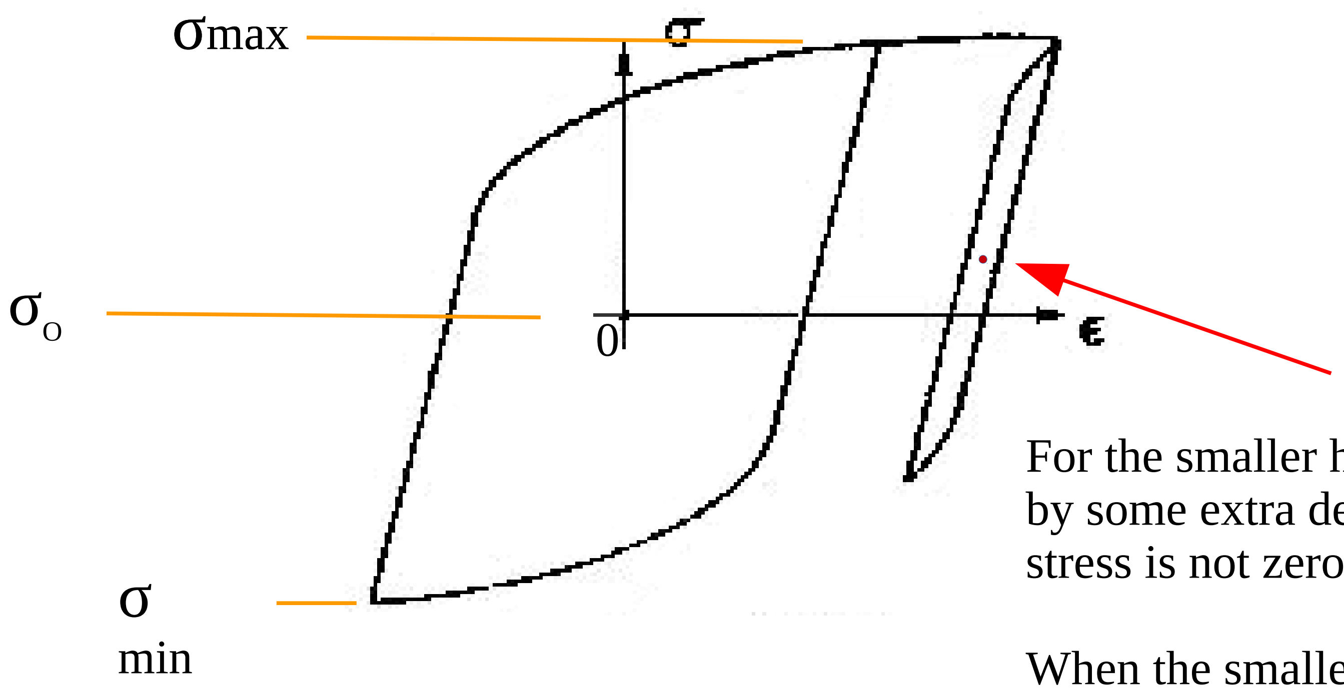
Material Stress-Strain Behavior   Part 2

