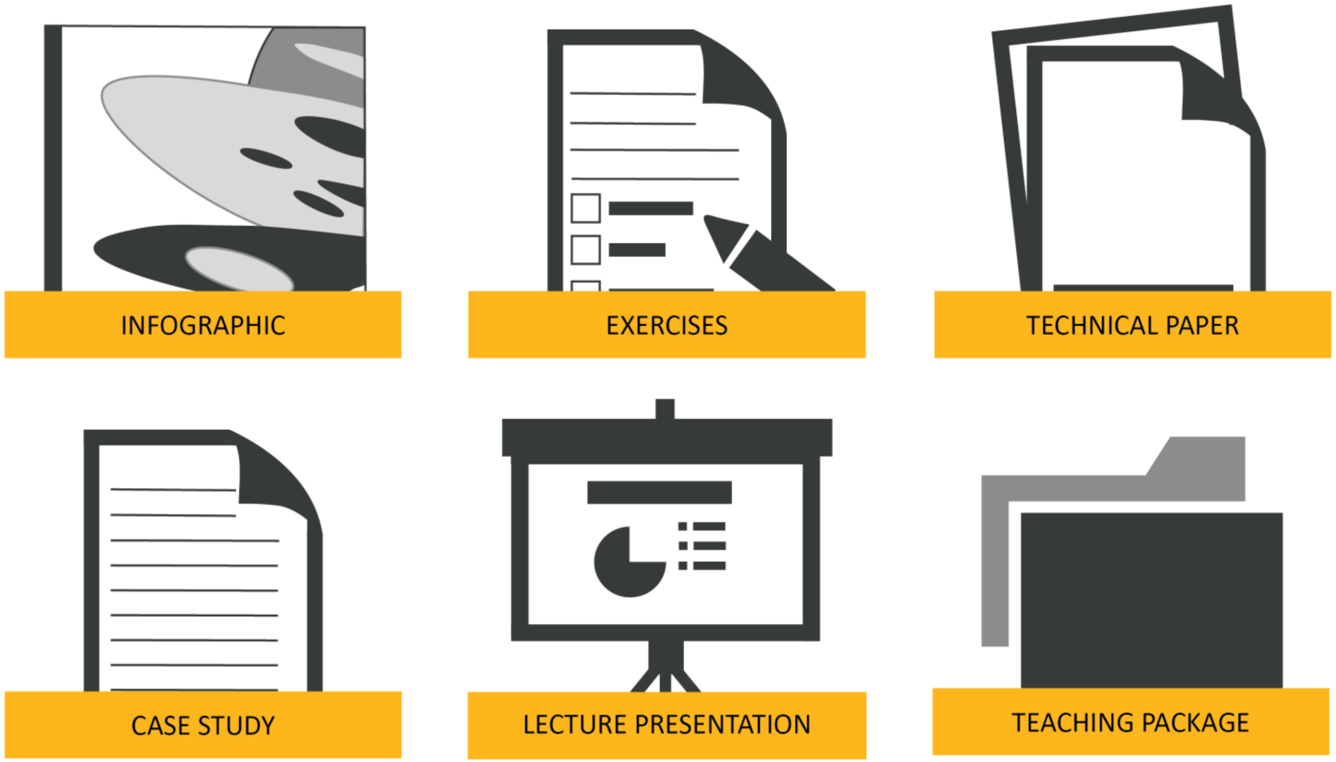
Figure 2. (a) Tensile stress. (b) Shear stress. (c) Hydrostatic pressure.

With relevant textbooks listed for Further Reading

HELP! Video tutorials, White Papers… more



Ansys Education Resources



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- Case Studies
- White Papers
- Recorded Webinars
- Posters

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Summary

- **Classification** lets materials data be **organized** and **retrieved**

- Data take two broad forms:

  (a) **Numeric, non-numeric data** that can be **structured**

  (b) **Documentation,** usually in the form of text, graphs and images

- **Ansys Granta EduPack software allows** access to data via

  Browse **or** **Search**

- **Underlying science** provided via
  - **Science notes** linked to material property names
  - **White Papers** accessed via **Help**
  - **References** to leading texts

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