Muddy Card Responses Lecture M19 3/8/2004

Can you explain again the deformation of the atomic structure at the tip of the crack. I assume that this was referring to the case of cleavage fracture. See Ashby and Jones Fig 14.3 and the associated text. See also A&J Ch 4 on interatomic bonding. Page 43.

When atoms are split where do the electrons from the bonds go (picture attached – similar to A&J figure 14.3). Very good question. If a material undergoes a cleavage fracture in a vacuum then the bonds are left "dangling, i.e. the valence electrons of the atoms do not participate in bonding, which means that the atom is not in it is minimum energy state. This means that if the other crack surface is brought back in contact with it the bonds can reform and the crack can heal to some extent. This also requires the surfaces to be very smooth. If fracture occurs in air then the "dangling" bonds will tend to react with species in the air - the surface will oxidize or other stray crud (often hydrocarbons) will adsorb onto the surface.

What is the difference between fracture toughness Kc and the Toughness Gc. Why does Kc vary with the square root of Gc? Is this because Gc is proportional to the crack sizes, whereas Kc is in reference to crack length? I did not quite understand the second part of this. The distinction between Kc and Gc is important. Kc is the fracture toughness and has units of MPa√m. Gc is the Toughness and has units of J/m^2. The two quantities are linked by $K_c=\sqrt{(EG_c)}$. The use of Kc in preference to Gc is really because it relates the condition for crack propagation to a linear variation in stress. I.e. fracture occurs when $K_c = \sigma\sqrt{\pi a}$. This is convenient because stresses can be superimposed linearly. Gc depends on the stress squared, so cross-coupling terms are introduced.

Could you reemphasize the difference between toughness and strength. Strength is a critical value of the stress at which some permanent deformation (or failure) occurs, e.g. yield strength, fracture strength, ultimate tensile strength. Strength has the units of stress, i.e. MPa. Toughness is the resistance to propagation of a crack and has units of J/m^2

Just to be clear we've covered three modes of failure? (1) "buckling' (2) yield and (3) fracture. (1) is due to compressive loads, (2) tensile loads and (3) tensile loads in combination with cracks. This is nearly correct. Yield can occur in compression too – remember it is the shear stresses that matter here.

Differentiate between strength, stiffness and toughness please and also what brittle and plastic means in these terms. See answers above. Also, The Strengths of a material are defined by Fig 8.11 in A&J. Toughness and Fracture Toughness are exactly defined in Chapter 13, p135. Stiffness is slightly different, as it is not a single material property as such, so the stiffness of a material is quantified by the elastic moduli (as incorporated in the stiffness tensor) for that material. However, if you understand the definitions of Young's modulus, Shear Modulus (and bulk modulus) then you understand the definition of stiffness at the material level. A brittle material (the opposite of a tough material) has a little resistance to crack propagation, i.e. little energy is absorbed during the crack propagation process. Plastic deformation is irreversible deformation that results in a permanent deformation after unloading. The irreversibility means that energy is absorbed in doing plastic deformation.

There is a critical crack length that defines fracture, but what if there are a large number of miniscule cracks? If you take these into account do they change the material properties of a material as a whole. Excellent question. In most cases in metallic structures it is the largest crack that sees the highest stress that results in fracture. However, in some cases, notably the Aloha airlines incident, a large number of small cracks combined (like the perforations around a postage stamp) to cause failure. Also, in composite materials, fracture often consists of multiple interacting cracks rather than a single large one. The evolution of these cracks is accompanied by a loss of stiffness. .

So where can I get the bird chopping video?

Can we see this bird meets blade video? I will try to locate it and arrange a viewing.

Hmm… the chickens they chuck into engines – do they just get them from the Grocery store? Or do they special order in bulk from Costco? No idea. I do know that they are looking to make artificial birds so that they don't have to use real ones, and can obtain more consistent results. I had to review a technical paper on matching the impact properties of chickens with a gelatin composite!

With the carbon fiber fan blades how do the fibers affect a blade ingestion during a blade out? Does the engine eat the blade easier than it does a titanium blade? I do not know. I would guess that the carbon fiber blades tend to fragment more easily, but I do not know for a fact.

Could you explain Scott's question about stresses at the crack tip again?
Please read Ashby and Jones chapter 14. The key points are that the stresses at the crack tip will be very high, sufficiently high to cause yield. If yield occurs this absorbs energy, which increases the toughness.

There were 2 muddy cards with no mud and a number of positive comments regarding my attendance at the Hockey game. Thank you for inviting me, I thoroughly enjoyed it.

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