An Example of Using Yield Stress for Materials Selection

This exercise will demonstrate that the material property that is most relevant in a given situation depends upon which question we ask. We will use the subscript zero for properties that are known – either handbook values or design specifications.

For example, for a material's density we will use

$\rho = (SG)\ \rho_0,$

where in this case (*SG*) is the specific gravity and ρ_0 is the density of water.

Consider that we wish to choose a metal of length L_0 that must support a force of F_0, and we must not exceed the yield strength of our choice by a factor of safety $(FS)_0$.

$$\sigma \le \frac{\sigma_y}{(FS)_0}$$

A note on terminology: Safety Factor (*SF*) and Factor of Safety (*FS*) mean the same thing and are used about equally in the literature. Common practice is to define factors of safety such that they are numerically greater than one – hence its appearance in the denominator. The stress in our material will be:

$$\sigma = \frac{F_0}{A}$$

with *A* being the cross-sectional area. Combination of these last two equations gives:

$$A \ge \left[\frac{1}{\sigma_y}\right]\left[(FS)_0 F_0\right]$$

The first bracket contains only material properties. The second bracket contains only known parameters. Our interpretation is that to minimize the cross-sectional area, and hence also the volume, we need to select the metal with the greatest yield stress.

However, what if our primary concern is to minimize the weight? The mass of our member is calculated as:

$$m = (SG)\rho_0(AL_0)$$

Combination of this equation with the resulting equation for *A* gives:

$$m \geq \left[\frac{(SG)}{\sigma_y}\right]\left[(FS)_0\,\rho_0 F_0 L_0\right]$$

Now our interpretation is that to minimize the weight, we need to select the metal with the greatest value of yield stress divided by specific gravity. This combination is sometimes referred to as the specific yield strength. We conclude by illustrating with numerical values. Metals can have a range of yield strengths, but representative values might be:

	(SG)	σ_y (MPa)
steel	7.9	600
titanium ally	4.5	500
aluminum alloy	2.7	300
magnesium alloy	1.7	200

To minimize the volume, steel ranks first and a magnesium alloy ranks last. When we consider specific yield strength, our table is reordered.

	$\sigma_y/(SG)$ (MPa)
magnesium alloy	120
titanium ally	110
aluminum alloy	110
steel	75

To minimize the weight, now the magnesium alloy ranks first and the steel ranks last.