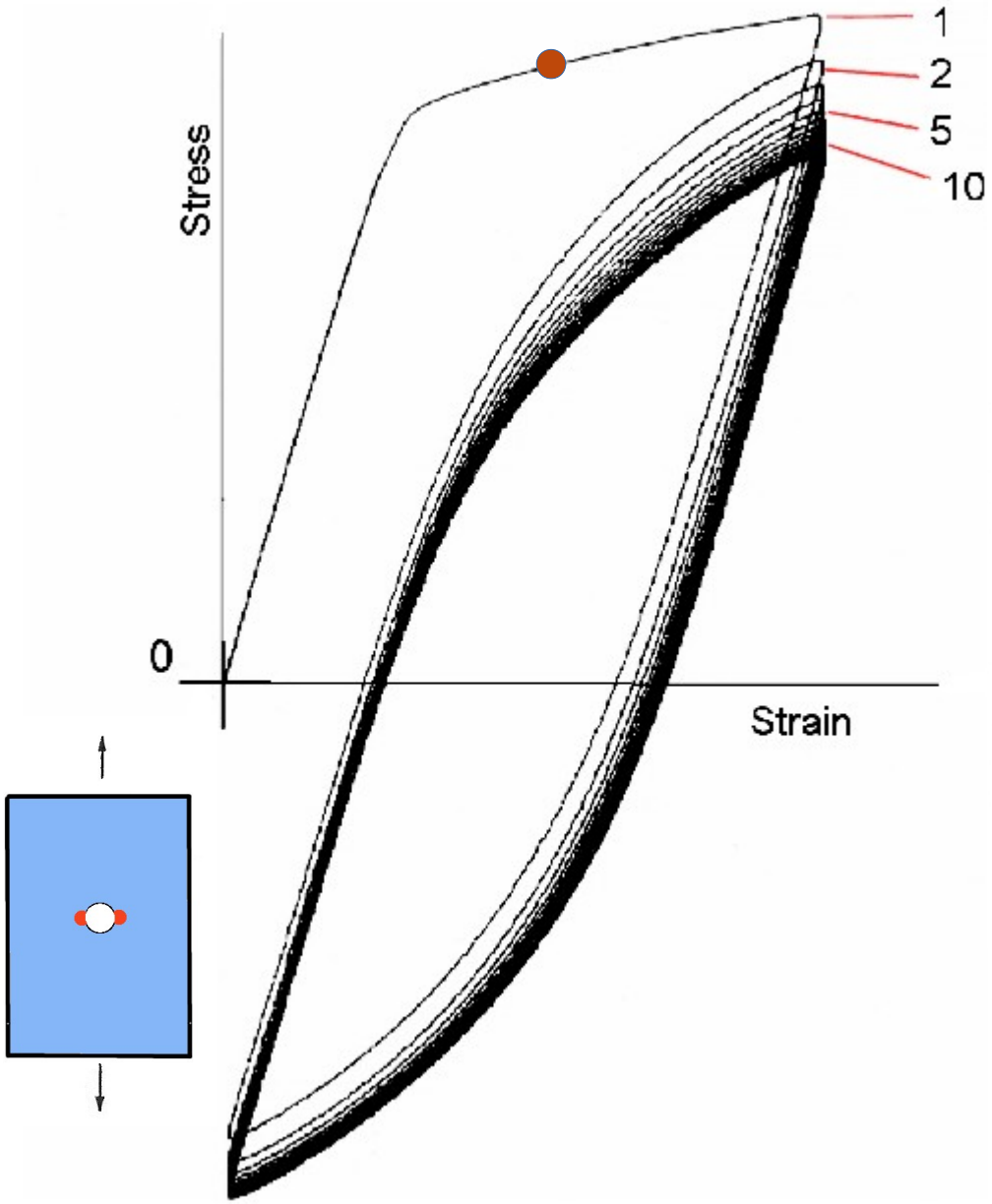
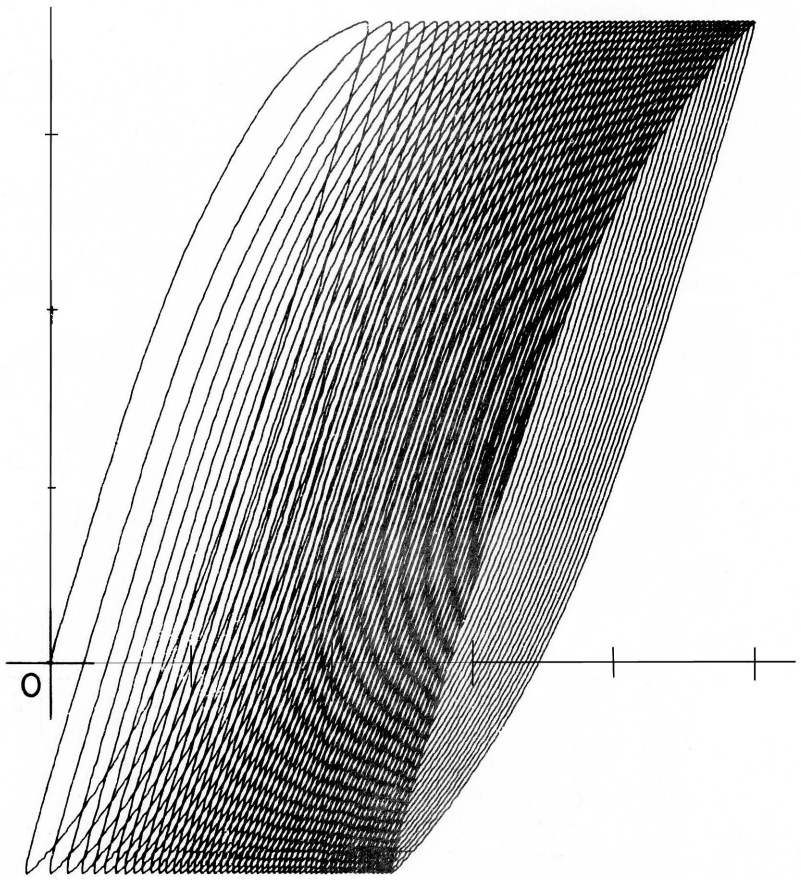
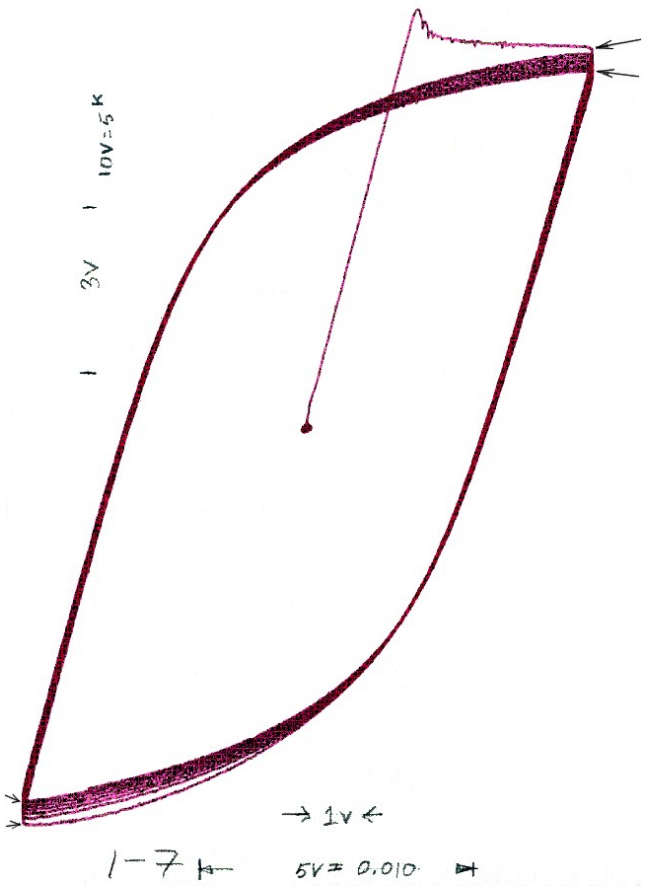
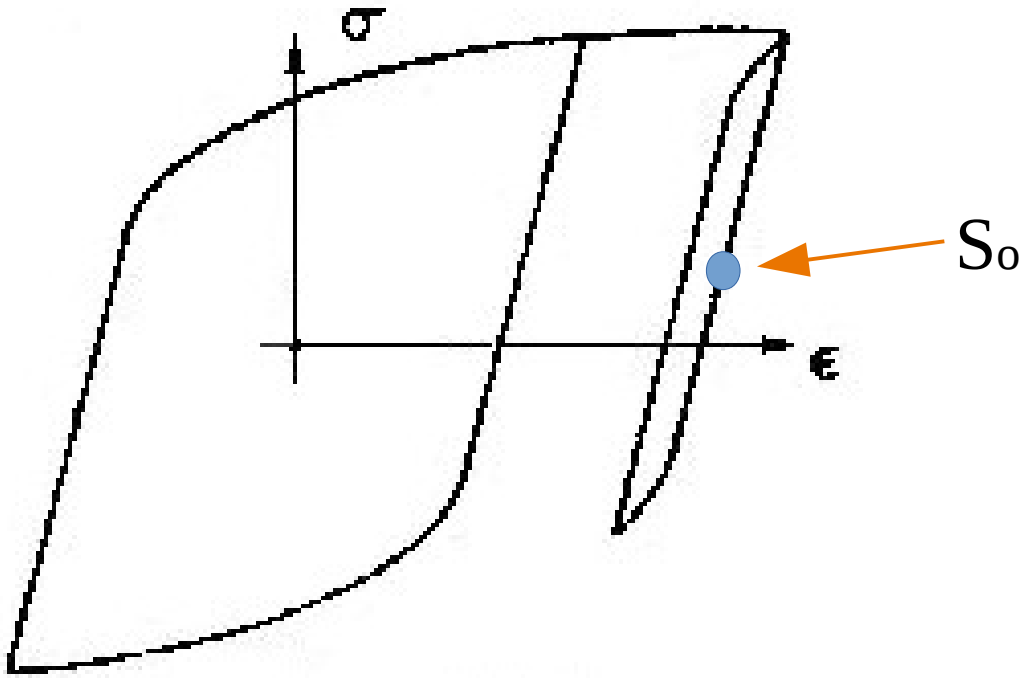
Cyclic Mean Stress Relaxation

