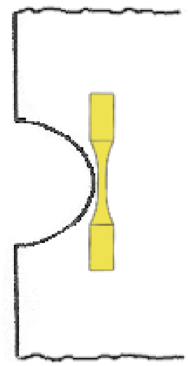
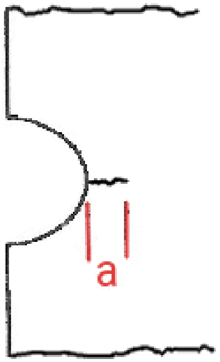
Computing Fatigue Damage
Overview



There are two philosophies regarding the computation of fatigue damage.

The first assumes that the simulated failure of an axial specimen at the fatigue hot-spot indicates the initiation of a crack.

The second assumes that all of fatigue life is spent in crack propagation, from very small to very large cracks.



The two philosophies require two different computational methods and engineers must decide which is more appropriate for their applications.

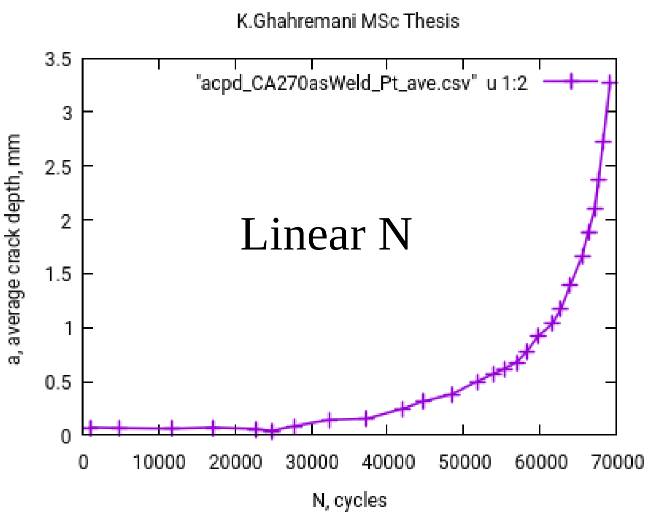
The off-shore oil industry, for example, designs very large welded steel structures. For safety their engineers must assume that welds will have flaws (cracks) from the beginning, and thus apply mostly the propagation methods to their predictions.

The ground vehicle industry is more weight savings sensitive, has no way of inspecting components in service on a regular basis, and therefore designs for crack initiation to compute service life.

The aircraft industry uses crack initiation for first design, and then, with an assumed flaw size, predicts crack propagation life such that no fractures occur between aircraft inspection intervals.

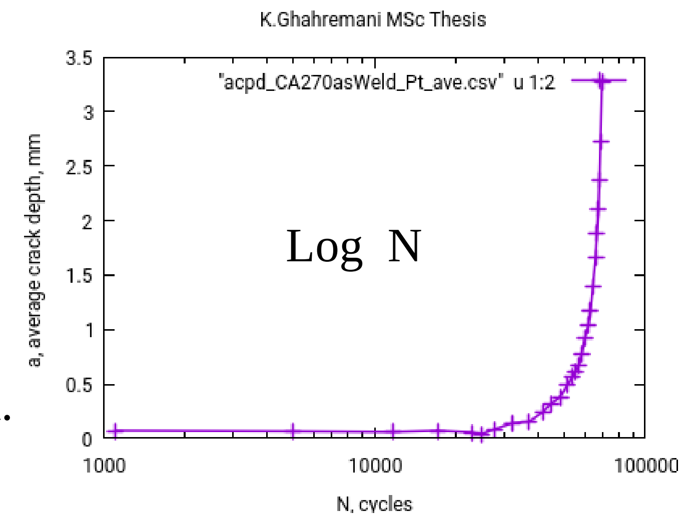
"Damage" due to cyclic loading, starts as dislocation slip bands and extrusions in a material's micro-structural grains. The slip features of several grains eventually form a visible crack. The term "visible" depends of course on the method of observation.

