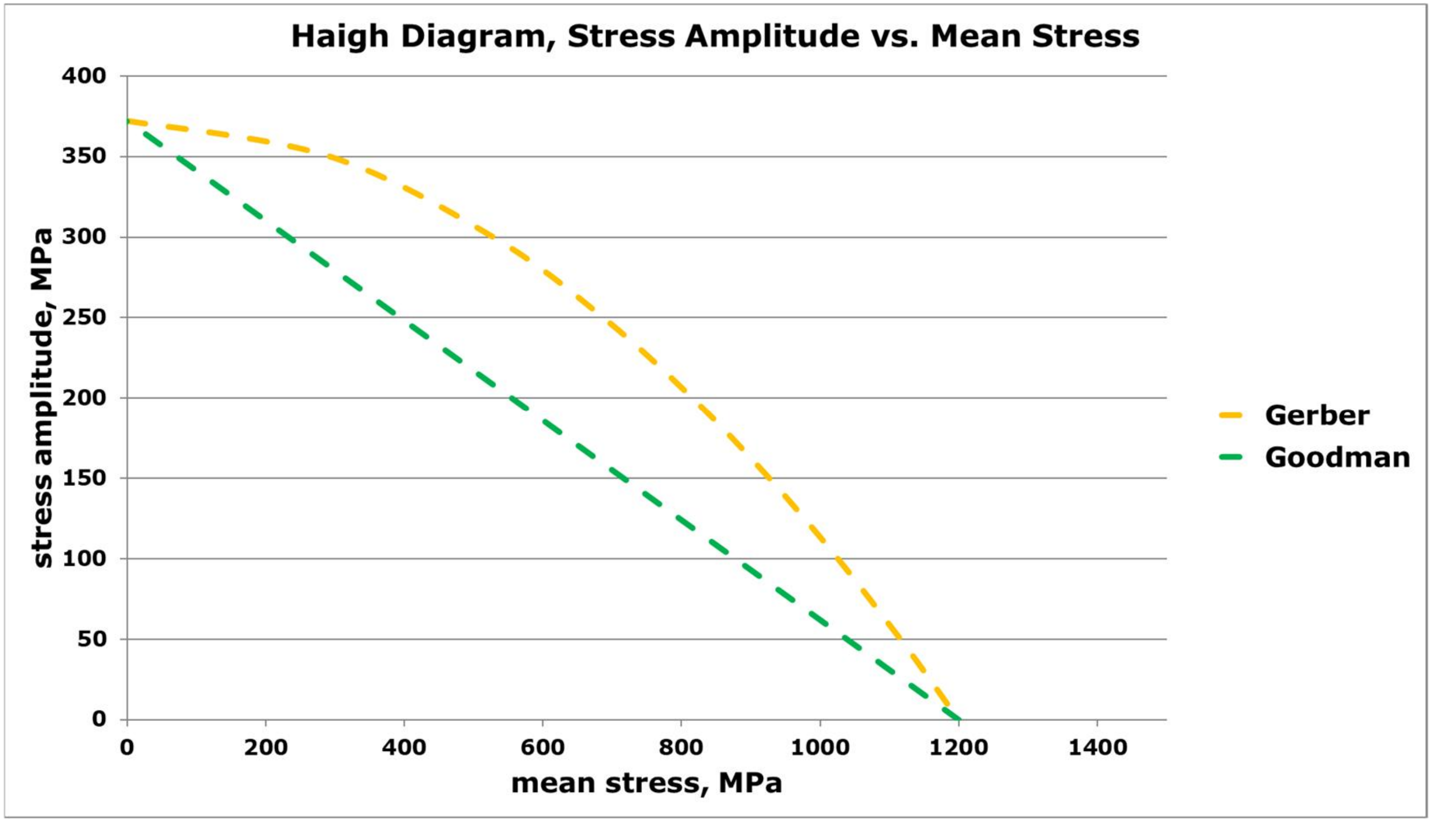
The Influence of Monotonic Damage on Fatigue at High Stress Ratios

