“Neuber Stress” Plots

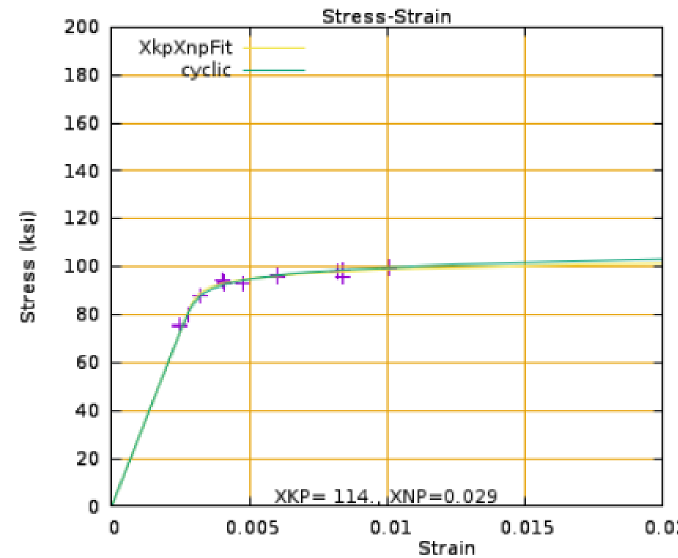
Part 1

AISI Bar Fatigue Group
Mar. 29 2018
F.A. Conle

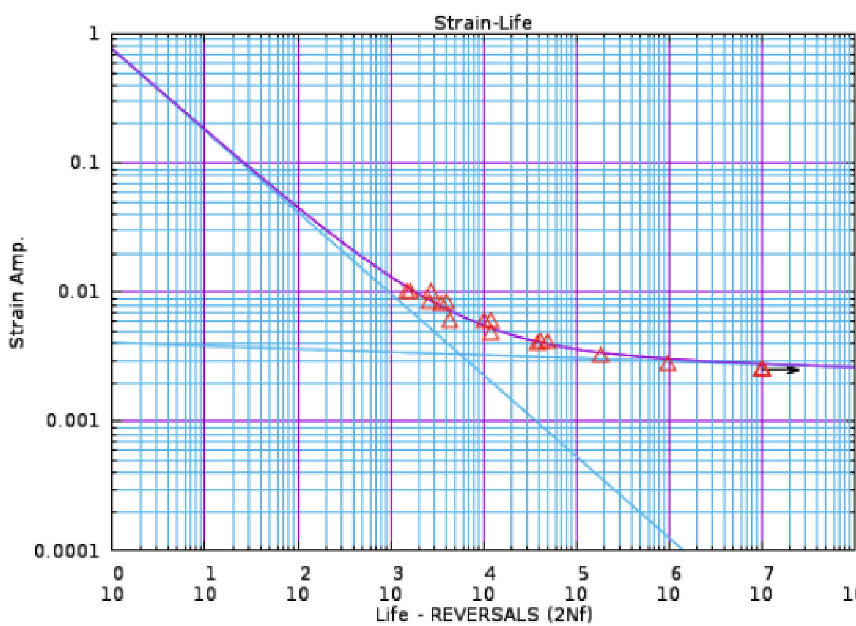
SAE4320 Aisilt$_4$9 BHN= 188

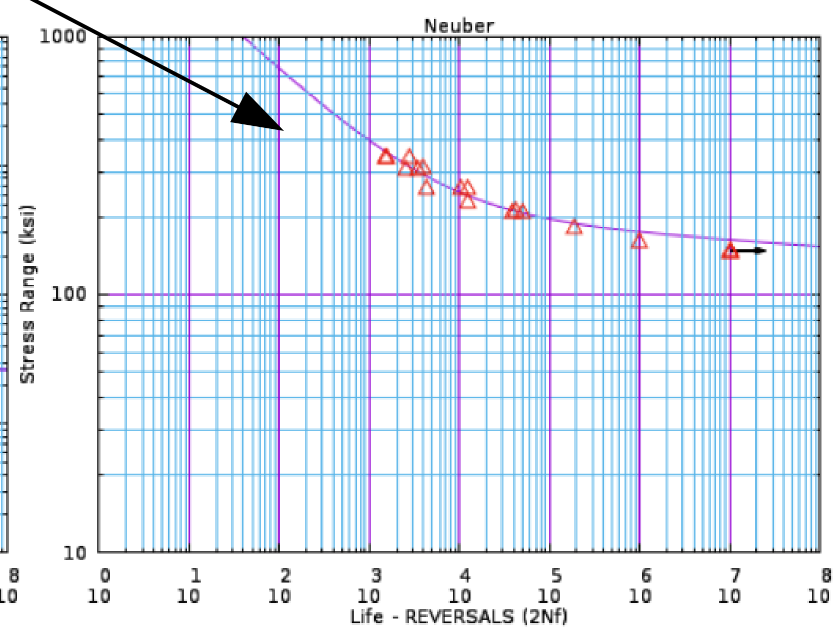
SAE4320 Quenched + Tempered to simulate Core of a carburized part
Rb=94, BHN=188 85%Martensite, 10%Bainite, 5%Ferrite
ElecFrun., ConCast(279x375), HotRolled to 63.5mm bar
Inclusions TypeA,B,C, none, TypeD=1
Test: UoWaterloo M.Khalil, T.Topper March 2002

