It is interesting to note that if one calculates the theoretical strength of any "pure" elemental crystalline material based on the interatomic bonds of the element, the predicted strengths are orders of magnitude larger that those seen in any test of a "real" material, as seen in Table 2-8. The huge differences in actual versus theoretical strengths are attributed to disruptions of the atomic bonds due to crystal defects in the real material. That is, it is considered impossible to manufacture "pure anything" on any realistic superatomic scale. It is presumed that if we could make a "wire" of pure iron only one atom in diameter, it would exhibit its theoretical "super strength." Crystal "whiskers" have been successfully made of some elemental materials and exhibit very high tensile strengths which approach their theoretical values (Table 2-8).

Other empirical evidence for this theory comes from the fact that fibers of any material made in very small diameters exhibit much higher tensile strengths than would be expected from stress-strain tests of larger samples of the same material. Presumably, the very small cross sections are approaching a "purer" material state. For example, it is well known that glass has poor tensile strength. However, small-diameter glass fibers show much larger tensile strength than sheet glass, making them a practical (and inexpensive) fiber for use in boat hulls, which are subjected to large tensile stresses in use. Small-diameter fibers of carbon and boron exhibit even higher tensile strengths than glass fiber, which explains their use in composites for spacecraft and military aircraft applications, where their relatively high cost is not a barrier.

2.8 SUMMARY

There are many different kinds of material strengths. It is important to understand which ones are important in particular loading situations. The most commonly measured and reported strengths are the **ultimate tensile strength** S_{ut} and the **tensile yield strength** S_y. The S_{ut} indicates the largest stress that the material will accept before fracture, and S_y indicates the stress beyond which the material will take a permanent set. Many materials have **compressive strengths** about equal to their tensile strengths and are called **even materials**. Most wrought metals are in the *even* category. Some materials have significantly different compressive and tensile strengths and these are called **uneven materials**. Cast metals are usually in the *uneven* category, with compressive strengths much greater than their tensile strengths. The **shear strengths** of even materials tend to be about half their tensile strengths, while shear strengths of uneven materials tend to be between their tensile and compressive strengths.

Table 2-8
Iron and Steel Strengths

Form	S_{ut} kpsi (MPa)
Theoretical	2 900 (20*E*3)
Whisker	1 800 (12*E*3)
Fine wire	1 400 (10*E*3)
Mild steel	60 (414)
Cast iron	40 (276)

One or more of these strengths may be of interest when the loading is static. If the material is ductile, then S_y is the usual criterion of failure, as a ductile material is capable of significant distortion before fracture. If the material is brittle, as are most cast materials, then the S_{ut} is a more interesting parameter, because the material will fracture before any significant yielding distortion takes place. Yield strength values are nevertheless reported for brittle materials, but are usually calculated based on an arbitrary, small value of strain rather than on any measured yielding of the specimen. Chapter 5