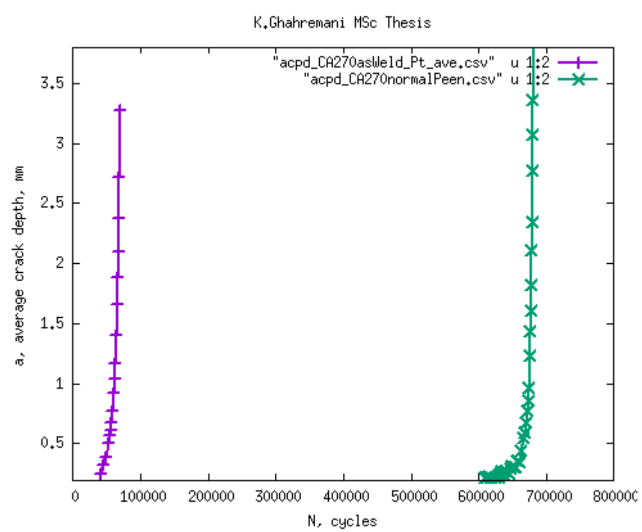
A highly sensitive AC potential drop method was used by Ghahremani* on welded specimens.



These two plots show the crack size, a vs. cycles for the same constant amplitude test.

In the figure below an additional const. ampl. test for a needle peened specimen has been added.

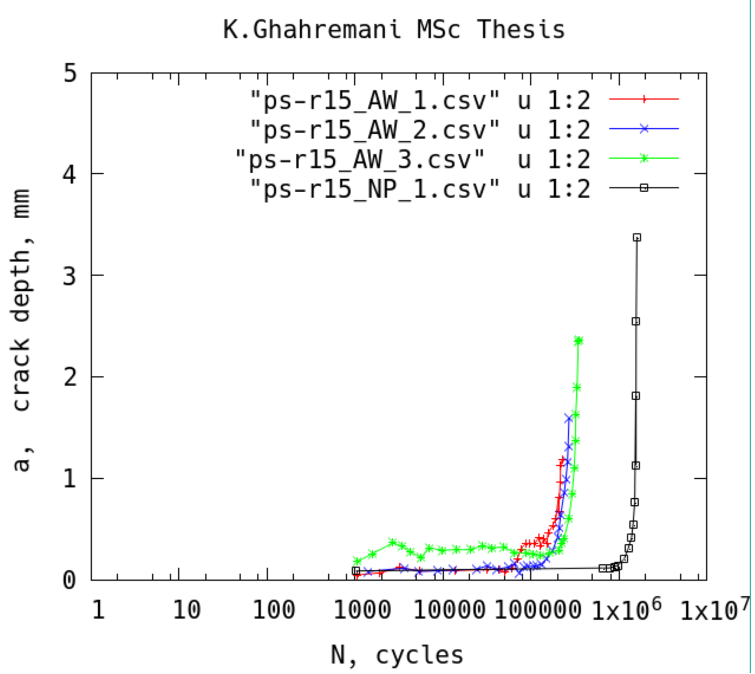




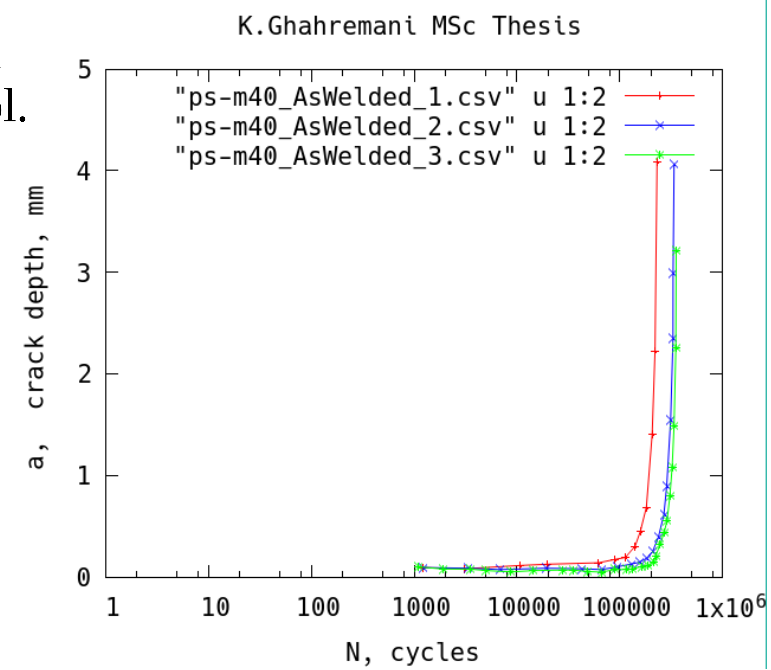
There is a difference in the cycles to "initiation" value.

