How accurate is material data?

This brief will attempt to give guidance on the accuracy of material data reported in various sources.

There are three main sources for the scatter in reported property values.

1) Measurement error & sample preparation.
2) Sample composition variation.
3) Heat-treatment variation.

The variation due to measurement error and sample preparation can be seen in round-robin studies. These studies typically involve a large amount of material from one batch being divided up and sent to several different laboratories for testing. All laboratories should follow the same testing standard. The magnitude of this error should be the smallest possible. Also note that laboratories which take part in these types of studies are probably the most careful, not all labs will be as careful or as well maintained.

The variation due to composition variation will depend on the specifics of the material being tested. Some metals have wide composition ranges, some pure metals are very sensitive to impurities, some are stable at RT but age or anneal at high temperatures. If the material is not stable over the measurement range, then a repeat measurement will give different results. The glass phase in some ceramics is unstable at high temperatures. Many polymers are sensitive to moisture and to the mold geometry. Glasses and polymers are sensitive to the cooling rate. The thermal, electrical, and magnetic properties of metal at low temperatures are very sensitive to composition and impurities, especially for the purer alloys, and the spread in values will be correspondingly larger than at RT. The size of the test sample can also have an effect due to texture or different cooling rates for the inner and outer material.

Heat treatments are frequently ill-defined. They may say “annealed” or “aged” where the exact time and temperature are not specified, or a range of temperature/times may be given. Annealing conditions can change from manufacturer to manufacture or from year to year but the material just described as “annealed”.

All values given for the spread in the individual properties are approximate and are meant to guide your expectations. I’ve never seen error bars on an FEA simulation.

Property	Typical range on values	Notes	Reference
Thermal expansion data	+/-5% pure materials +/-10% alloys; +/20% liquids		13
Thermal Conductivity	+/-15%	laser flash	1
Thermal Diffusivity	+/-10%	laser flash	1
Specific heat/Heat capacity	+/-15%	DSC	1
Electrical resistivity/conductivity	+/-10%	estimated from limited data	
Elastic properties (E, G, v, K)	+/-5% (Ultrasonic) +/-10% (stress-strain curve)	Poisson's ratio is a calculated value, the error will be correspondingly higher	2, 6, 10, 15
Stress-strain curves & Strength (UTS, YS & % elongation)	+/-10% to +/-25% (stress) +/-50% (% elongation)		7, 8, 9, 10, 16, 19
Fatigue (S-N)	+/-20% on stress, 10x on cycles		3, 8, 9
Fatigue (ε-N)	+/-50% on strain, 10x on cycles		4
Stress rupture, Creep strength & Isochronal creep	+/-25% in stress and up to 10x on rupture life	See material "HR6W" for scatter on the rupture life and "IN-519" for scatter on the Larson-Miller parameter	5, 6, 8, 9
Creep rate	Some data shows a 40x variation in creep rate at the same stress level, a more typical value is a 10x variation	See Table 56 in reference 20	20
Flexural strength/modulus (polymers)	+/-10%	estimated	
Specific volume	+/-5%	estimated	
Vapor pressure	+/-10% near boiling point, larger far below the boiling point	estimated	
Viscosity	+/-10% for liquids +/-50% for glasses	estimated from limited data	
Surface tension	+/-10%	estimated from limited data	
Emissivity	+/-30%	very sensitive to the surface condition	14
Magnetic properties	+/-5%	estimated	
Refractive Index	+/-0.1%		11, 17, 18
Permittivity (dielectric constant)	+/-5%	estimated from limited data	12
Dissipation factor (dielectric loss)	+/-20%	estimated from limited data	12

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