Monotonic Props.	Cyclic Props.
ELAS. MOD.= 29298. KSI, 202. GPA	K' = 120.6 KSI, 832.MPA
YIELD,0.2%= 133. KSI, 920. MPA	N' = 0.0378
ULT. STRG.= 144. KSI, 994. MPA	F. STRG COEF= 119.4 KSI, 823.MPA
K = 0.0 KSI, 0. MPA	F.STRG EXP, b=-0.0238
N = 0.0000	FAT DUCT COEF= 0.7560
RED. IN AREA = 63.0	F.DUCT EXP, c=-0.6294
T. FRAC. STG.= 0.0 KSI, 1336. MPA	Exp Cyc Yld = 95. Ksi, 657.MPA
T. FRAC. STR.= 0.000	Fit Cyc Yld = 95. Ksi, 658.MPA
No. data points= 18	



Some standard data sheets show
a “Neuber Stress” plot





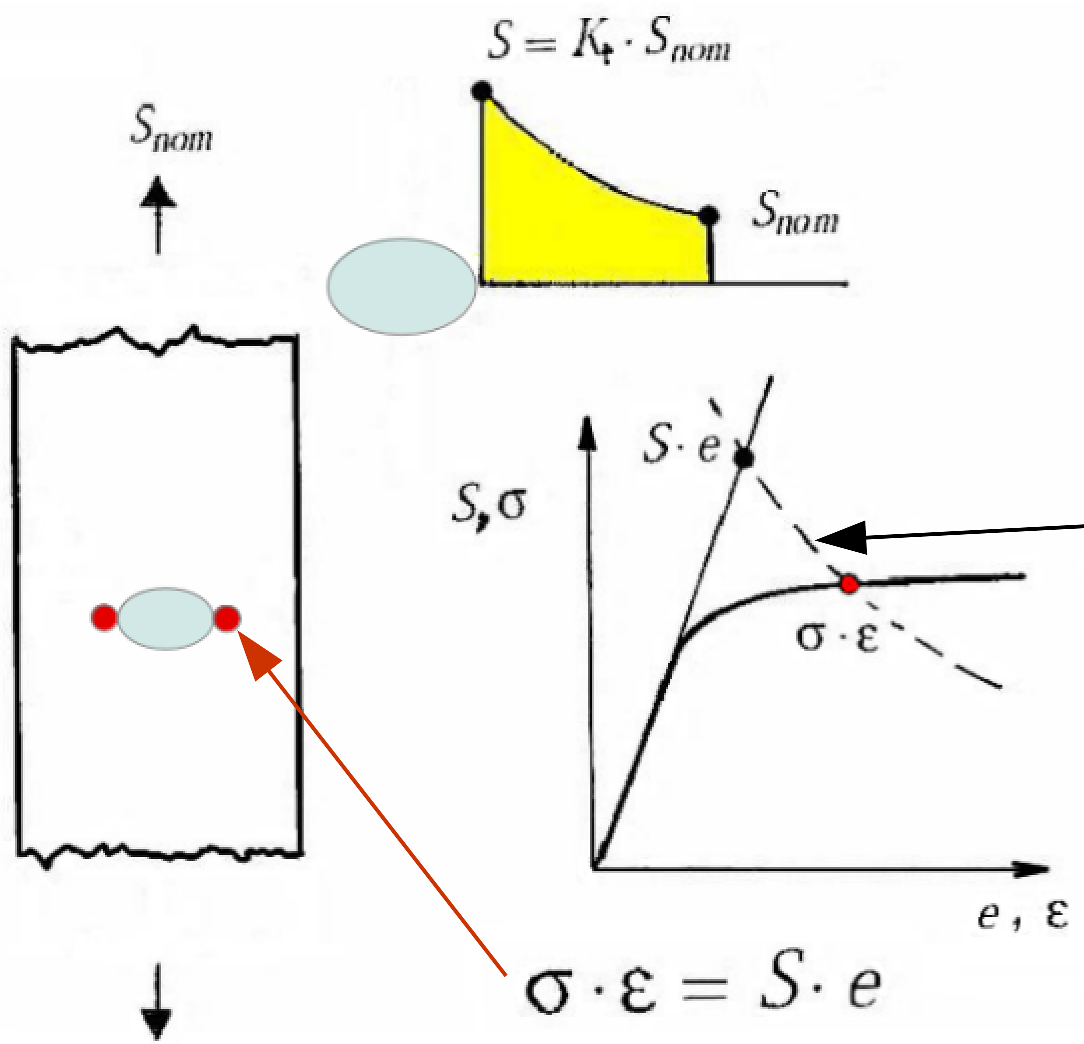
Part 1 of this article explains how a "Neuber Stress" is calculated from unnotched axially loaded fatigue specimen tests to create the plot. Part 2 will explain how it is useful to fatigue design engineers.