The problem for engineers doing simulations is always "What value of initial crack length should be applied?"

* Ref.: K.Ghahremani, MSc. Thesis, Civ.Engr., U.Waterloo, 2010



These two results are from Ghahremani's variable ampl. tests for two different load histories.



In general, as shown by Dowling*, in long life tests crack initiation dominates, while in short life fatigue crack propagation dominates. These proportions also depend on material hardness. A very hard steel will have a very short crack propagation life.

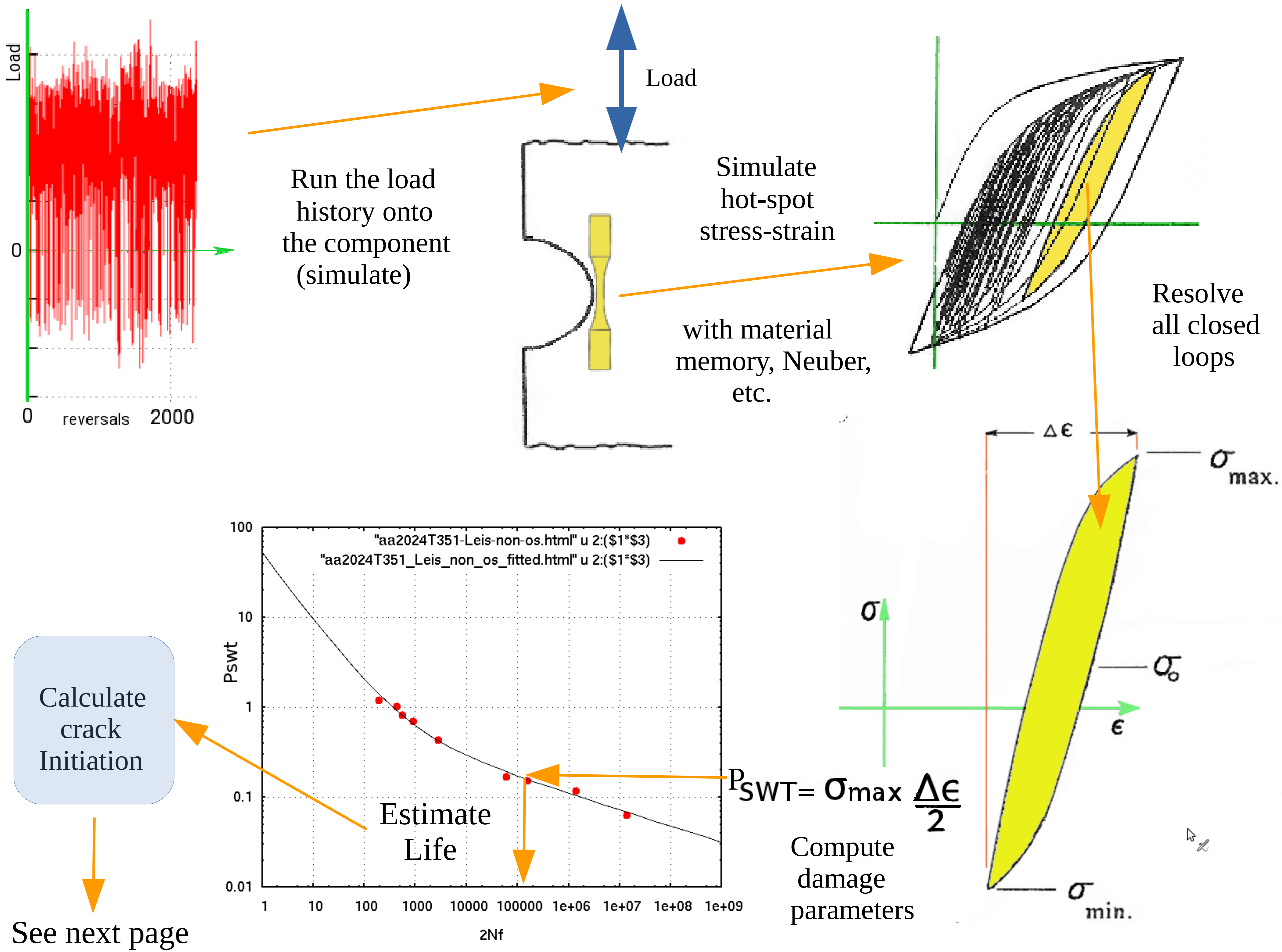
At present (2017) research is still being done on modelling the complete fatigue life using only crack propagation simulations. In my opinion the techniques are promising, but not well proven to apply to many situations.

