3.3 MATERIALS INFORMATION FOR DESIGN

The engineer, in selecting materials for a developing design, needs data for the materials' properties. Engineers are often conservative in their choice, reluctant to consider materials with which they are unfamiliar, and with good reason. Data for the old, well-tried materials are established, reliable, and easily found. Data for newer, emerging, materials may be incomplete or untrustworthy. Yet innovation is often made possible by new materials. So it is important to know how to judge data quality.

If you're going to design something, what sort of materials information do you need? Figure 3.2 draws relevant distinctions. On the left a material is tested and the *data* are captured. But these raw data—unqualified numbers—are, for our purposes, useless. To make data useful requires statistical analysis. What is the mean value of the property when measured on a large batch of samples? What is the standard deviation? Given these, it is possible to calculate *allowables*: values of properties that, with a given certainty (say, one part in 10^6) can be guaranteed. Material texts generally present test data; by contrast, data in most engineering handbooks are allowables.

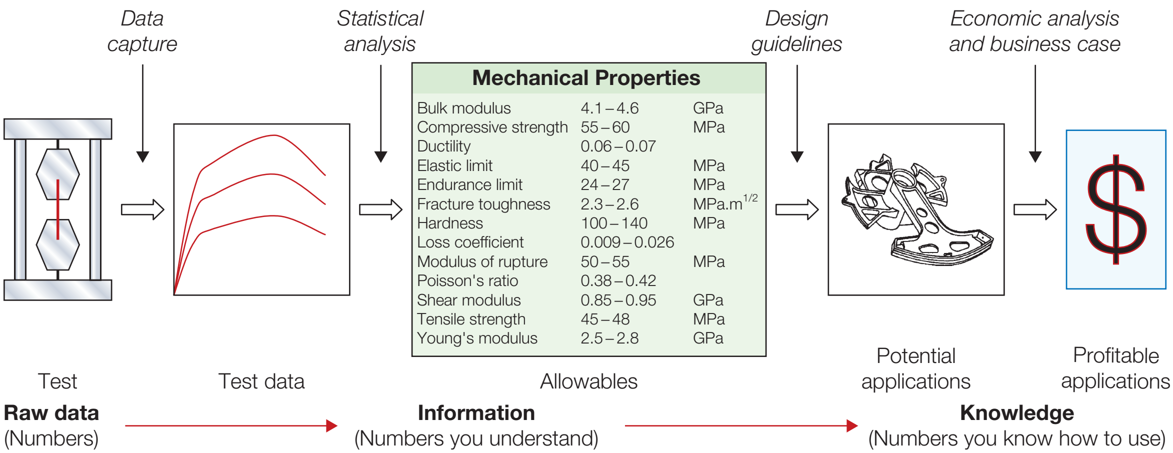

FIGURE 3.2

Types of material information. We are interested here in the types found in the center of this schematic: structured data for design "allowables" and the characteristics of a material that relate to its ability to be formed, joined, and finished; records of experience with its use; and design guidelines for its use.

One can think of data with known precision and provenance as *information*. Information can generally be reported as tables of numbers, as yes/no statements or as rankings: that is, it can be *structured*. Many attributes that can be structured are common to all materials; all have a density, an elastic modulus, a strength, a thermal conductivity. Structured information can be stored in a database and—since all materials have values—it is the starting point for selecting between them. The cover picture of this chapter shows part of a record for the polymer ABS with structured data on the left, reported as ranges that derive from differences in the way different producers make it.

This is a step forward, but it is not enough. To design with a material, you need to know its real character, its strengths, and its weaknesses. How do you shape it? How do you join it? Who has used it before and for what? Did it fail? Why? This information exists in handbooks, is documented as design guidelines, and is reported in failure analyses and case studies. It consists largely of text, graphs and images, and while certain bits of it may be available for one material, for another they may not. It is messier, but it is essential in reaching a final selection. We refer to this supporting information as *documentation*. The image and text on the right of the ABS cover are examples of documentation.

There is more. Material uses are subject to standards and codes. These rarely refer to a single material but to classes or subclasses. For a material to be used in contact with food or drugs, it must carry FDA approval or the equivalent. Metals and composites for use in U.S. military aircraft must have military specification approval. To qualify for best-practice design for the environment, material usage must confirm to ISO 14040 guidelines. And so forth. This, too, is a form of documentation (Table 3.1). The ensemble of information about a material, structured and unstructured, constitutes *knowledge*.

There is yet more (Figure 3.2, *right*). To succeed in the marketplace, a product must be economically viable and compete successfully, in terms of performance, consumer appeal, and cost, with the competition. All of these

Table 3.1 Basic Design-Limiting Material Properties and Their Usual SI Units*

Class	Property	Symbol and Units
General	Density	ρ (kg/m^3 or Mg/m^3)
	Price	C_m ($/kg)
Mechanical	Elastic moduli (Young's, shear, bulk)	E, G, K (GPa)
	Yield strength	σ_y (MPa)
	Tensile (ultimate) strength	σ_{ts} (MPa)
	Compressive strength	σ_c (MPa)
	Failure strength	σ_f (MPa)
	Hardness	H *(Vickers)*
	Elongation	ε (–)
	Fatigue endurance limit	σ_e (MPa)
	Fracture toughness	K_{1c} (MPa.m$^{1/2}$)
	Toughness	G_{1c} (kJ/m^2)
	Loss coefficient (damping capacity)	η (–)
	Wear rate (Archard) constant	K_AMPa^{-1}
Thermal	Melting point	T_m (°C or K)
	Glass temperature	T_g (°C or K)
	Maximum service temperature	T_{max} (°C or K)
	Minimum service temperature	T_{min} (°C or K)
	Thermal conductivity	λ (W/m.K)
	Specific heat	C_p (J/kg.K)
	Thermal expansion coefficient	α (K^{-1})
	Thermal shock resistance	ΔT_s (°C or K)
Electrical	Electrical resistivity	ρ_e (Ω.m or $\mu\Omega$.cm)
	Dielectric constant	ε_r (–)
	Breakdown potential	V_b (10^6 V/m)
	Power factor	P (–)
Optical	Refractive index	n (–)
Eco-properties	Embodied energy	H_m (MJ/kg)
	Carbon footprint	CO_2 (kg/kg)

* *Conversion factors from metric to imperial and cgs units appear inside the back and front covers of this book.*

depend on material choice and the way the material is processed. Much can be said about this, but not here; for now the focus is on structured data and documentation.

That's the essential background. Now for the properties themselves.