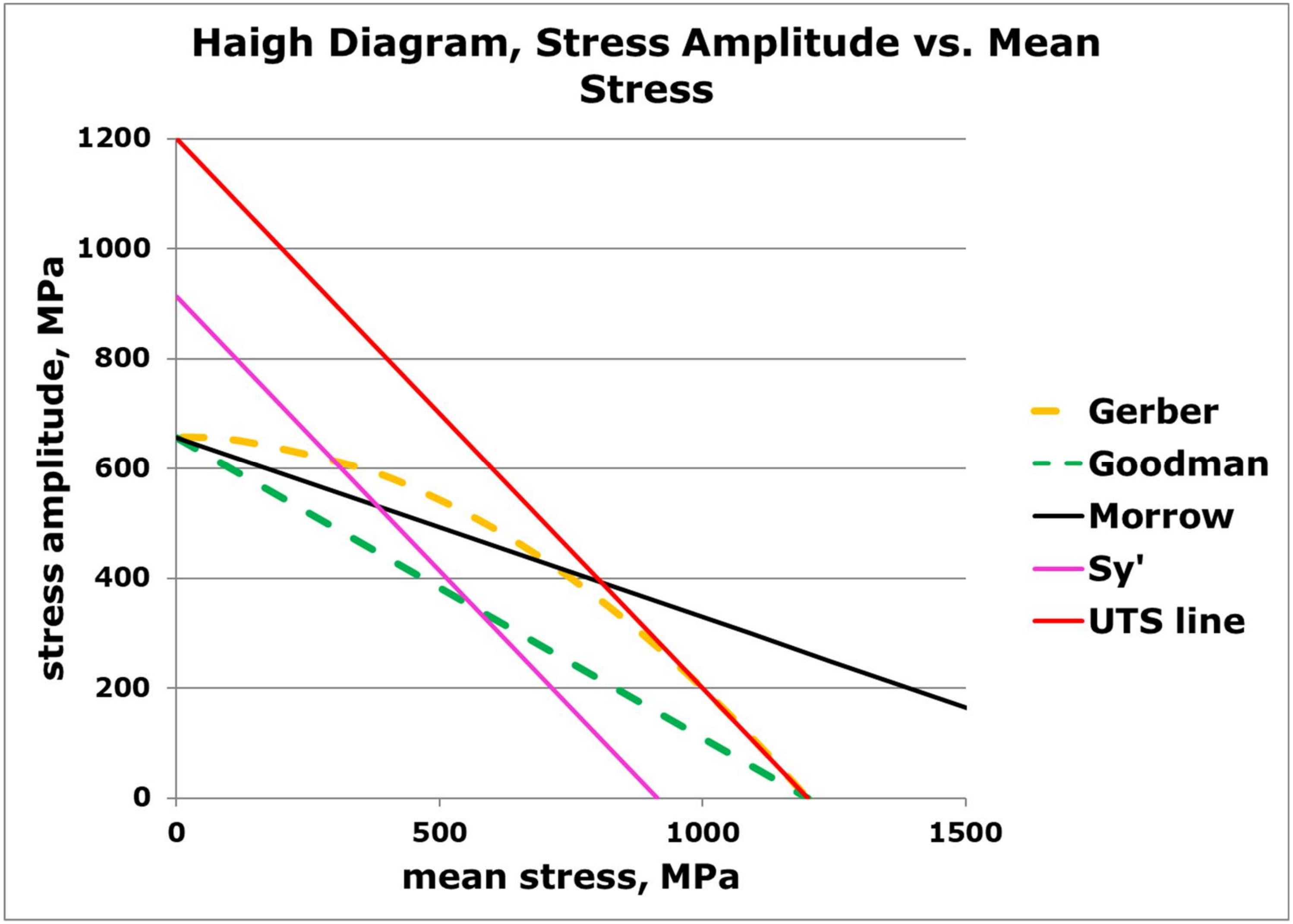
Peter Huffman

John Deere



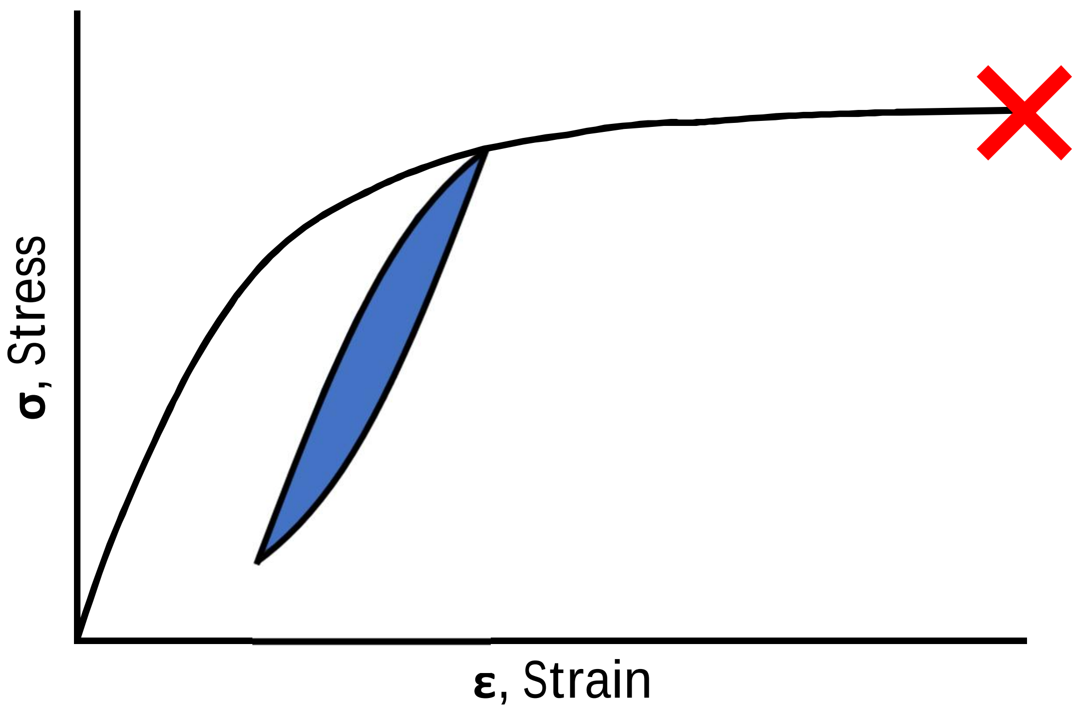
$$\sigma_a = \sigma_e \left[1 - \left(\frac{\sigma_m}{\sigma_{UTS}} \right)^2 \right]$$