In brief a Neuber stress graph plots energy vs. fatigue life. Specifically $\sqrt{E \cdot \Delta\varepsilon \cdot \Delta\sigma}$ which has units of stress. It represents the energy at a fatigue hot spot such as the region at the root of a stress concentration where the fatigue crack will initiate.

Background References:
1. H.Neuber, "Theory of stress concentration for shear strained prismatical bodies with arbitrary non-linear stress-strain law," J. of Appl. Mech., Dec. 1961 pp.544-550

2. T.H.Topper, R.Wetzel and J.D.Morrow, "Neuber's rule applied to fatigue of notched specimens," ASTM J.of Matls., V4 N1, Mar.1969, pp.200-209

The Neuber Plasticity Correction transforms Elastic Analysis Stresses into strains and stresses from the cyclic stress-strain curve



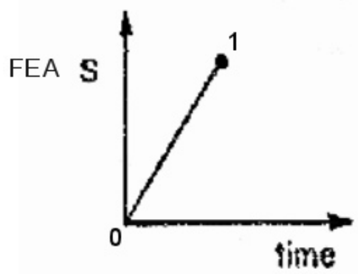
The transformation is based on equal Energy i.e.: Stress X Strain

$$\sigma \cdot \varepsilon = S \cdot e$$

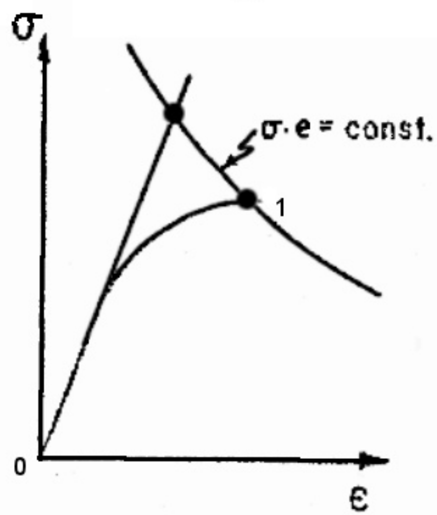
Elastic+Plastic stress-strain curve

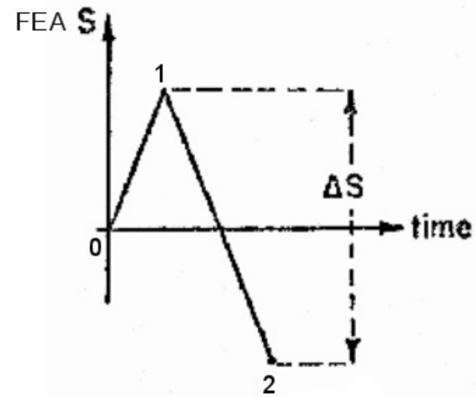
Elastic Analysis

Note the feature of cyclic material deformation behavior :



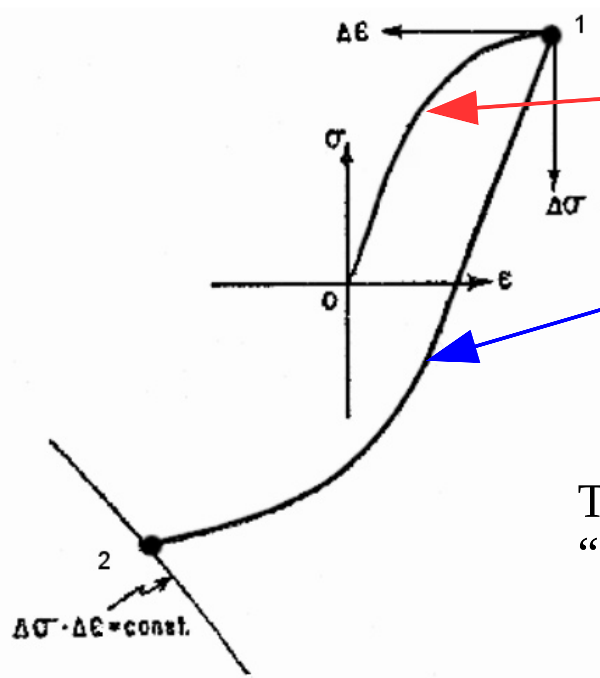
$$S*e=S*\frac{S}{E}=Constant$$





$$\Delta S*\frac{\Delta S}{E}=constant=\Delta\sigma*\Delta\epsilon$$

The first half-cycle has a shape different from following fatigue half cycles.