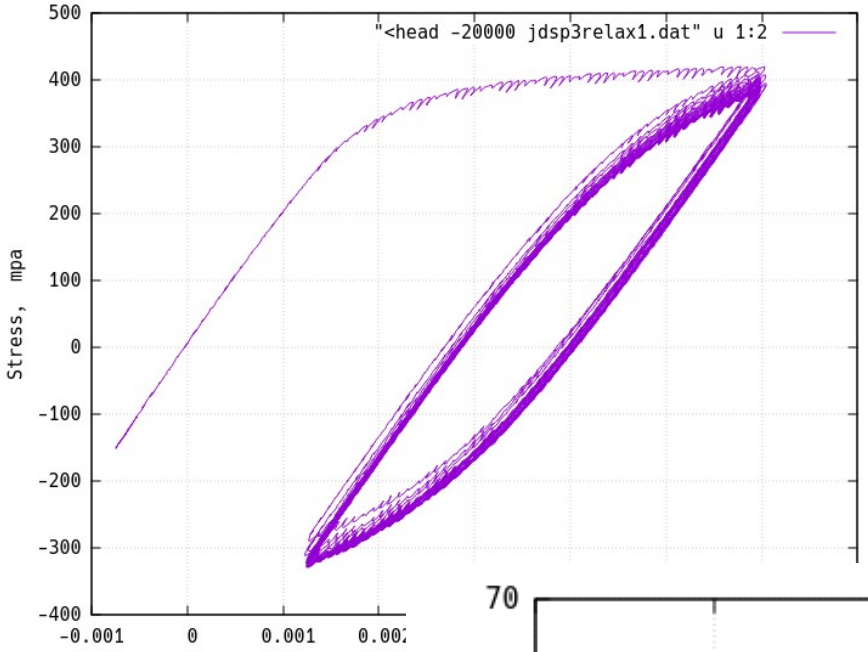


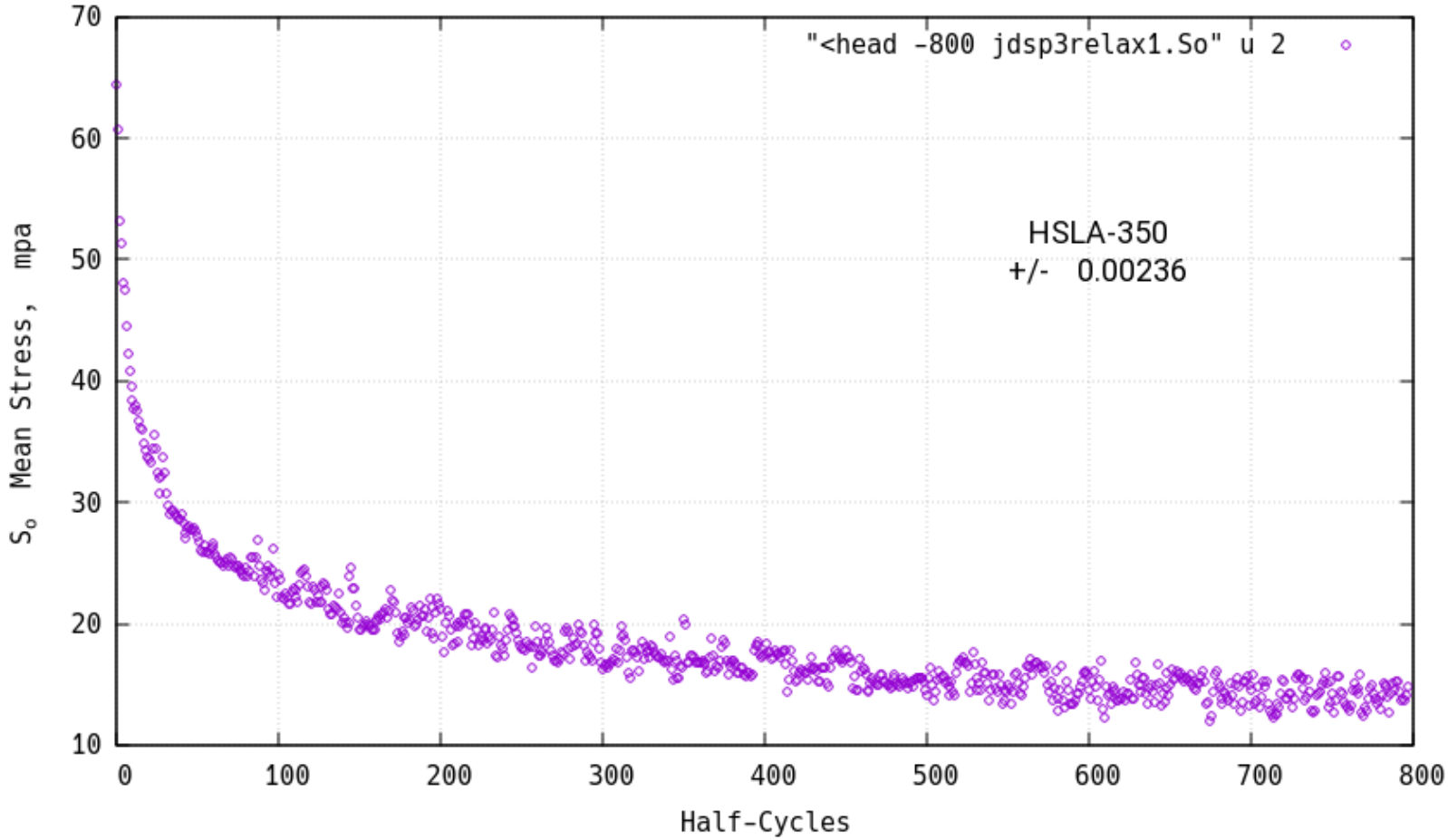


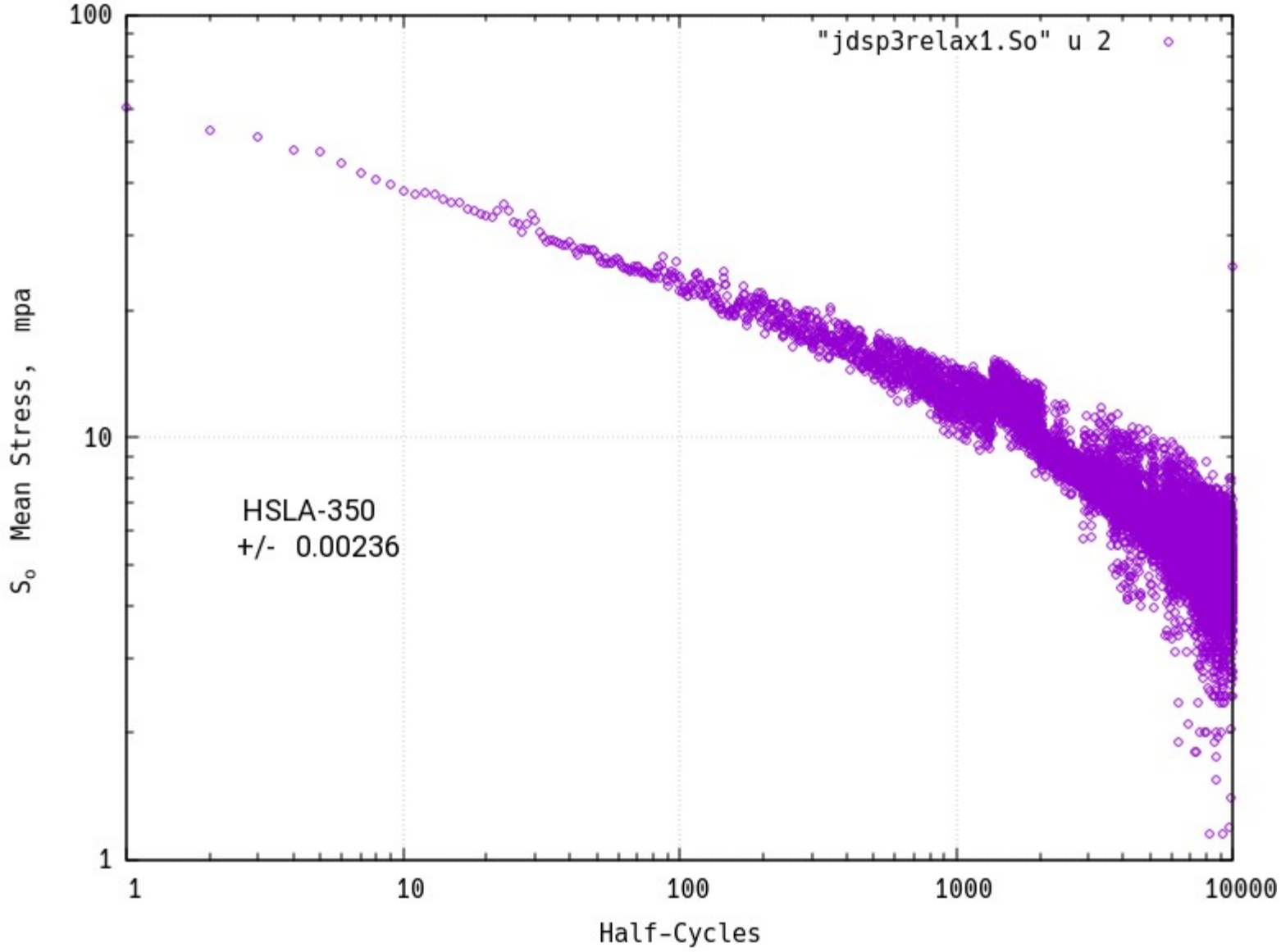
A. Conle
F.D.E. Spring 2019 Meeting
Cobo Hall, Detroit.