Cyclic Mean Stress Relaxation and Cyclic Creep

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

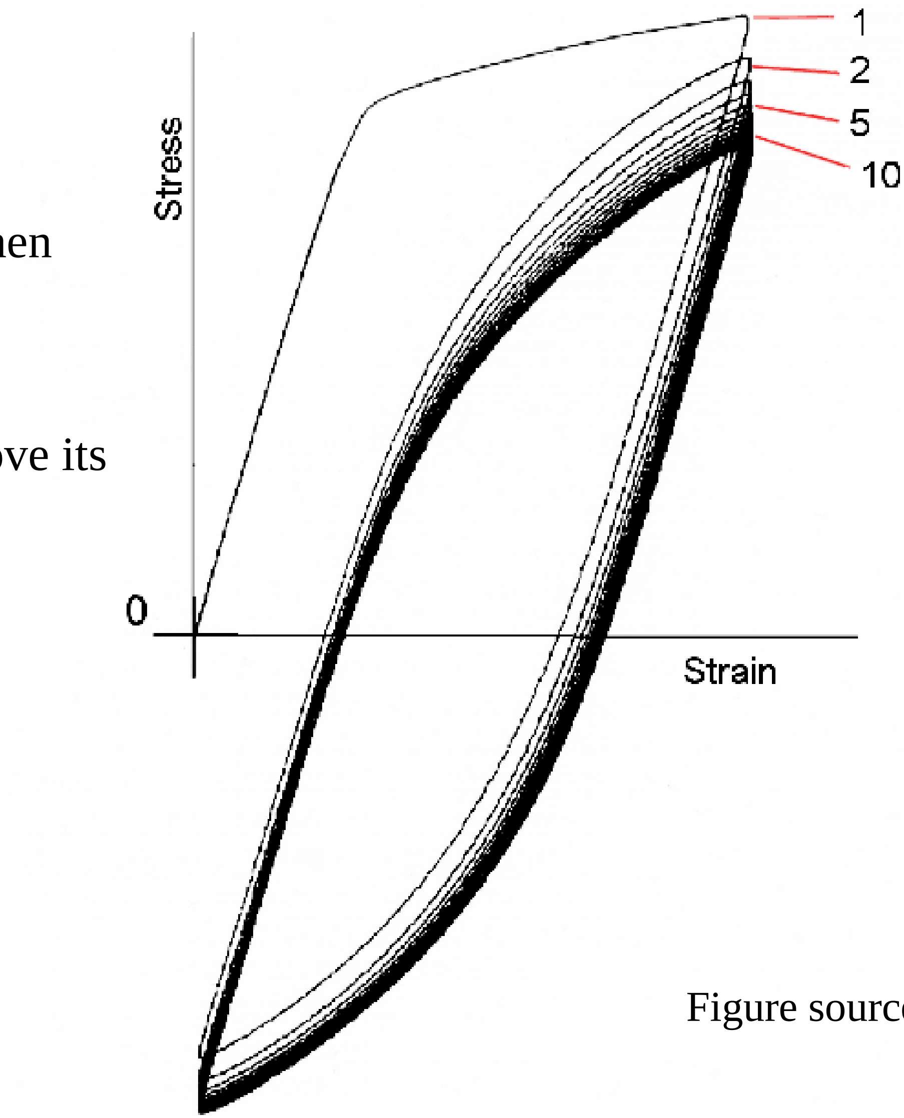


For the smaller hysteresis loop, created by some extra deformation, the mean stress is not zero.

When the smaller loop is repeated the presence of the plasticity causes the mean stress to "wash out" to zero, eventually.

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.



The same thing happens when the mean stress is in compression.

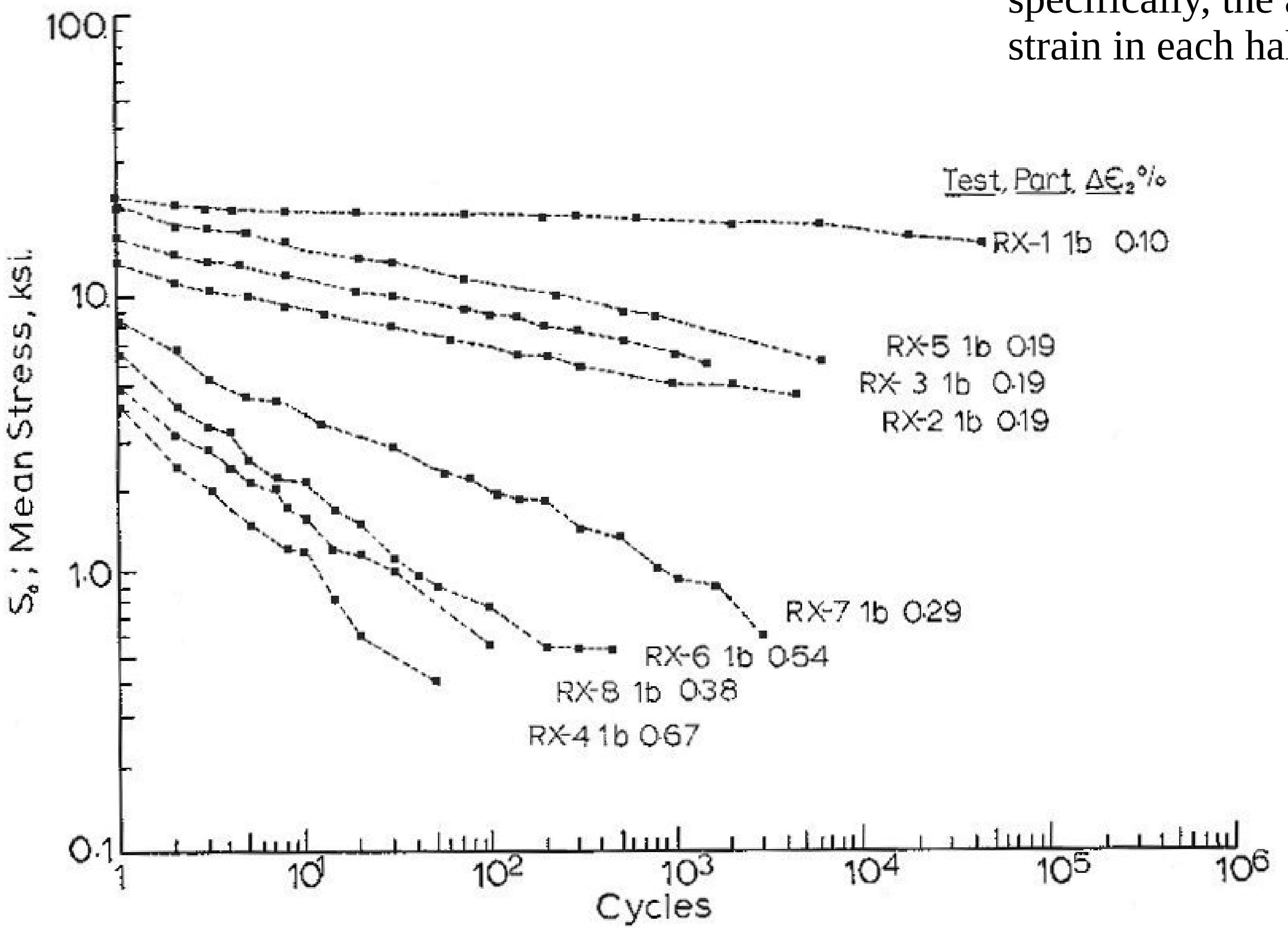
The hysteresis loop will move its mean stress towards zero.