As a result for this tutorial we will model the fatigue process in two stages:

1. Simulate to crack initiation, and then

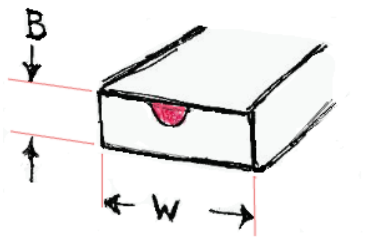
2. Assuming a crack size from initiation, simulate the crack propagation.

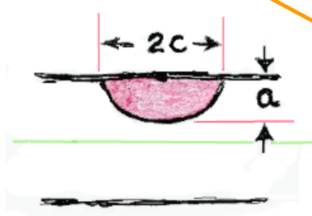
Computing Fatigue Damage Overview of Part 1



Computing Fatigue Damage Overview of Part 2

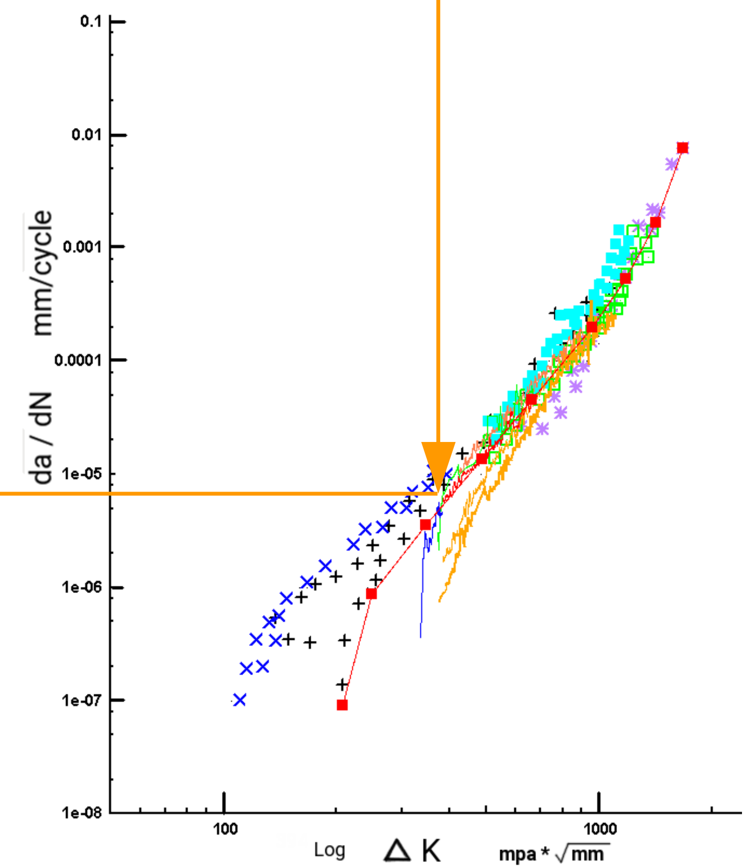
Estimate Initiation Crack Size

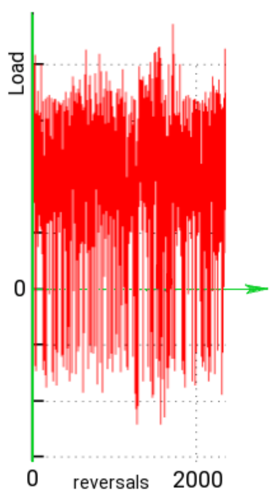




With crack a,c, etc. compute crack stresses and Stress Intensity K for the next half cycle

Use a material memory model with Stress Intensity K to compute "closed loops", get ΔK





Get a load, compute Bend. Moment and Axial Forces on section

Update and check crack lengths a, c, etc.

Fracture ?