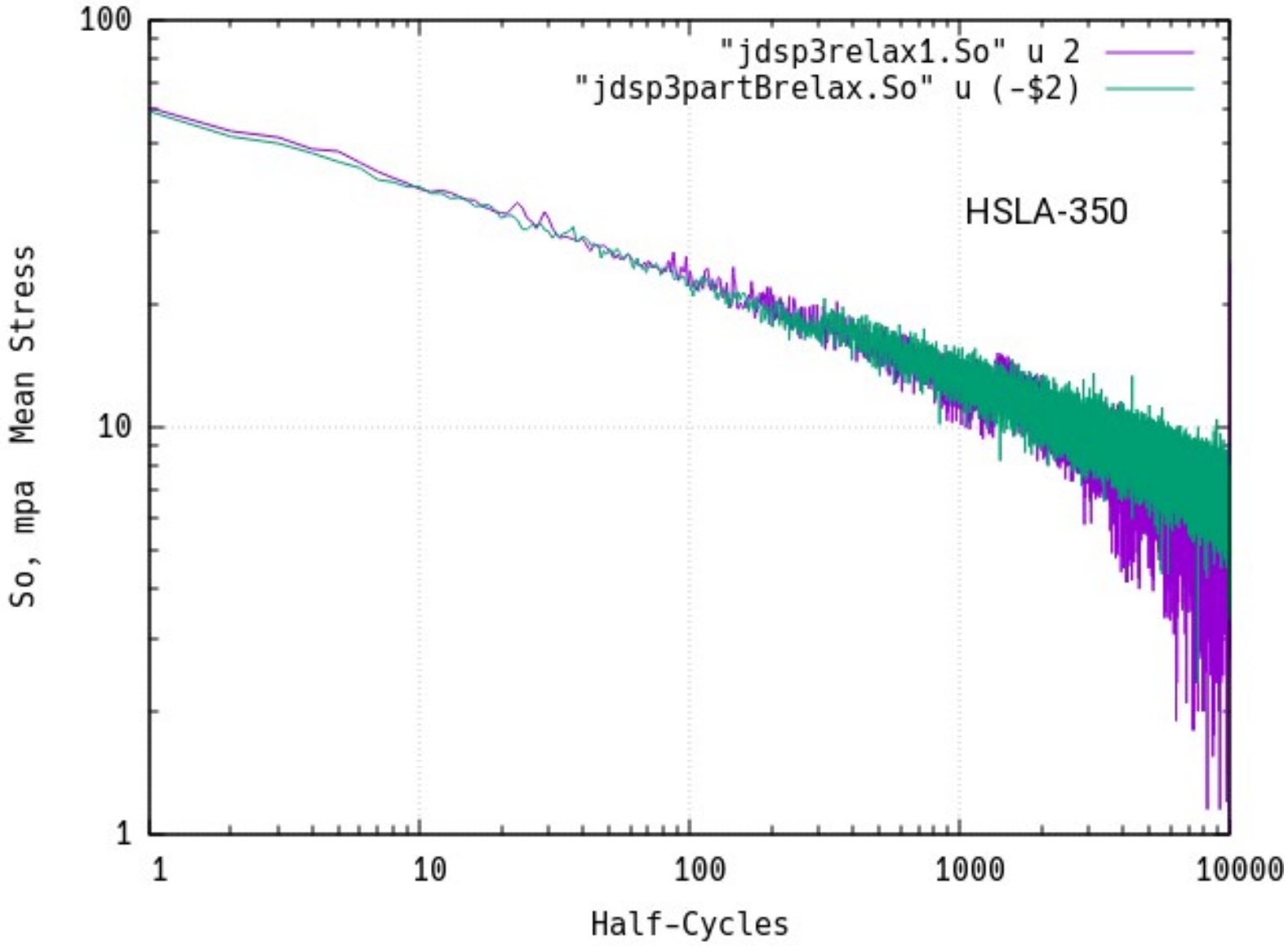

10V=5K
3V
→ 1V ←
1-7
5V = 0.010


σ
ε
So

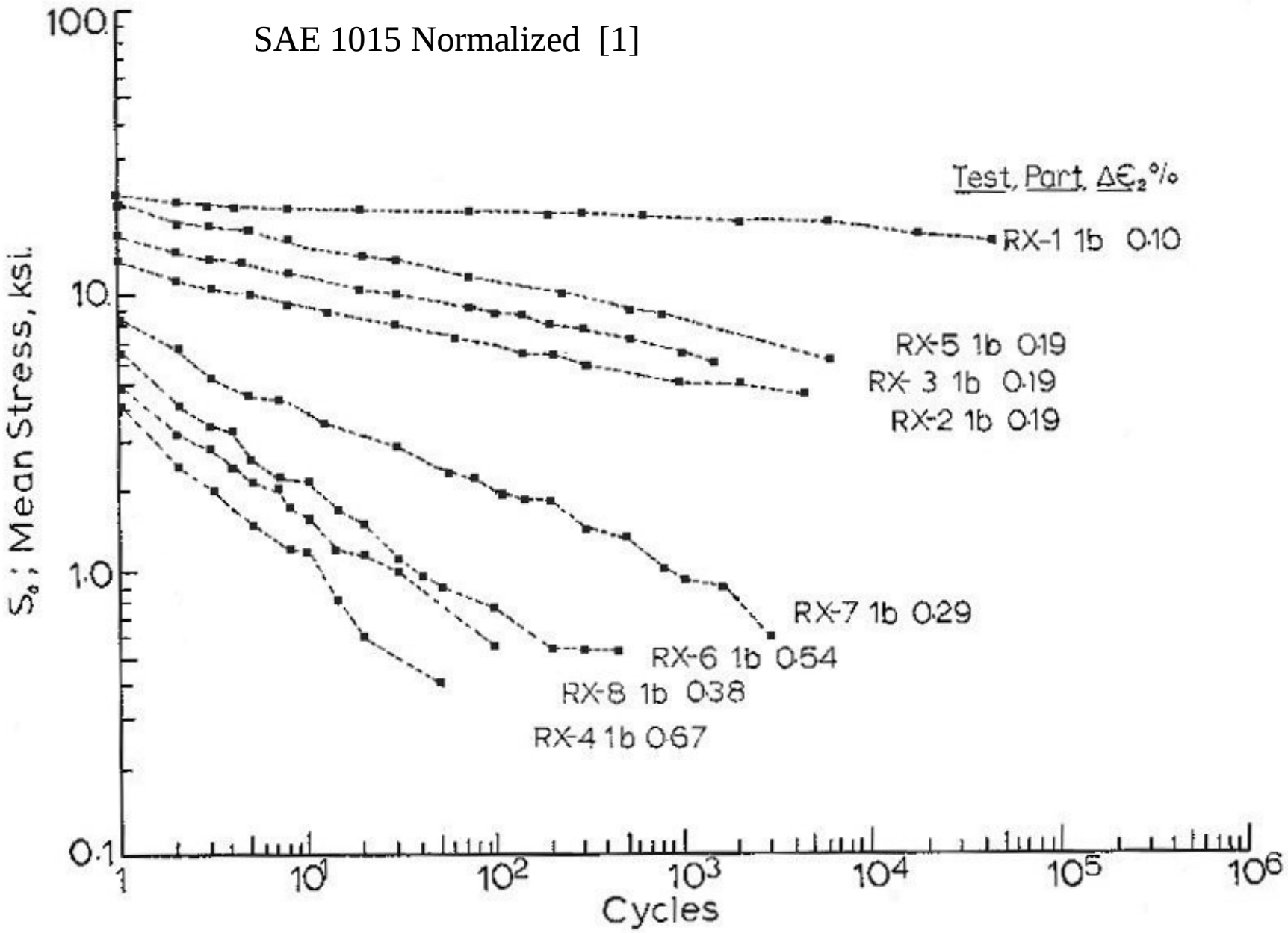

"<head -20000 jdsp3relax1.dat" u 1:2
Stress, mpa
500
400
300
200
100
0
-100
-200
-300
-400
-0.001
0
0.001


"<head -800 jdsp3relax1.So" u 2
HSLA-350
+/- 0.00236
So Mean Stress, mpa
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
Half-Cycles


"jdsp3relax1.So" u 2
HSLA-350
+/- 0.00236
S_o Mean Stress, mpa
Half-Cycles
100
10
1
1
10
100
1000
10000


"jdsp3relax1.So" u 2
"jdsp3partBrelax.So" u (-$2)
HSLA-350
So, mpa Mean Stress
Half-Cycles
100
10
1
1
10
100
1000
10000

SAE 1015 Normalized [1]



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

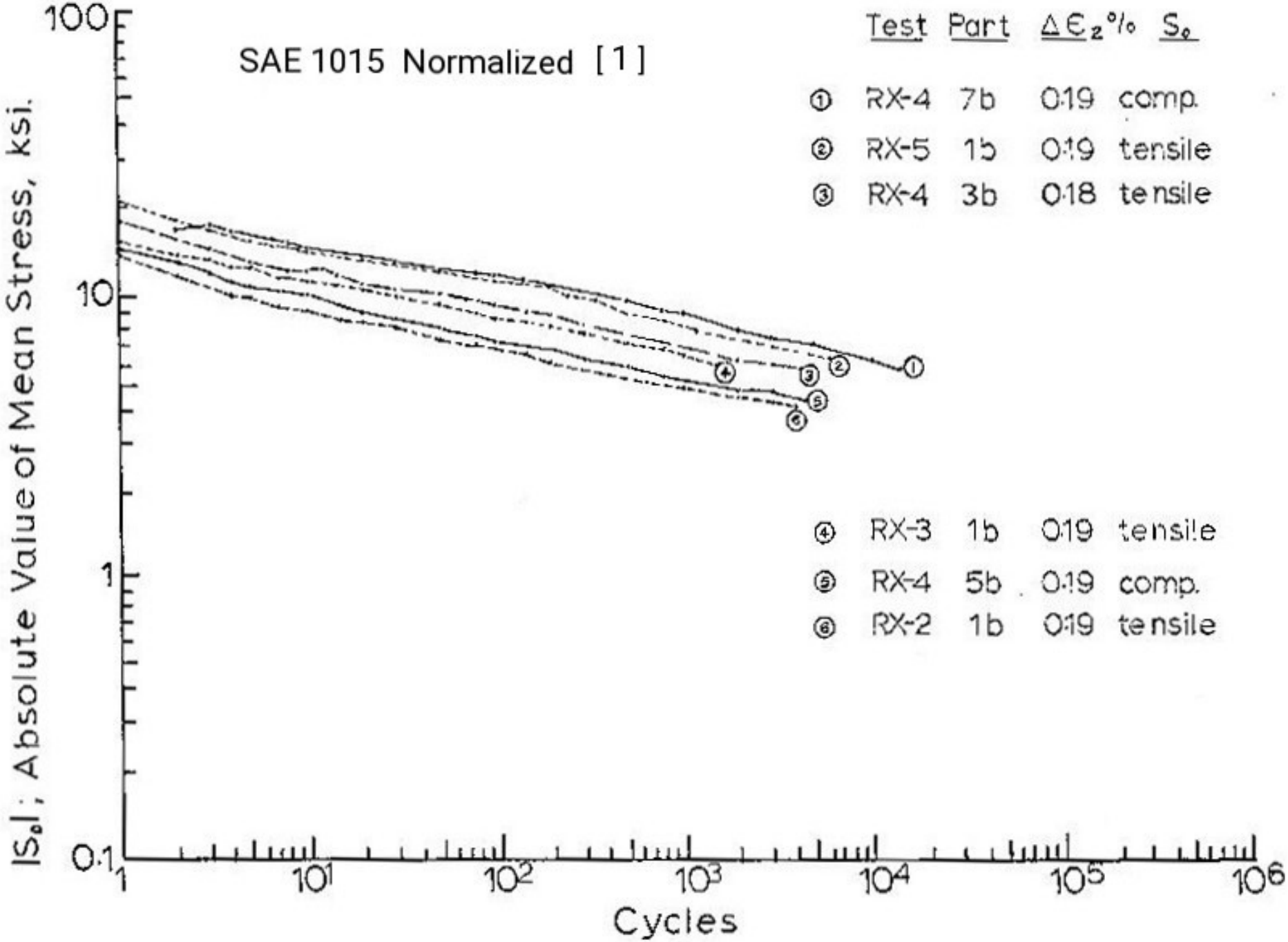


Fig.4 Absolute Value of Mean Stress vs. Cycles at Secondary Strain Range $\Delta\epsilon_2 \doteq 0.2\%$

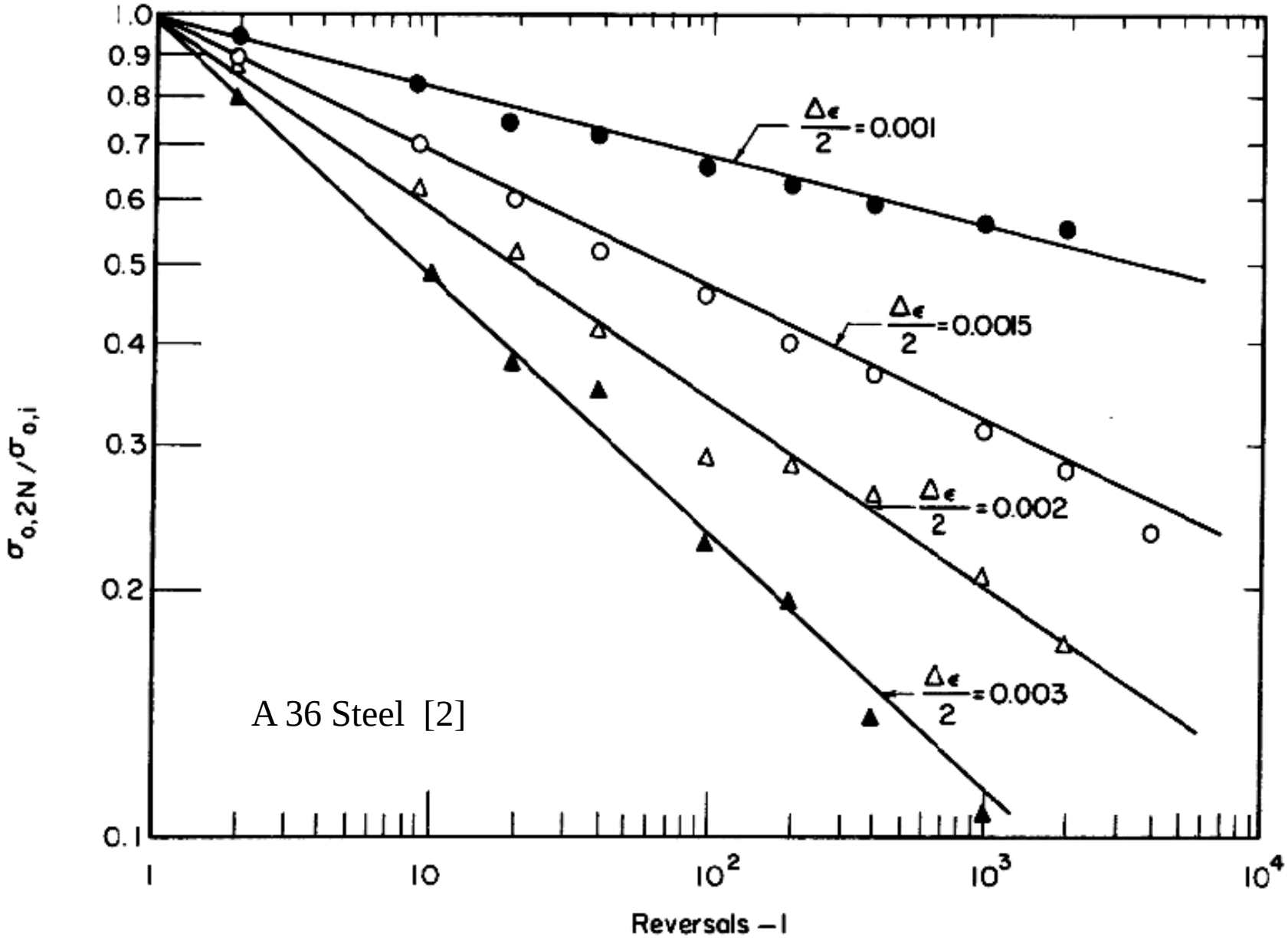


Fig. C-1 Cyclic Relaxation of the Mean Stress for A-36 Steel (Constant Mean Strain of +0.005)