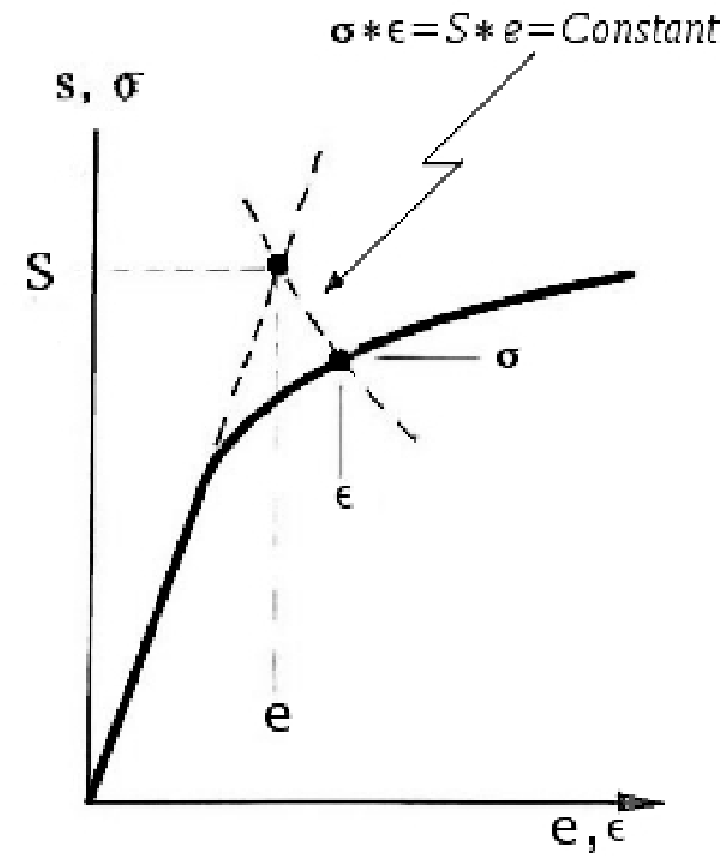


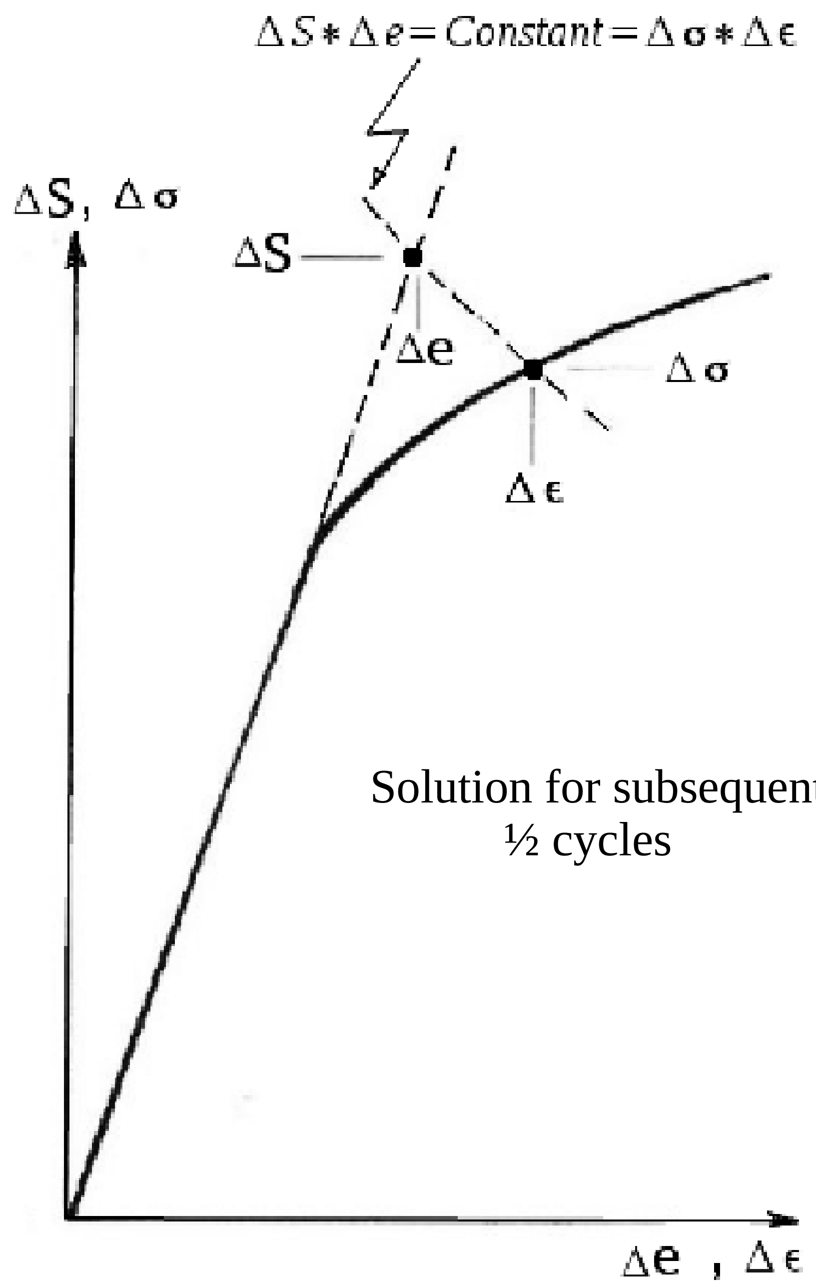
The cyclic stress-strain curve is assumed ½ the size of

