Fast Fracture Toughness

Comparison of Materials

The following table shows the general ranges of fast fracture toughness for our major materials groups.

Critical Stress Intensity (*MPa•√m*)

50 – 500	METALS			
5 – 50	METALS			COMPOSITES (woods)
0.5 – 5		PLASTICS	CERAMICS (glasses)	(woods)
0.05 – 0.5		(foams)	(porous)	

Key:	CERAMICS	Engineering Ceramics
	PLASTICS	Engineering Polymers
	COMPOSITES	Engineering Composites
	(porous)	Porous Ceramics
	(foams)	Foamed Polymers

Commentary

Fast fracture occurs as microcracks become unstable and propagate rapidly (at the speed of sound). Materials with preexisting cracks, such as sintered ceramics and concrete, inherently have lower fracture toughness. This also includes large welded structures such as ships and bridges. Often, the best prevention is to detect the existence of these cracks; our limitation is the resolution of our test equipment. (Beyond this course, if you want to learn more about crack detection, you can research key words of *dye penetrant*, *magnetic particle*, and *ultrasonic* followed by *crack detection*.)

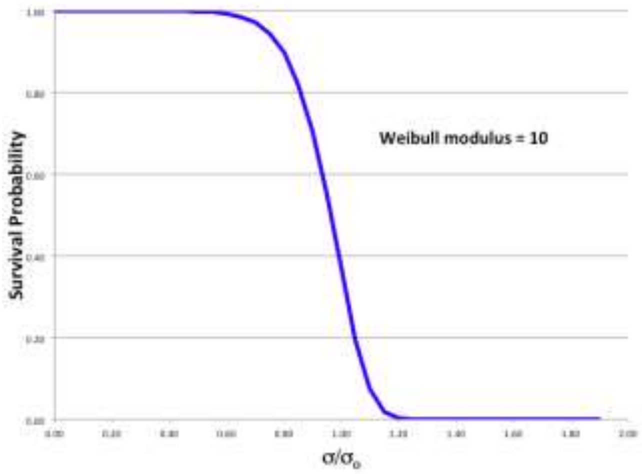
Numerical values of K_c usefully compare materials tested under standardized conditions. However, there is a size effect with fast fracture. Consider that a large sample has a few cracks of critical length. If several small samples are cut from this material, most will not have critical cracks, and relatively few will fail by fast fracture. But if large samples are cut from the initial piece, a higher fraction will have critical cracks, and hence a higher fraction will fail by fast fracture.

Statistical Analysis

Fast fracture results lend themselves to statistical analysis. Most commonly used is the *Weibull distribution*, named for the Swedish engineer Waloddi Weibull. He proposed that, for specific materials and load conditions, the stress on many samples be gradually increased until fast fracture occurred, and that the probability that an individual sample survive to a stress level σ be fitted by:

$$P_S(\sigma) = \exp\left[-(\sigma/\sigma_o)^m\right]$$

Here, m is called the Weibull modulus, and σ_o is approximately the mean of the measured fracture stresses. As noted above, σ_o depends on the size of the test samples, among other factors. If m were equal to one, this would be the familiar smooth exponential decay. However, the curve sharpens quickly as m takes on larger values. Below is a plot for $m = 10$.



For chalk, brick, pottery, and cement: $m \approx 5$.
For engineering ceramics like SiC, Al_2O_3, and Si_3N_4: $m \approx 10$.
For metals: $m \approx 100$.