Appendix

Quantities and units

The quantities and units used to describe properties of high-performance fibres have a diversity based on technical, historical and cultural factors. No attempt has been made in editing this book to enforce uniformity. Authors have used the terminology with which they are most comfortable, and this has an educational value for readers. This Appendix describes the factors involved and provides guidance for interconversion.

The size of fibres can be expressed either spatially or gravimetrically. Dimensions are normally expressed as diameters in μm, though sub-multiples of inches are found in older literature. Fibre densities are normally expressed in g/cm^3, though strict SI uses kg/m^3, which gives numbers 1000 times larger. For yarns, account must be taken of the space between fibres, defined by the packing factor, so that linear dimensions are not used as a specification, though they are needed in calculations of fabric geometry.

For both fibres and yarns, the linear density, namely, the mass per unit length, is the best way of characterising the size. Historically, there are many units: both direct 'weight per unit length' units and indirect counts, which derive from the number of hanks of a given length making a certain weight. In the glass fibre industry, there is use of yardage, namely yards per pound. Strand count is defined as yardage/100. The manufactured textile fibre industry adopted the silk unit of *denier*, but later a rational metric unit, *tex*, which is accepted by SI, was introduced and is now the preferred form. Because of the similarity in magnitude to denier, the sub-unit *decitex* (*dtex*) is widely used. These units are:

tex = gram per kilometre (g/km)
decitex = 0.1 gram per kilometre
denier = gram per 9000 metres   1 denier = 0.11 tex = 1.1 dtex

strand count = 100 yards per pound = 4960/tex

The diversity becomes enormous when covering stress and related strength and stiffness values.

Table A1 Unit conversions

Specific stress		Stress: density in g/cm^3 times	
1	– N/tex, kJ/g, GPa/g cm^{-3}, (km/s)^2	1	– GPa, J/mm^3
	– 10 cN/dtex, 10.2 gf/dtex, 11.3 gf/den		–
	– 102 gf/tex, kmf, kgf mm^{-2}/g cm^{-3}		– 102 kg/mm^2 145 ksi
	239 cal/g, 430 Btu/lb		
10^3	– mN/tex, J/g, MPa/g cm^{-3}	10^3	– MPa, N/mm^2
	–		– 10^4 bar, 9869 atm
	– 145 000 psi/g cm^{-3}		– 145 000 psi (psi = lbf/in^2)
*10^6	– N/kg m^{-1}, J/kg, Pa/kg m^{-3}	10^6	–
	– 3.94 × 10^6 inchf, psi/(lb/cu in)		– 7.5 × 10^6 mm Hg
	–		–
10^9	–	*10^9	– Pa, N/m^2, J/m^3, kg m^{-1} s^{-1}
	– 10^{10} dyn/g cm^{-1}, erg/g		– 10^{10} dyn/cm^2

Notes: * strict SI units.
Other multiples are also used.
Gravitational units, written above as gf etc, are also found in forms such as: g, e.g. d/den, gm, or g-wt; lb or lb-wt; km, km-wt or Rkm.

First, either volume or mass measures may be used. In physics and engineering, stress is defined as force/area. Because of the uncertainty in the area of cross-section of yarns and fabrics and, even for solid fibres, the fact that linear density is easier to measure than area, the use of specific stress, namely force/(linear density) is preferred. Unless drastic changes occur, the linear density at zero stress is invariant, whereas packing factors can vary. It is also easy to compare the conversion of properties from molecules to fibres to yarns to fabrics: at all levels the mass is known.

Second, gravitational force units, often abbreviating g-wt or gf to g or gm, may be used instead of the physically correct inertial units. Third, quantities that are dimensionally identical can be defined and used in different ways. Fourth, there is a choice of unit systems: CGS or SI metric units or the old Imperial units, which are still widely used in USA. It is not uncommon to find mixtures, such as psi/(g/cm^3).

The preferred unit for specific stress, specific modulus and tenacity is N/tex. Expressed in other ways, this equals stress/density in GPa/(g/cm^3) and energy per unit mass in kJ/g. The modulus in N/tex equals the wave velocity in (km/s)^2. Strength can also be expressed in terms of break length, namely the length of material that will break under its own weight. Kilometre-force is most used, but brochures of one fibre manufacturer give strength in inches. Finally, for the first 50 years of manufactured fibres, the common unit was g/den. Because of the similarity in size, the use of cN/dtex, equal to 1.13 g/den, is common.

Table A1 gives the conversion factors between the above units and many others, which may be found in the literature or used in particular contexts.

Index