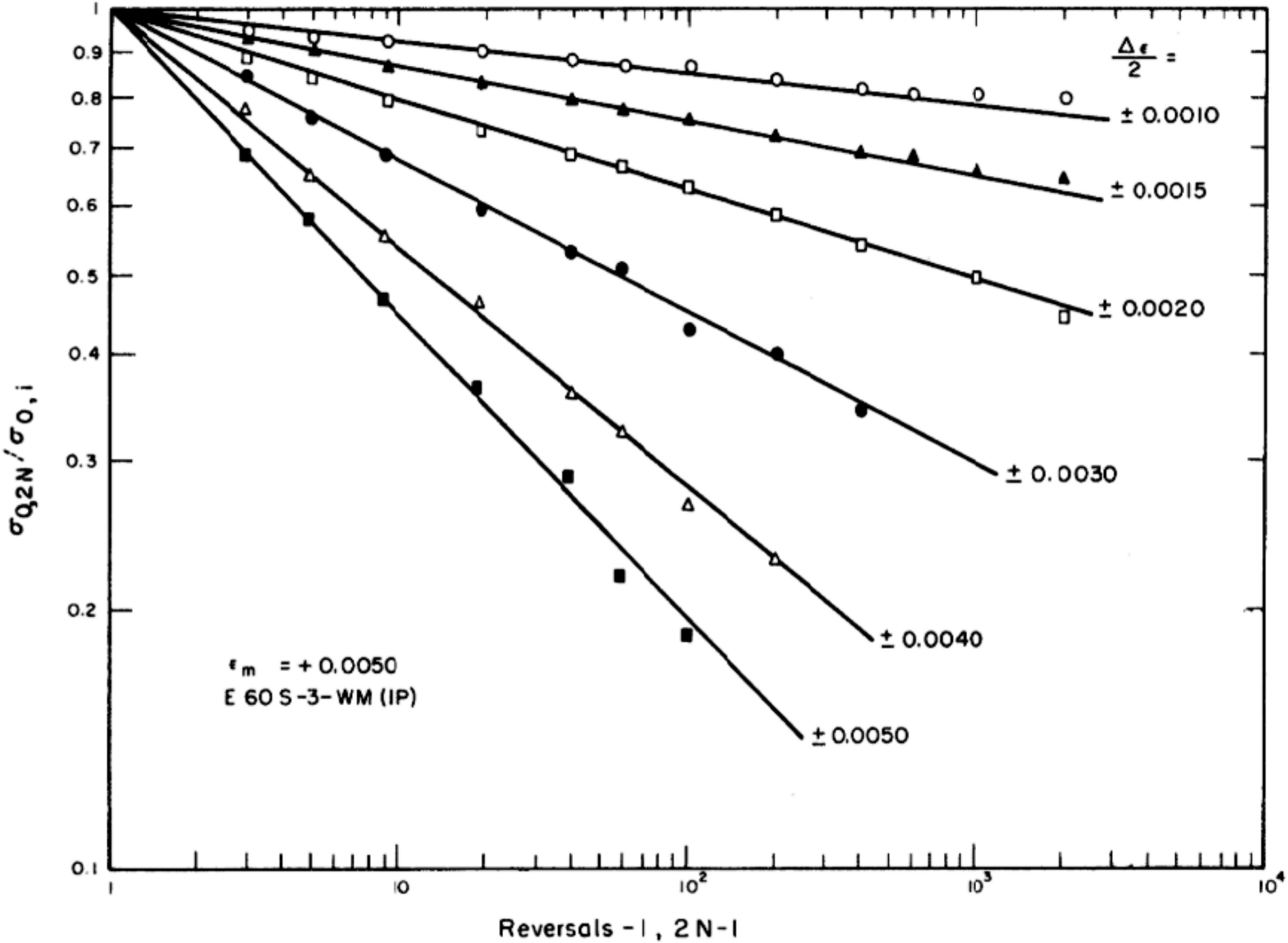


Fig. 71 Cyclic Relaxation Data of the Mean Stress (Dimensionless Value) for E60S-3-WM(1P) at Constant Mean Strain of +0.005

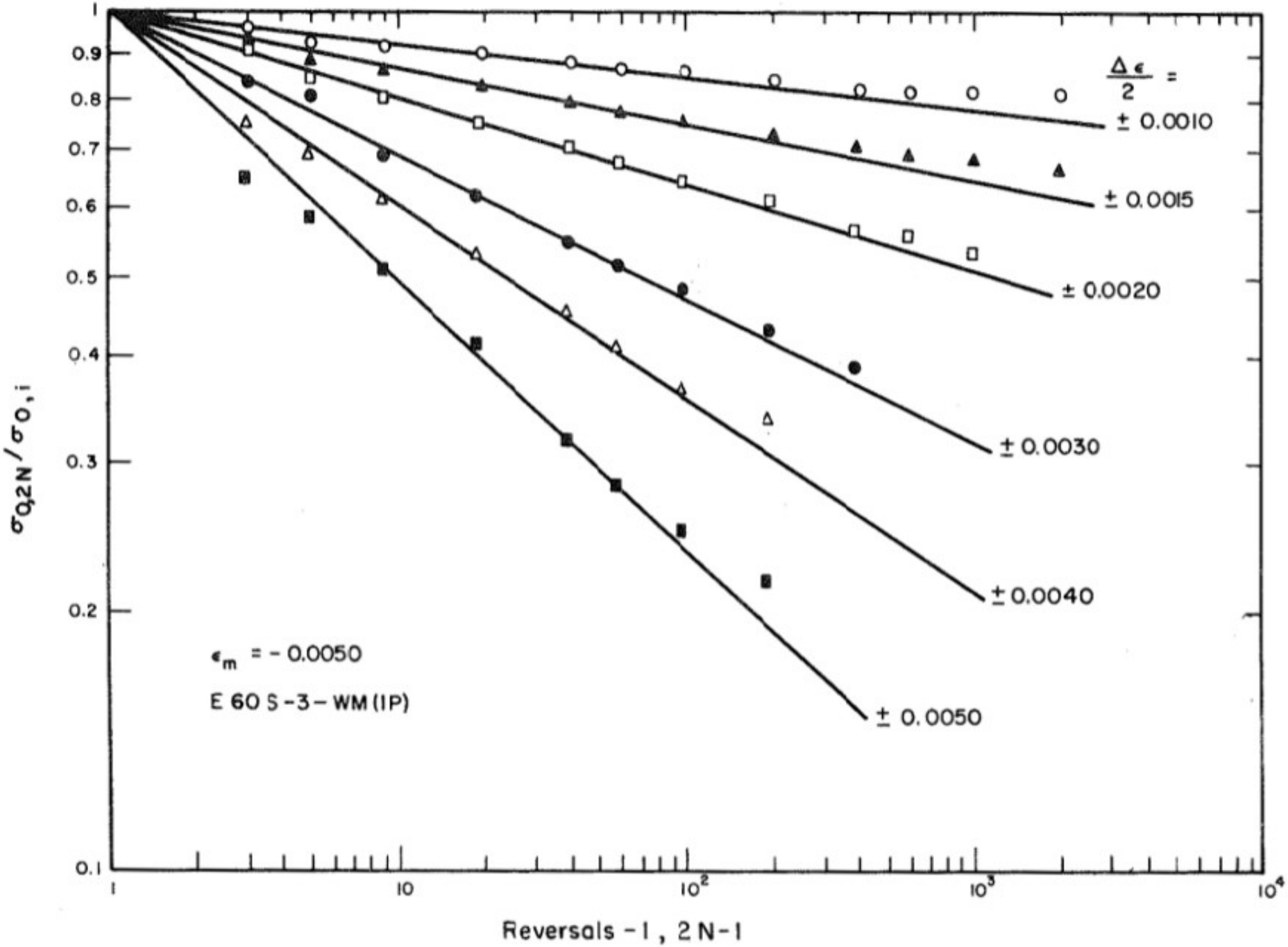
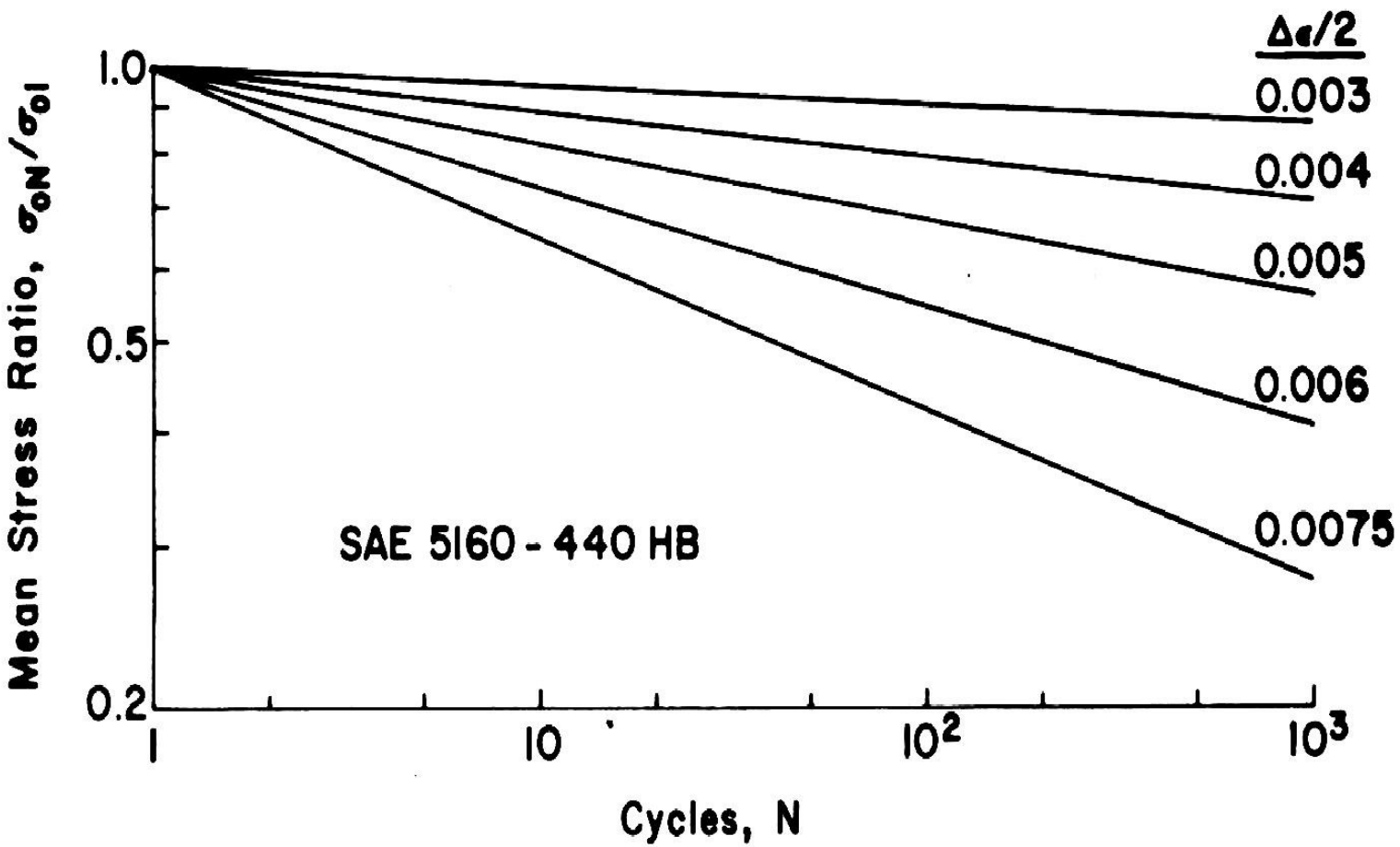
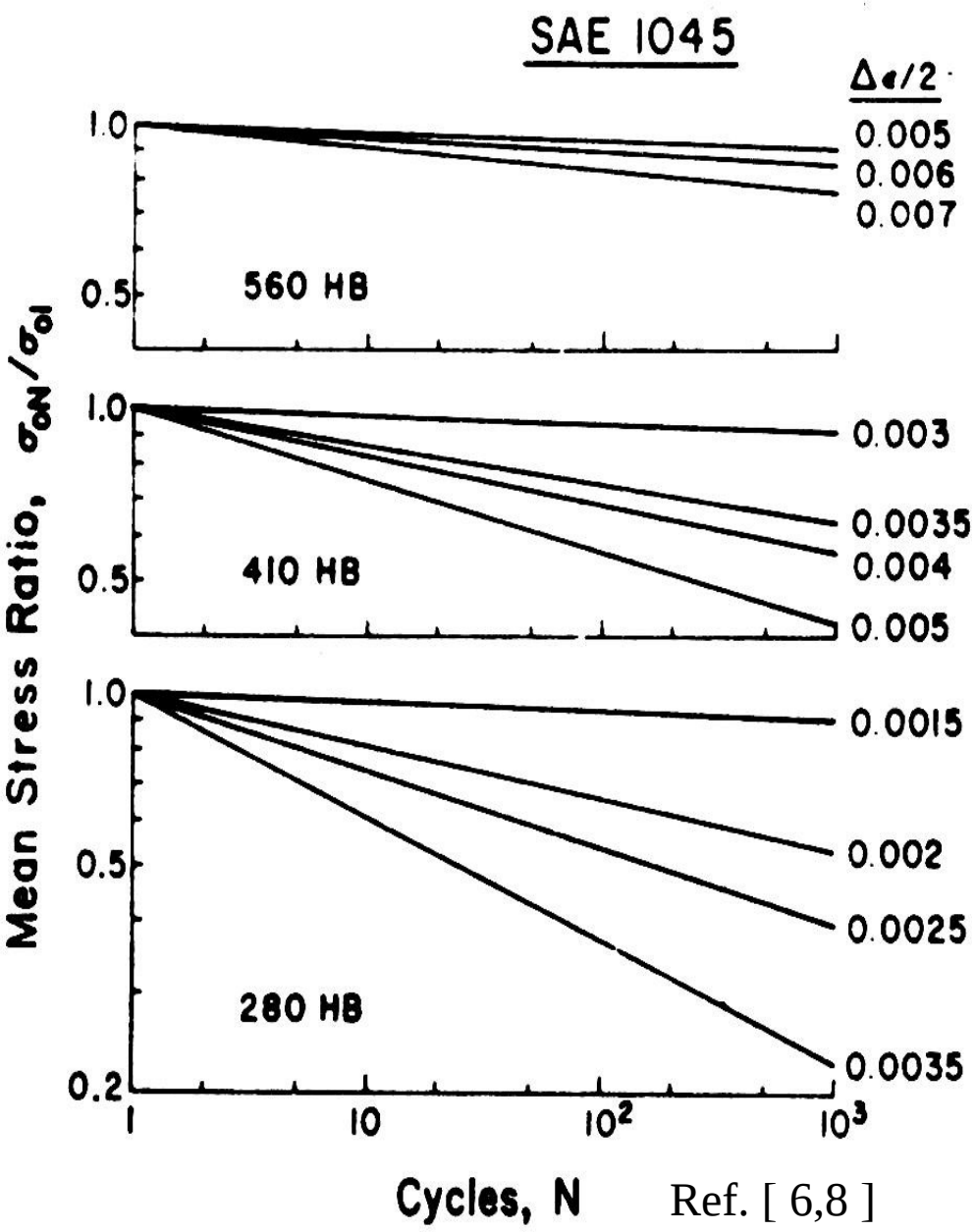


