9.11: Sub-critical crack growth and R-curves

It is commonly observed that cracks can grow stably in a structure over a period of time. Oddly this phenomenon, known as fatigue, tends to occur in tougher materials. This suggests that toughening does not simply increase the magnitude of the fracture energy but changes the way in which a crack grows.

Consider a material toughened by crack bridging in which intact ligaments across the crack faces are left behind as the crack grows. Toughening occurs because separating the crack faces then requires extra work in order to either stretch the ligament or pull it out of the matrix in which it is embedded. This type of mechanism occurs in many different materials, including:

- rubber toughened polymer
- materials containing either fibres or elongated grains

This animation shows how an R-curve is generated when a crack propagates through a material containing ligaments perpendicular to the direction of crack propagation.

After each critical point, the simulation will pause. It can then be continued by clicking the 'proceed' button.

**Note:** This animation requires Adobe Flash Player 8 and later, which can be downloaded here.
This type of behaviour is known as R-curve behaviour. We can see that as we load the material containing a small flaw, it will begin to grow (under an increasing applied stress intensity factor) until the process zone is fully developed. The crack in the process zone has a different shape to that outside it because of the forces that due to the intact ligaments. Once the process zone has developed fully then the whole crack will move forward with the process zone size remaining a constant size. As process zones exist in all toughened materials we might expect that they would all show R-curves and this is the case as shown below.

![Graph showing R-curve behavior](https://eng.libretexts.org/Bookshelves/Materials_Science/TLP_Library_Vol._1/09%3A_Brittle_Fracture/9.a11%3A_Sub-critical...

Showing the R-curve due to grain interface bridging in a silicon nitride containing elongated grains and an alumina containing silicon carbide fibres.