## Material Stress-Strain Behavior Part 2

Cyclic Mean Stress Relaxation and Cyclic Creep

During fully reversed testing a large loop will have enough plasticity such that its mean Stress  $\sigma_0 = (\sigma \max + \sigma \min)/2$  is close to zero. (compressive stresses have negative values)



The small loop also has a non-zero mean strain, but the material does not care, or react, when we are in strain limit test control. As the small cycles continue, their stress-strain hysteresis loop relaxes its mean stress.



An animation of relaxation:

http://fde.uwaterloo.ca/Fde/Notches.new/Weld+Residuals/VideoA/animation.gif (9Mb)



The rate of relaxation depends upon the size of the hysteresis loop;

specifically, the amount of plastic strain in each half-cycle.

The absence or presence of relaxation is important for fatigue life analysis.

Large tensile mean stresses hasten the fatigue process.

Thus a designer/analyst must estimate both the initial amount of mean stress at the fatigue critical hot-spot, and if the hot-spot hysteresis loops have enough plasticity to wash out the mean stress.

Numerous studies have been done on this phenomenon. One is available here: http://fde.uwaterloo.ca/Fde/Articles/Relax/conleSo.html If one plots the plastic strain amplitude versus the number of reversals required to relax the mean stress to 50% of its original value for a number of steels, a graph is created that can be used to predict if relaxation will occur.

(more information at: http://fde.uwaterloo.ca/Fde/Articles/fde2019RelaxPres4Web.pdf )



Plastic Strain Ampl. vs. Half Cycles to 50% Relaxation. Color by BHN

The cyclic mean stress relaxation described in the above pages is observed during Strain Controlled tests of axial samples.

Cyclic Creep or "Ratcheting" is observed in Load Control tests, and is the same mechanism.



Ratcheting is not often a design problem because fatigue hot-spots tend to be surrounded by elastic fields.

It can occur in components like rods, or wires.

Figure source: R.W. Landgraf

A similar animation of process: http://fde.uwaterloo.ca/FatigueClass/Videos/ratchet.gif 5Mb