Fig. 72 Cyclic Relaxation Data of the Mean Stress (Dimensionless Value) for E60S-3-WM(1P) at Constant Mean Strain of -0.005

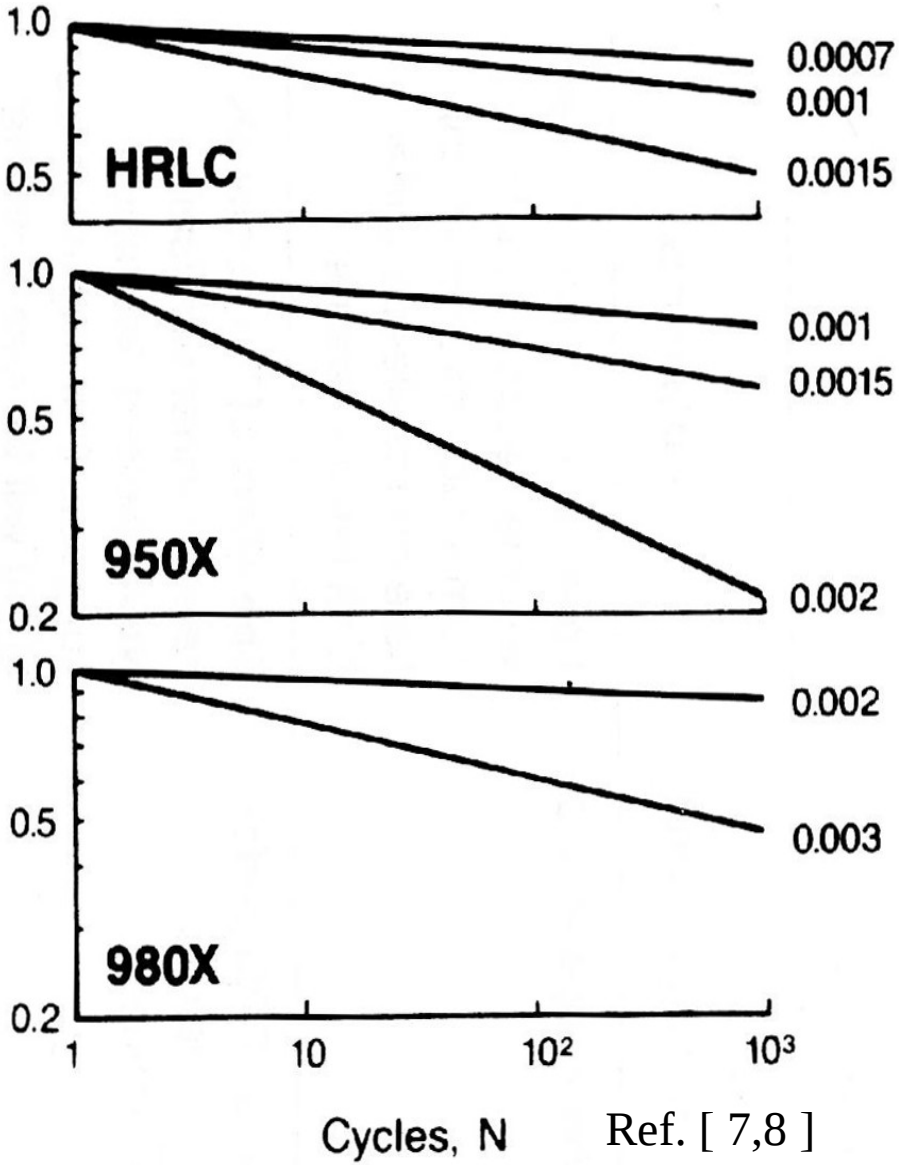
[3]


Δε/2
0.003
0.004
0.005
0.006
0.0075
1.0
0.5
0.2
Mean Stress Ratio, σ_oN/σ_oI
SAE 5160 - 440 HB
1
10
10^2
10^3
Cycles, N

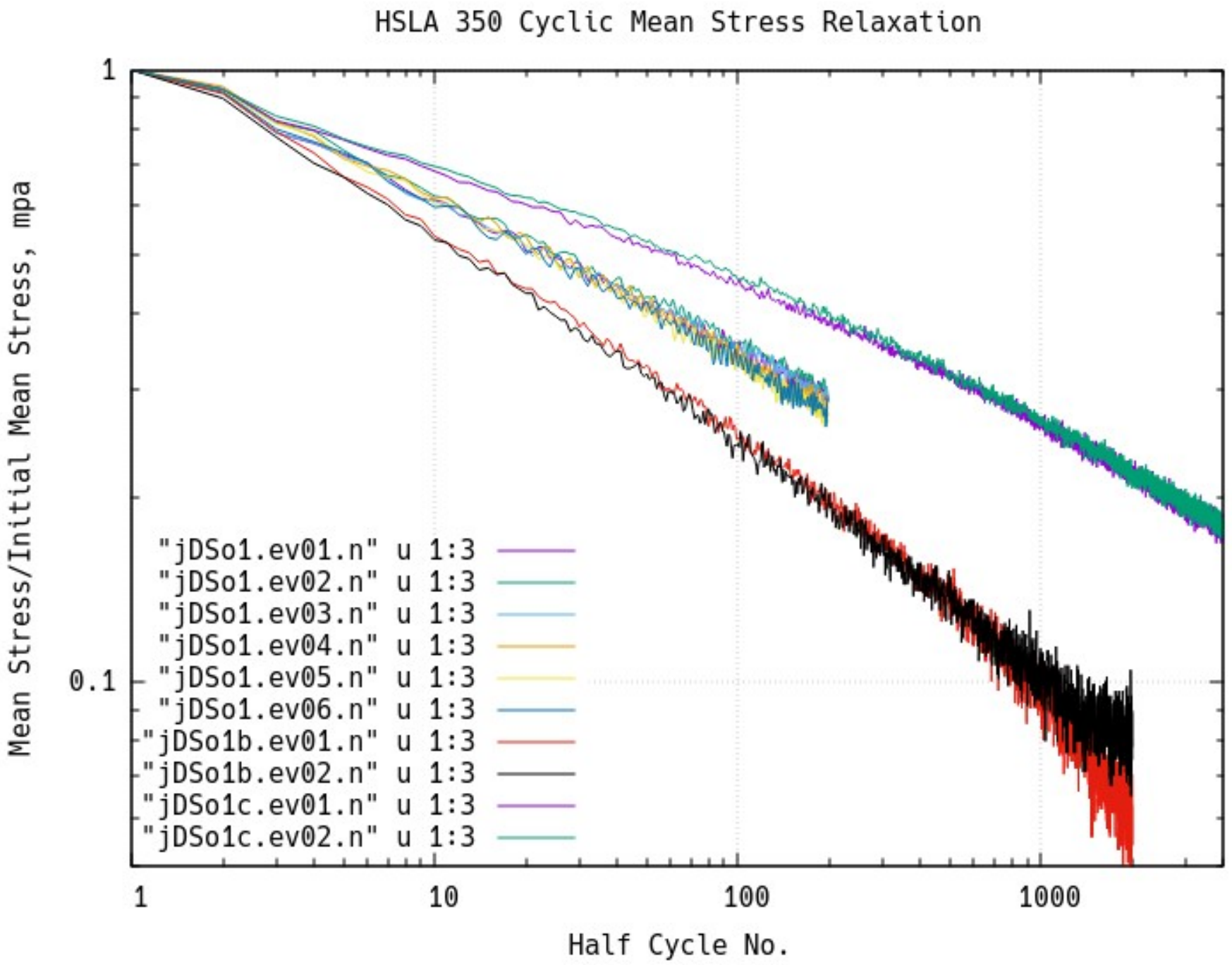
Ref. [5]