Figure source: R.W. Landgraf

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.



Mean Stress vs. Cycles at Secondary Strain Range $\Delta\epsilon_2$ for Part 1b of all Tests. (First application of Cycles at $\Delta\epsilon_2$)

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

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.

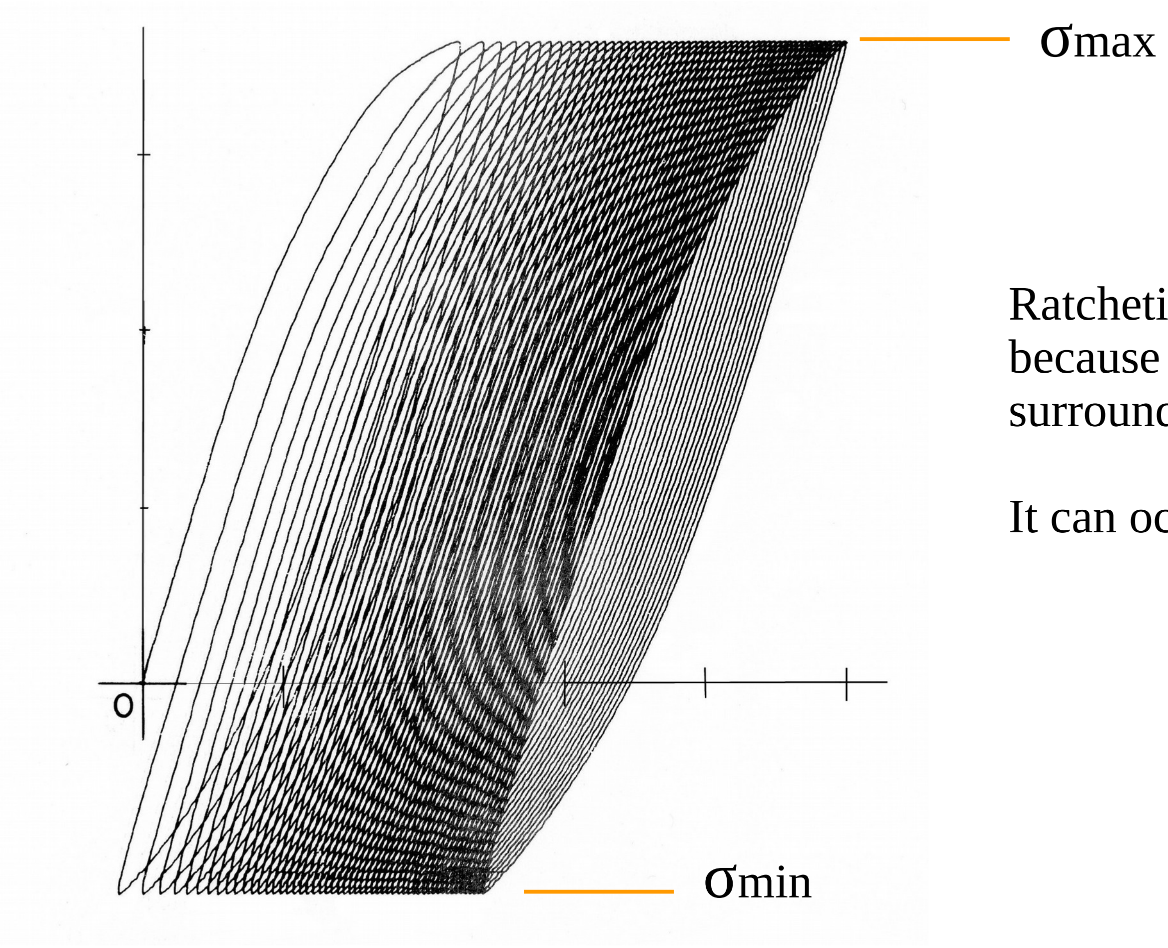


Figure source: R.W. Landgraf

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.

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

The cyclic mean stress relaxation mechanism is actually always "On". It does not just kick in when there is a mean stress in the hysteresis loop.

One just does not "see" the process when the loop has a nice symmetrical appearance.