hysteresis loop half-cycles curve.

This is termed “Masing’s hypothesis”

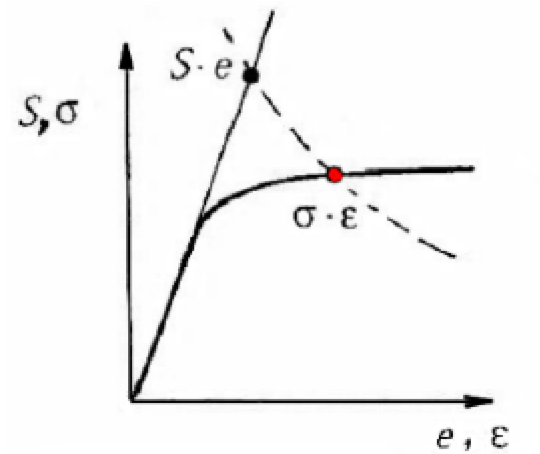
Solution for initial loading





Solution for subsequent ½ cycles

On-line: http://fde.uwaterloo.ca/Fde/Notches.new/neuber.html



$$\sigma \cdot \varepsilon = S \cdot e$$

If one accepts the previous plasticity correction analysis one can play with the equation and define an elastic stress term from the cyclic stress-strain axial test result terms

$$\sigma * \varepsilon * E = S * e * E$$

$$\sigma * \varepsilon * E = S * S$$

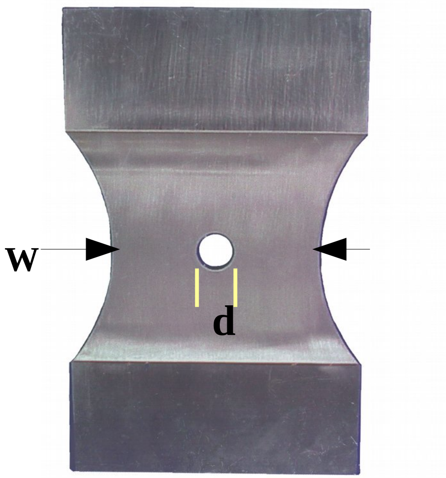
$$\sqrt{\sigma * \varepsilon * E} = S$$

"Neuber" Stress
(both sides have units of stress)

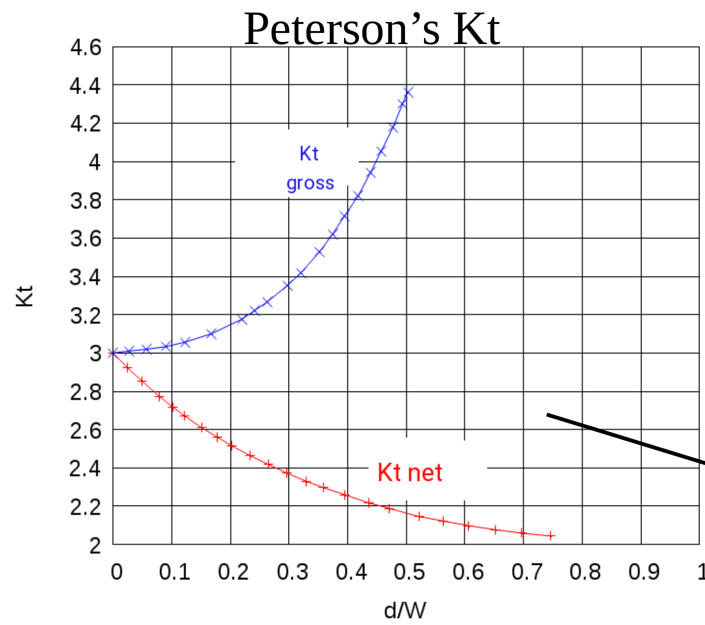
Elastic + Plastic side of equation

Elastic side of equation

Both elastic Finite Element and Stress Concentration(K_t) methods yield an elastic hot spot stress that needs plasticity correction:



S_n

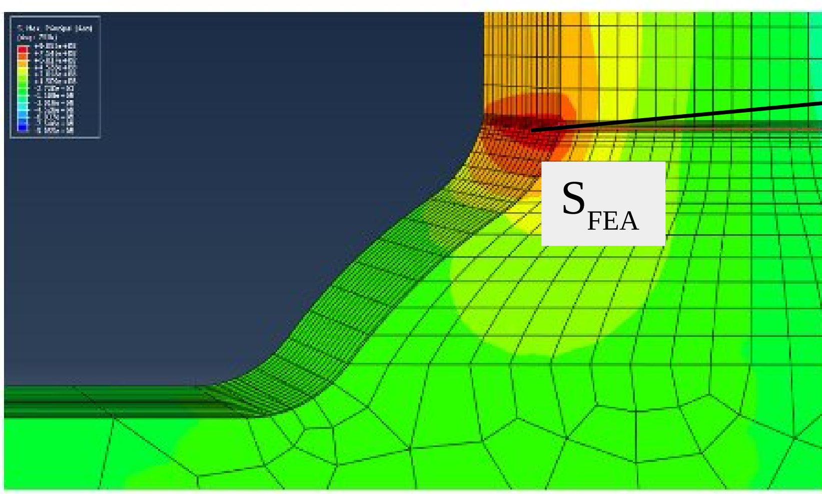


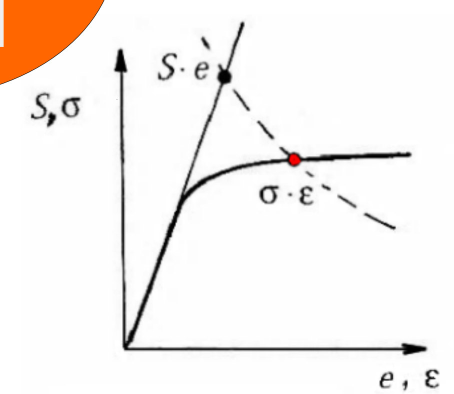
$S_n * K_t$

$S = S_n * K_t$

Hot Spot
Elastic
Stress
S

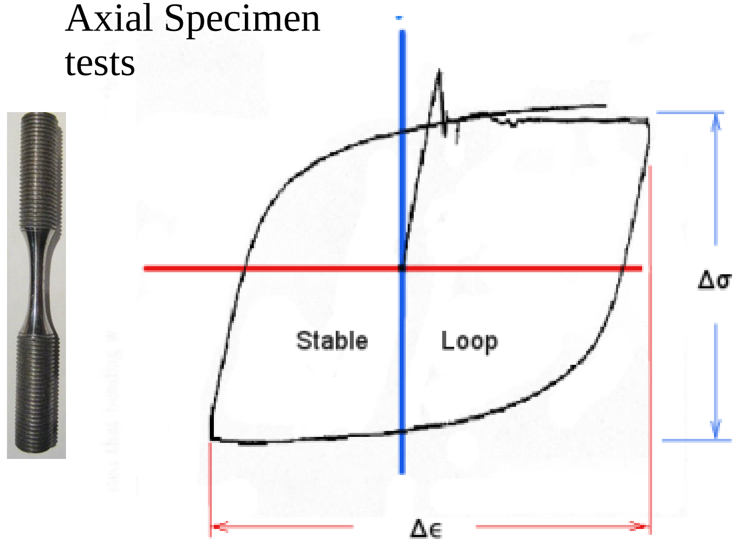
$S = S_{FEA}$





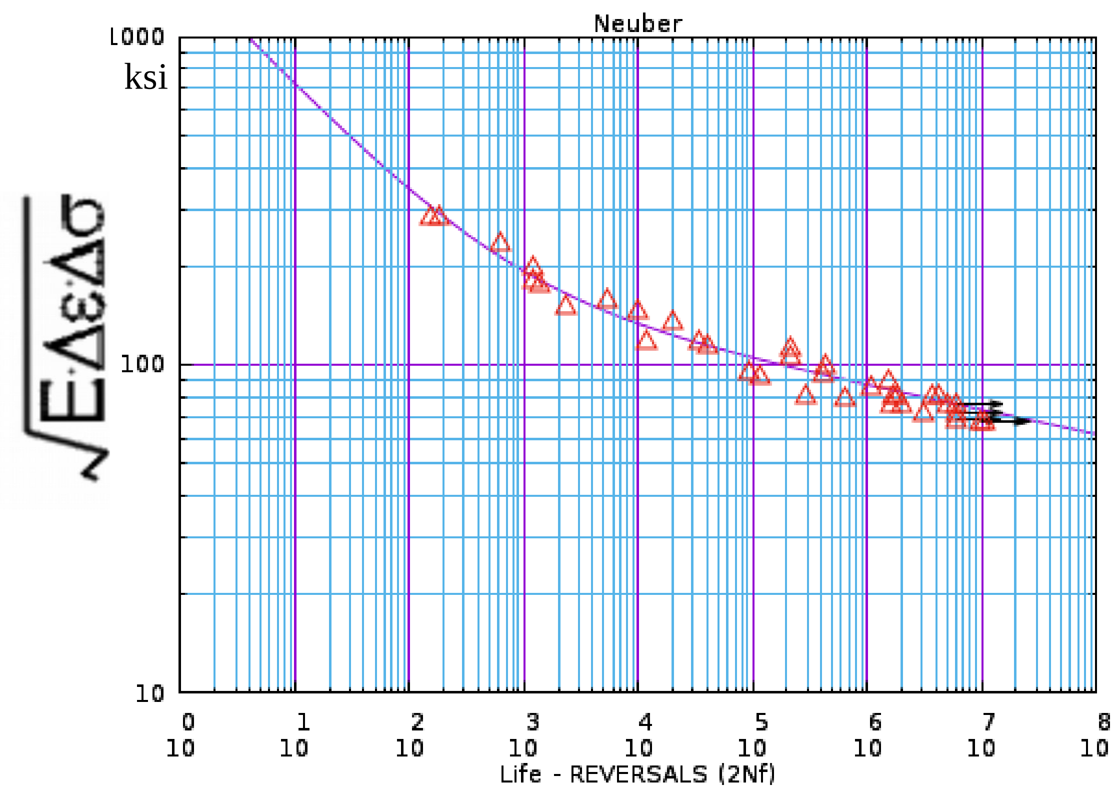
$$\sigma \cdot \varepsilon = S \cdot e$$

Axial Specimen tests



Given a series of constant amplitude axial specimen tests we can take the elastic modulus and the stable values of strain range, stress range and compute the energy term or "Neuber stress" to create a fatigue life plot.

$$\sqrt{\sigma * \varepsilon * E} \quad = \quad S$$



We can now enter the Y axis of this plot with the elastic analysis stress **S** to estimate a fatigue life.

The Neuber plasticity correction is built into the graph.