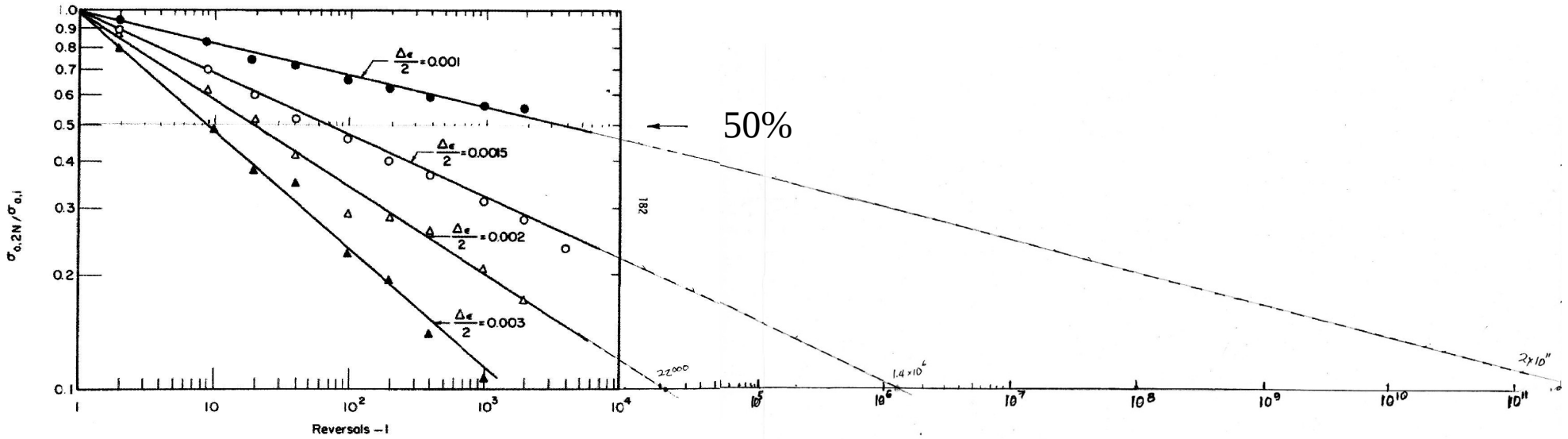

SAE 1045
Δε/2
0.005
0.006
0.007
560 HB
0.003
0.0035
0.004
0.005
410 HB
0.0015
0.002
0.0025
0.0035
280 HB
1.0
0.5
0.2
1
10
10²
10³
Mean Stress Ratio, σ_oN/σ_oI
Cycles, N

Ref. [6,8]

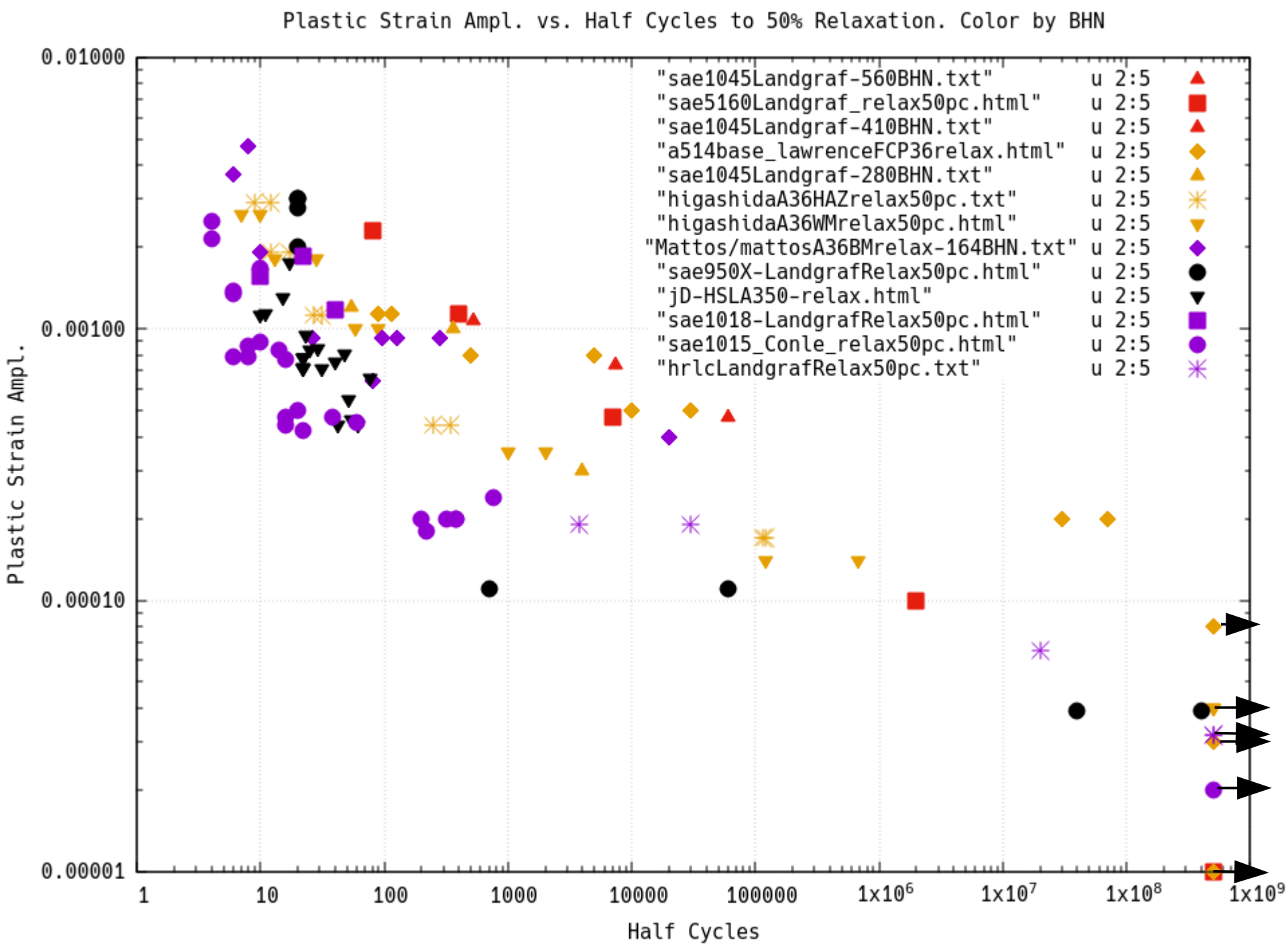

0.0007
0.001
0.0015
HRLC
0.001
0.0015
0.002
950X
0.002
0.003
980X
1.0
0.5
0.2
1
10
10²
10³
Cycles, N

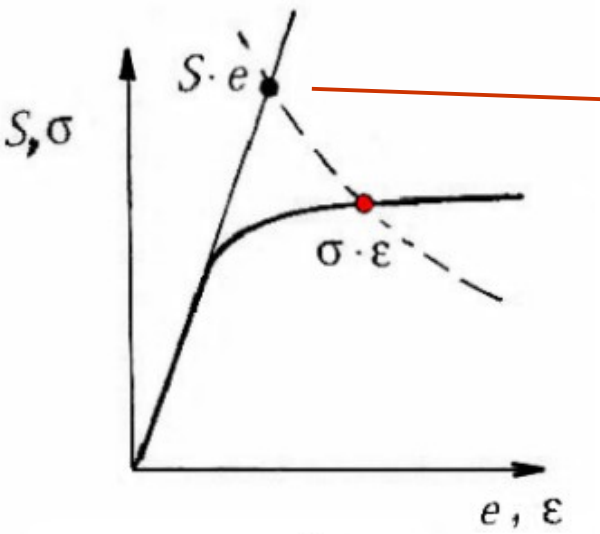
Ref. [7,8]


HSLA 350 Cyclic Mean Stress Relaxation
Mean Stress/Initial Mean Stress, mpa
1
0.1
1
10
100
1000
Half Cycle No.
"jDSo1.ev01.n" u 1:3
"jDSo1.ev02.n" u 1:3
"jDSo1.ev03.n" u 1:3
"jDSo1.ev04.n" u 1:3
"jDSo1.ev05.n" u 1:3
"jDSo1.ev06.n" u 1:3
"jDSo1b.ev01.n" u 1:3
"jDSo1b.ev02.n" u 1:3
"jDSo1c.ev01.n" u 1:3
"jDSo1c.ev02.n" u 1:3


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
σ0.2N/σa,i
Δε/2 = 0.001
Δε/2 = 0.0015
Δε/2 = 0.002
Δε/2 = 0.003
182
22,000
1.4×10^6
2×10^11
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^10
10^11
Reversals — I

← 50%


Plastic Strain Ampl. vs. Half Cycles to 50% Relaxation. Color by BHN
"sae1045Landgraf-560BHN.txt" u 2:5
"sae5160Landgraf_relax50pc.html" u 2:5
"sae1045Landgraf-410BHN.txt" u 2:5
"a514base_lawrenceFCP36relax.html" u 2:5
"sae1045Landgraf-280BHN.txt" u 2:5
"higashidaA36HAZrelax50pc.txt" u 2:5
"higashidaA36WMrelax50pc.html" u 2:5
"Mattos/mattosA36BMrelax-164BHN.txt" u 2:5
"sae950X-LandgrafRelax50pc.html" u 2:5
"jD-HSLA350-relax.html" u 2:5
"sae1018-LandgrafRelax50pc.html" u 2:5
"sae1015_Conle_relax50pc.html" u 2:5
"hrlcLandgrafRelax50pc.txt" u 2:5
0.01000
0.00100
0.00010
0.00001
Plastic Strain Ampl.
1
10
100
1000
10000
100000
1x10^6
1x10^7
1x10^8
1x10^9
Half Cycles



