

Muddy Card Responses Lecture M20 3/10/2004

Synopsis: Covered mechanisms and mechanics of fatigue. Fatigue in metals due to initiation and growth of cracks under cyclic loading. The fundamental mechanism is local plasticity allowing cracks to initiate from persistent slip bands at local stress concentrations (surface roughness, contact points, wear damage). Cracks grow due to plasticity at the crack tip. Empirical models exist for lifetime vs. applied stress amplitude (S-N curves) and for the crack growth rate as a function of stress intensity factor range. These models can be used in design and operation either for damage tolerant design or for safe life design.

You mentioned the different levels of visual inspection of aircraft. How often would a typical aircraft get a full tear-down? It seems like the cost for such a massive inspection would be prohibitive, particularly for an airline with thousands of aircraft in active service. I think that this occurs every 3-5 years. The cost is a big issue, however the cost of a structural failure on consumer confidence in the airline is much higher.

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 its 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.

Firstly I assume that the factors of 4, 2 etc. are obtained through testing. How are we sure they apply to all materials etc. You are correct, this sort of data is derived from extensive testing, and you cannot take data from one material and expect it to apply to others. The scatter in the data (which is where the factors of 4 and 2 on life estimates comes from) will also be material dependent.

Can you explain the difference between low cycle fatigue and high cycle fatigue, I missed that part? Generally low cycle fatigue implies that some significant fraction of the structure under test exceeds the yield stress in each cycle. In high cycle fatigue the structure behaves elastically at the macroscopic level (although there will be small scale plasticity). Some times high cycle fatigue is used to simply imply lifetimes greater than 10,000 cycles.

Is this correct (1) harder materials don't fatigue easily because the plasticity is low. (2) low cycle fatigue is due to low plasticity. The first answer is correct, the second is not. See explanation above.

Do Gc and Kc take into account non-metals or fibrous materials where the direction of the cracks seems to matter? This is an important question. Gc and Kc work quite well for all homogeneous materials: metals, ceramics, glasses and polymers. They work less well for heterogeneous materials such as composites or other laminated materials. As you say in these materials cracks can deflect at interfaces and failure is often not by the propagation of a single

dominant crack. The concepts of toughness or fracture toughness should be used carefully in these situations.

HYPOTHETICALLY... You have an absolutely perfectly symmetrical beam – Nothing leading it to buckle one way or the other... At ALL. So what really happens? Will it really buckle? Hmmm. Simple answer, it is hypothetical it won't really do anything (hypothetical=imaginary). Hypothetically it would not buckle – it could continue to deform axially. In reality one cannot achieve this perfect symmetry so in reality it will always buckle!

With cyclic loading does the material inside the crack experience work hardening also? Woun't help structure I wouldn't think, I'm just curious. This is an excellent question. Yes. The material at the crack tip does work harden. A key result of this is that if an overload (a single high load cycle) is applied then the material ahead of the crack tip yields and becomes harder. This actually slows the crack down (there is less plasticity in each subsequent cycle) until the crack has grown through the work hardened zone. This is a level of detail beyond what you need to know for Unified.

It might be worth mentioning that the definition of safety in aerospace is not the standard OED definition. Despite the fact that the safety factor is only 1.5 ish, the procedures and designs in place are robust enough to live up to the standard OED definition. How many catastrophic events are there each year? Not many at all. Most are human factors anyway. Technical problems are constantly being updated and worked on through AD 's and service bulletins. This is an important point. The design and operating process for aerospace structures is really pretty conservative given the high stress levels and light weight. The use of frequent inspections and the proactive efforts of the operators, manufacturers and regulators is a key to this. Fatigue failures are really very rare and are usually due to a human factors error themselves, i.e. someone skips a scheduled inspection or is incorrectly trained to conduct the inspection.

Thanks, now I'm scared to fly commercial. I should try to allay your fears. Commercial aircraft are really very safe indeed. The inspection process really works very well and is a very conservative approach to dealing with fatigue.

Materials was a fun subject even though it got really hard at the end. Thanks Prof. Spearing! Thankyou. Please do ask me about the bits you found hard – remember I am here to help.

Will you teach any other classes next semester. Unfortunately not!

No mud. I am sad that Materials is over; I've really enjoyed your lectures. I will miss you too!

No mud. Are there any course 16 materials classes (not structures like 16.20) but actually course 3 stuff. 16.21 has a module on fracture, fatigue, creep and yield, so this is the closest we get.

There were 3 other muddy cards with no mud.

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