Note that this does NOT include a mean stress correction.

```
                              GGG60     80.55.06   BHN=        215
# Merged files of  GGG 60  ASTM 80.55.06  Nodular Irong
# Some specimens are Rotating Bending with Kt=1.1
# Ref.1: M. Hück, W.Schütz, H. Walter, 'Moderne Schwingfestigkeitsnterlage
# f ür die Bemessung von Bauteilen aus Sphäroguss und Temperguss- Teil 1
# ATZ Automobile Zeitschrift 86 1984 7/8 pp.325-331.
# Ref.2: A.Fatemi, J.Williams,F.Montazersadgh, 'Fatigue Performance Evaluation
# of Forged Steel versus Ductile Cast Iron Crankshaft: A Comparative Study,'
# U.of Toledo Report, Aug. 2007.
# Data digitized from graphs and may contain errors.

         Monotonic Props.                   Cyclic Props.
   ELAS. MOD.= 24076. KSI,  166. GPA     K'      = 142.5 KSI,   982.MPA
   YIELD,0.2%=    58. KSI,  401. MPA     N'     = 0.1125
   ULT. STRG.=    93. KSI,  638. MPA       F. STRG COEF=  120.3 KSI,  830.MPA
   K      =      0.0 KSI,       0. MPA    F.STRG EXP, b=-0.0739
   N           = 0.0000                   FAT DUCT COEF=   0.2225
   RED. IN AREA =  6.4                   F.DUCT EXP, c=-0.6564
   T. FRAC. STG.=   0.0 KSI,  724. MPA   Exp Cyc Yld  =   71. Ksi, 488.MPA
   T. FRAC. STR.= 0.000                Fit Cyc Yld  =   71. Ksi, 488.MPA
   No. data points=   36
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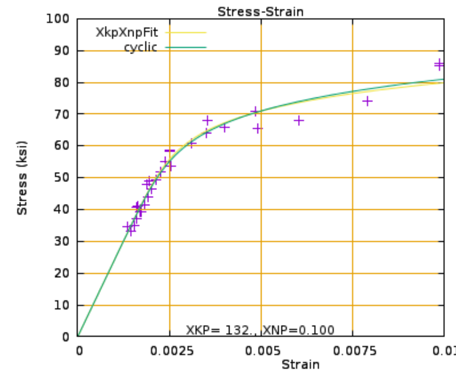

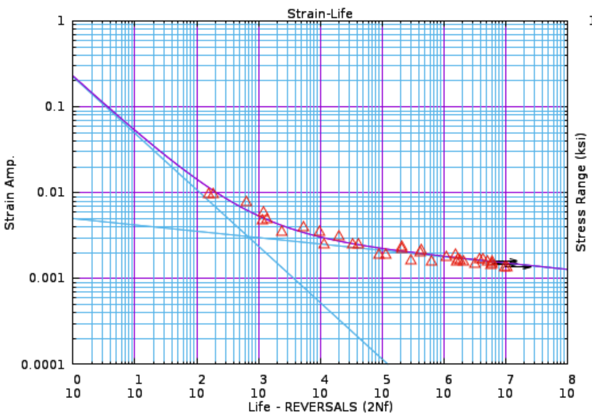

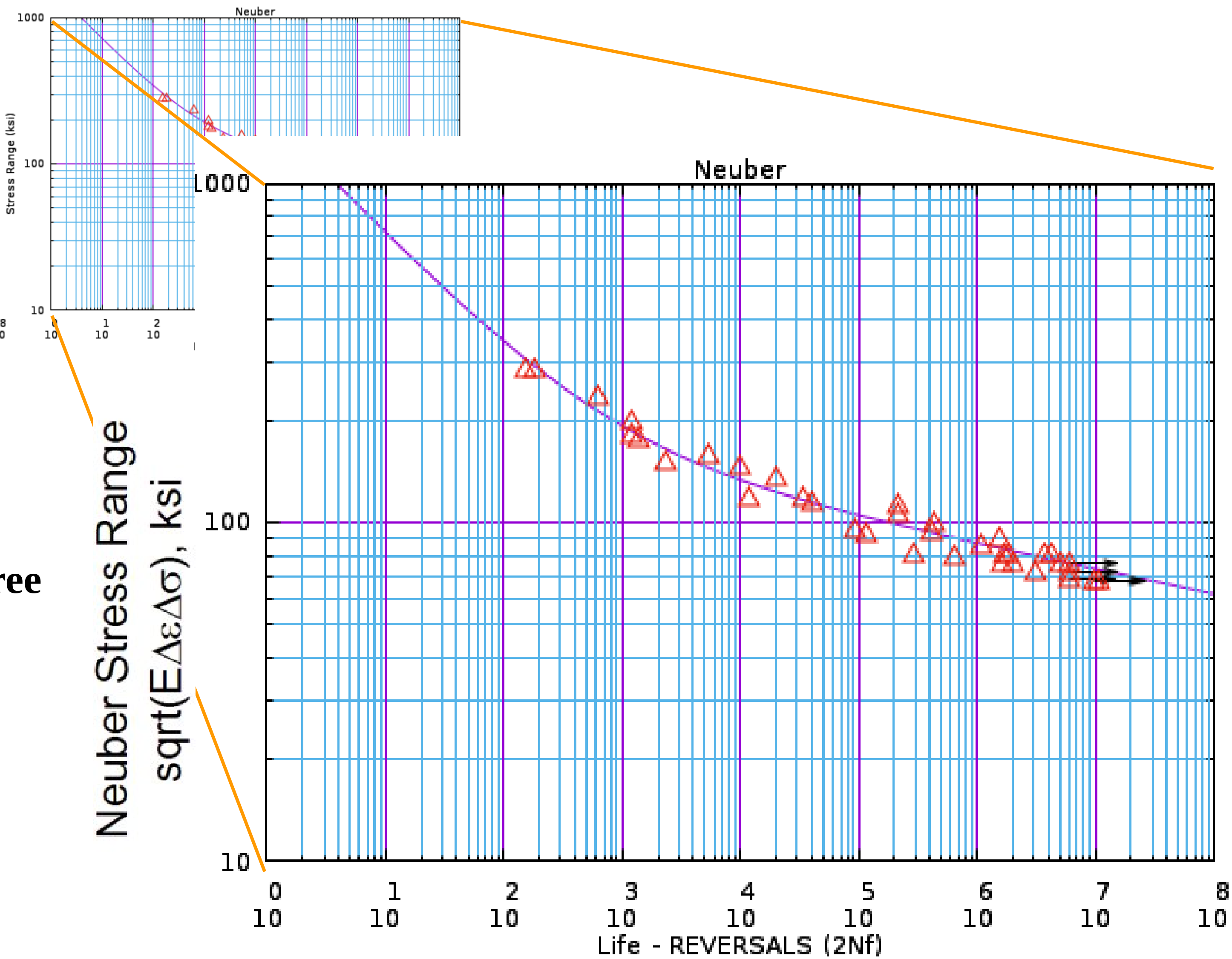

The advantage of this plot over a simple stress vs. life or strain vs. life plot is that it contains a measure of three variables, Strain

Stress

Elas.Modulus

of a material vs. life.

Part 2 of this article will show how this can be useful in a number of ways.