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

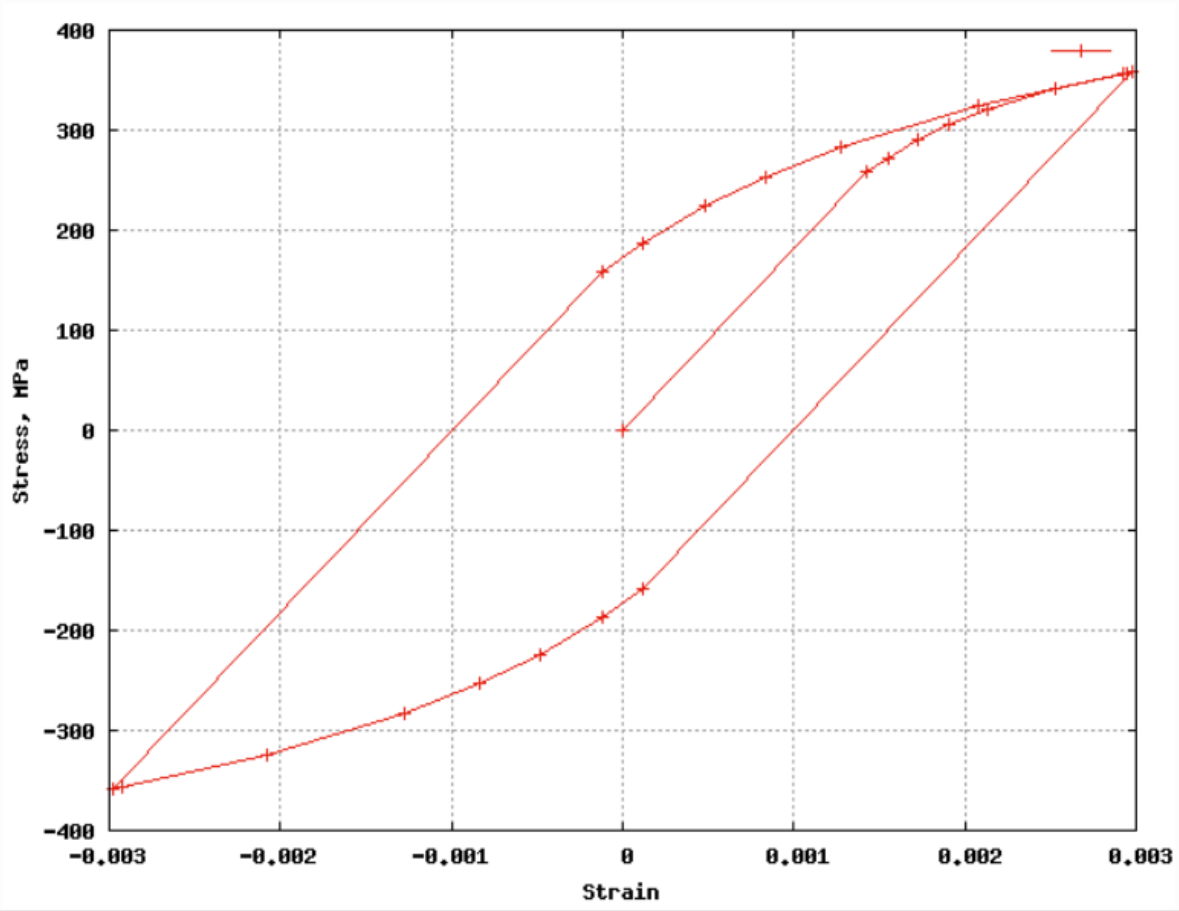
Nominal and Local Stress-Strain:

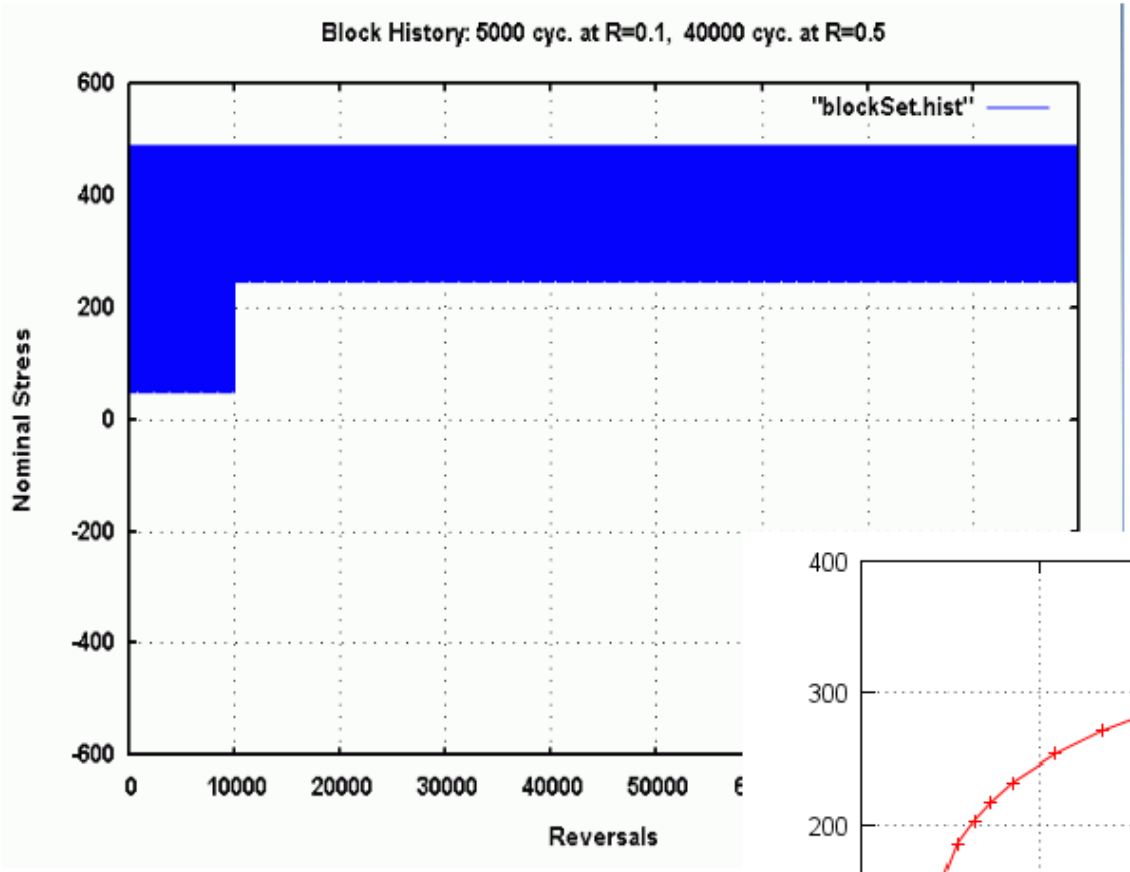
```
#xcalc2 Loop   Smax    Smin        N  Sigmax  Sigmin Delta Epsmax Epsmin DeltaEps
#xcalc2    1  450.0  -450.0      1.0   358.  -358.  717. 0.00298 -.00298 0.00596
```

Life Predictions (history repetitions):

```
#xcalc3  StrainLife_Reps SWaT_Life_Reps StressLife_Reps   Morrow_Reps   Goodman_Reps
#xcalc3     47982.2         47982.1         47982.2         47982.2         47982.2
```

Local Stress and Strain Response:



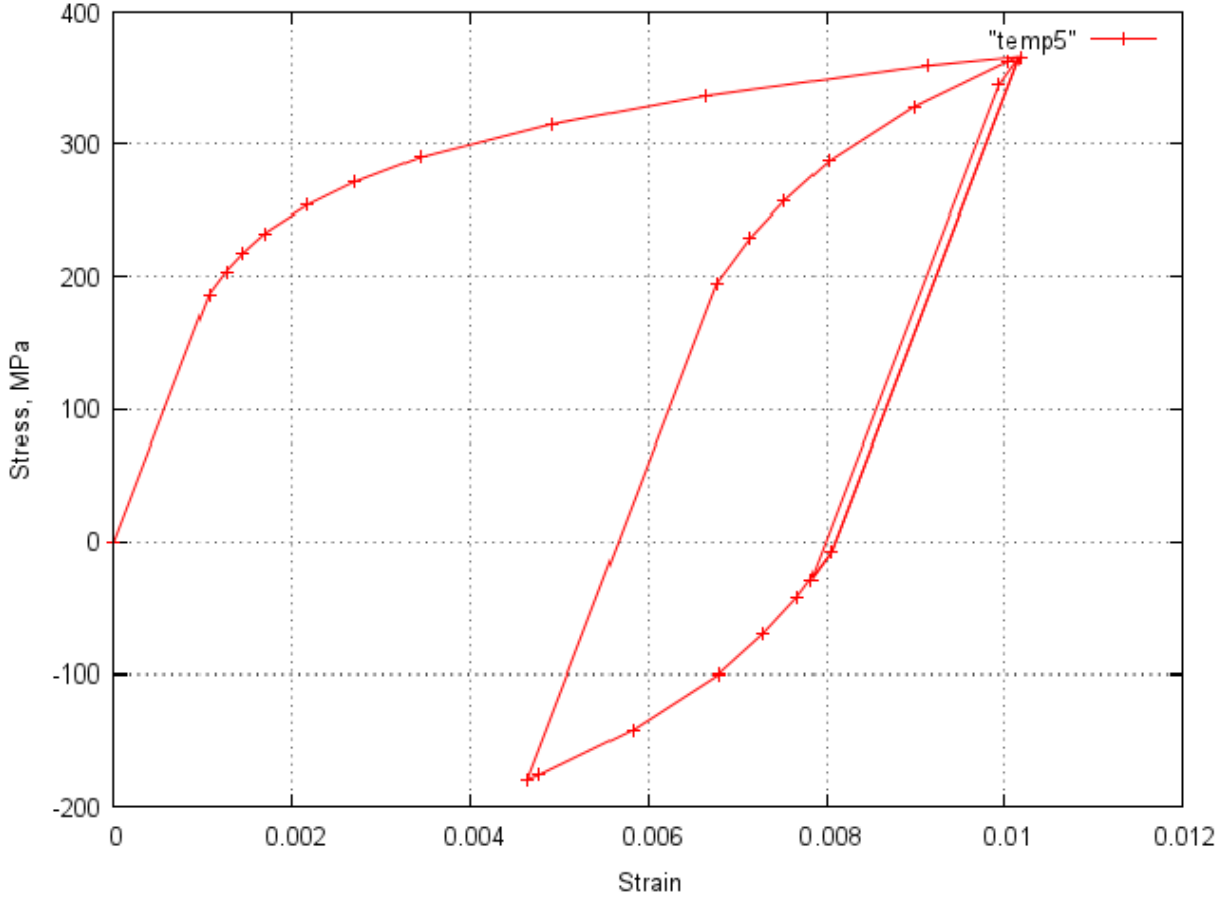


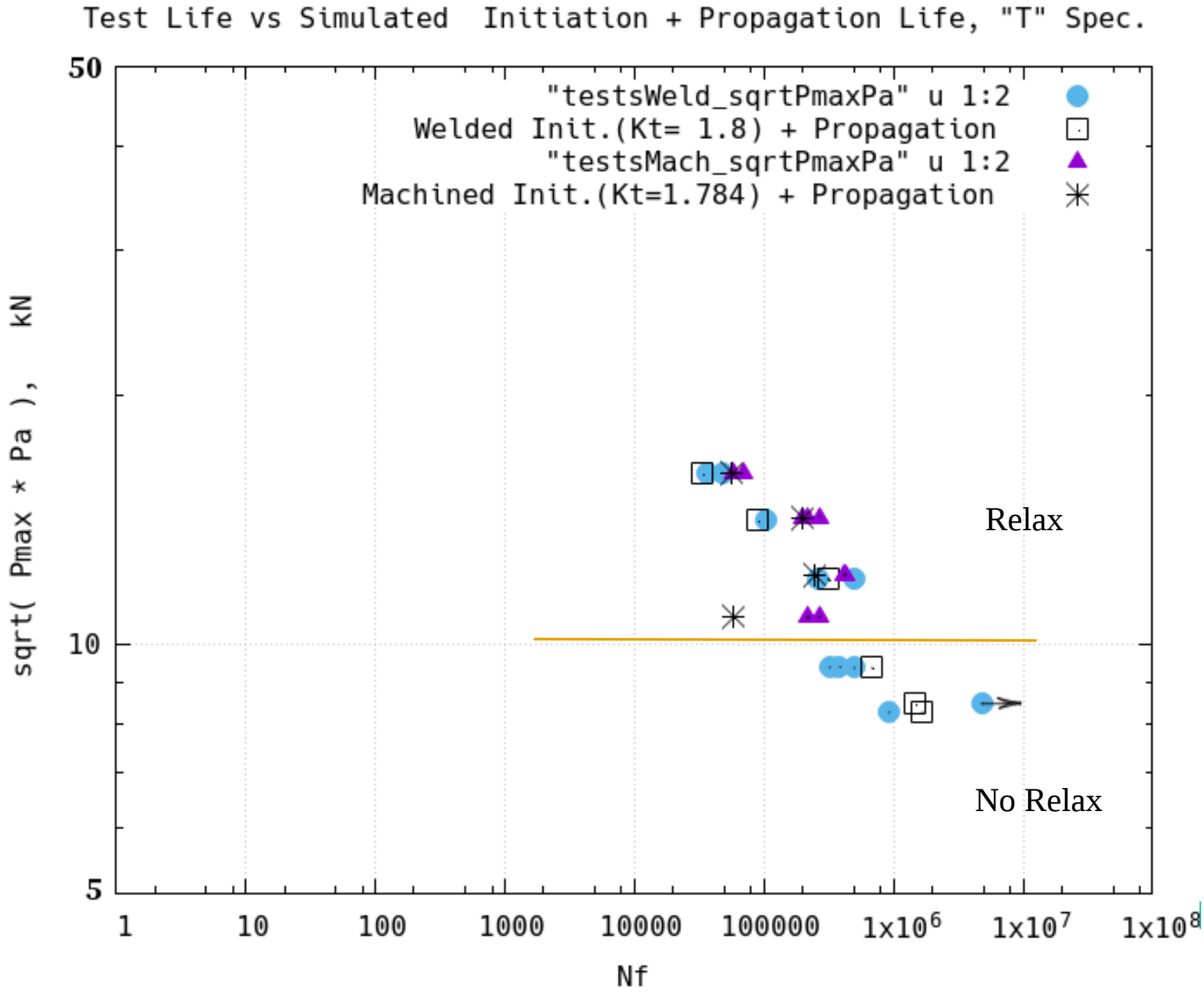
Test total life: 6.9 blks average

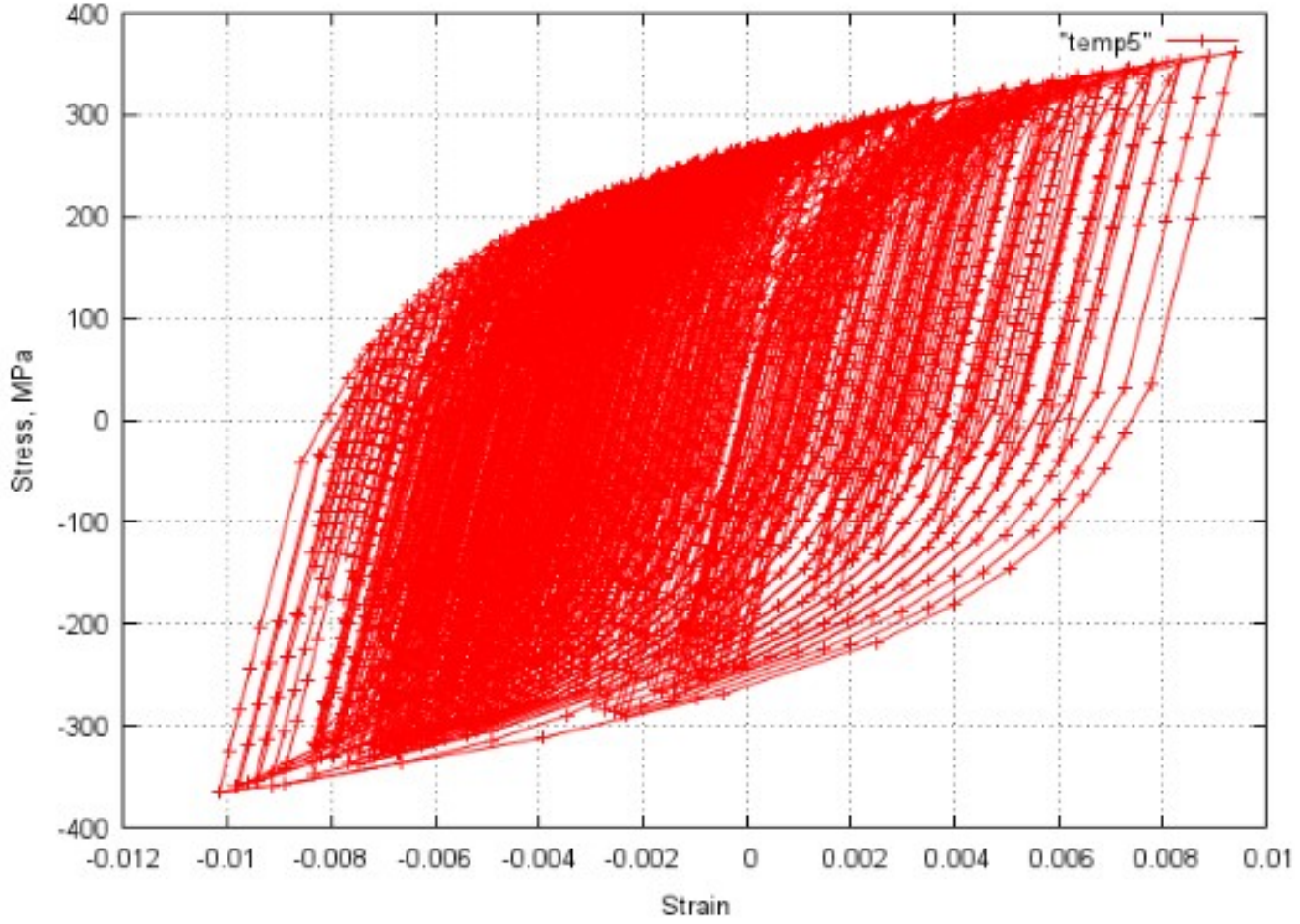
Sim.:

Initiation 7.4 blks
(non-periodic o/s
with relaxation)

Propagation <1 blk




Test Life vs Simulated Initiation + Propagation Life, "T" Spec.
"testsWeld_sqrtPmaxPa" u 1:2
Welded Init.(Kt= 1.8) + Propagation
"testsMach_sqrtPmaxPa" u 1:2
Machined Init.(Kt=1.784) + Propagation
Relax
No Relax
sqrt(Pmax * Pa), kN
Nf
50
10
5
1
10
100
1000
10000
100000
1x10^6
1x10^7
1x10^8



Test total life: 28.5 Blocks, average

Simulation:

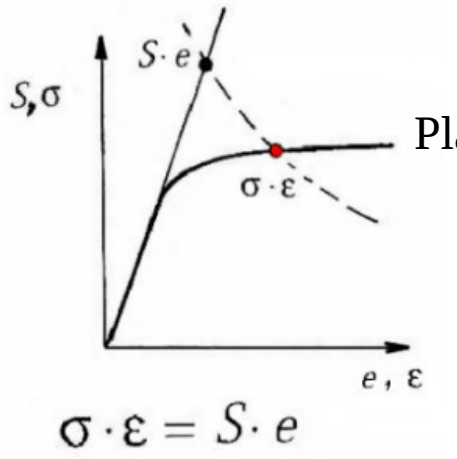
Initiation: 22.3 Blks (with periodic o/s)
Propagation= < 1 Blk.
Total: 22.5 Blks.

Suggested Process:

Kt

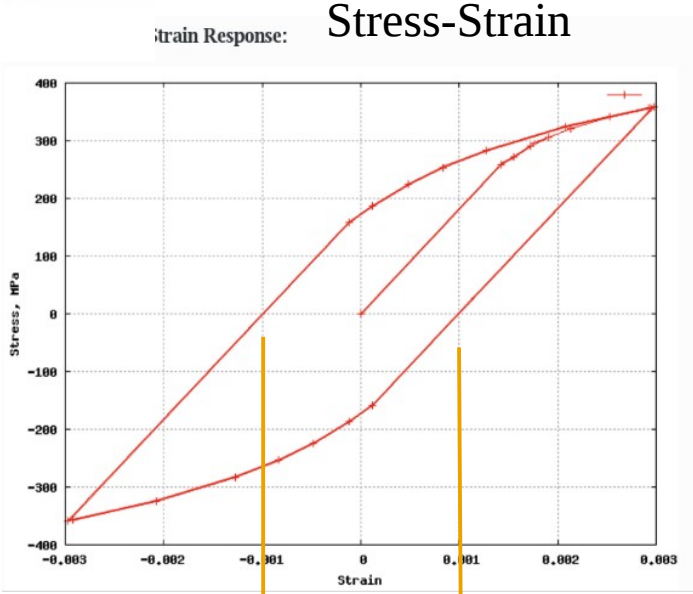
Smax

Smin

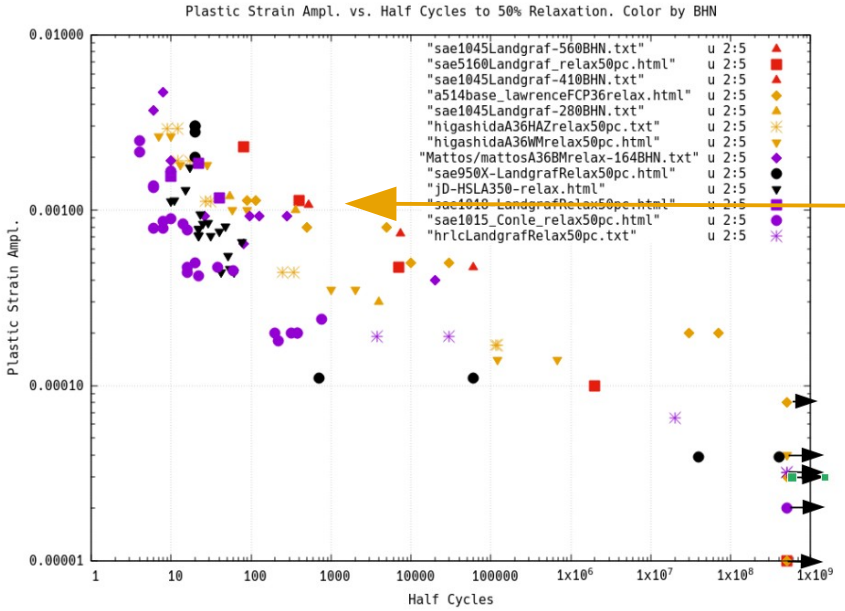


Apply Neuber Plasticity Correction

Get Local Stress-Strain



$\Delta\epsilon_p$



$\Delta\epsilon_p/2$

Estimate Plastic Strain Amplitude

References:

[1] A. Conle, “Data on Cyclic Mean Stress Relaxation in Mild Steel,” 3A Civil Engr. work term report, U.Waterloo, April, 1970. http://fde.uwaterloo.ca/Fde/Articles/Relax/conleSo.html

[2] R.J. Mattos, F.V. Lawrence, "Estimation of the Fatigue Crack Initiation Life in Welds Using Low Cycle Fatigue Concepts," Fracture Control Rep.19 Univ. of Illinois, Oct. 1975.

[3] Y. Higashida, F.V. Lawrence, “Strain Controlled Fatigue Behavior of Weld Metal and Heat-Affected Base Metal in A36 and A514 Steel Welds,” Fracture Control Report 22, Univ. of Illinois, Aug. 1976

[4] Y. Higashida, J.D. Burk, F.V. Lawrence jr, “Strain -Controlled Fatigue Behavior of ASTM A36 and A514 Grade F Steels and 5083-O Aluminum Weld Materials,” Welding Res. Supplement, Nov. 1978, pp. 334-s,344-s

[5] R.W. Landgraf, R.C. Francis, "Material and Processing Effects on Fatigue Performance of Leaf Springs," SAE Tech. Report 790407, 1979.

[6] R.W. Landgraf, R.A. Chernenkoff, "Residual Stress Effects on Fatigue of Surface Processed Steels," ASTM STP 1004 1988, pp.1-12.

[7] R.W. Landgraf, Prof., Virginia Tech., Personal Communication.