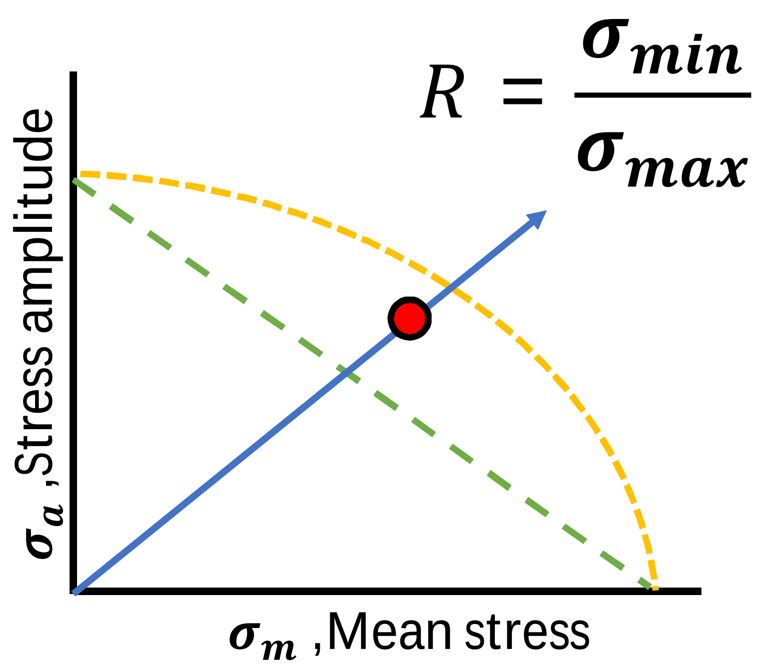
$$\sigma_a = \sigma_e \left[1 - \frac{\sigma_m}{\sigma_{UTS}} \right]$$



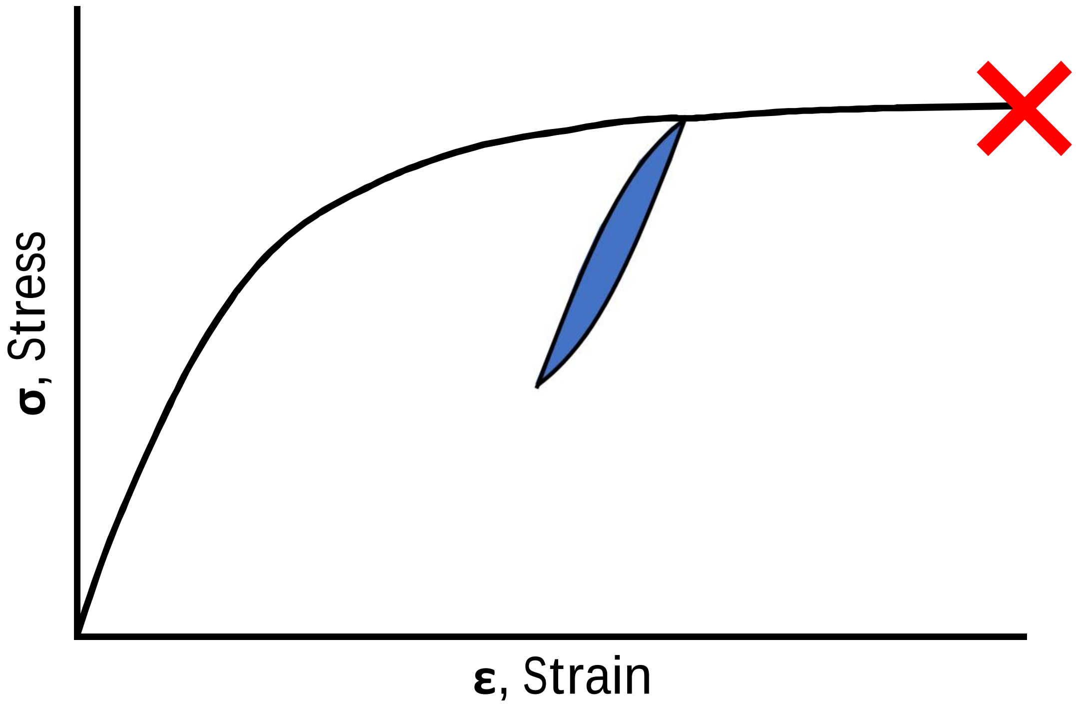
Haigh Diagram, Stress Amplitude vs. Mean Stress
stress amplitude, MPa
1200
1000
800
600
400
200
0
0
500
1000
1500
mean stress, MPa
Gerber
Goodman
Morrow
Sy'
UTS line

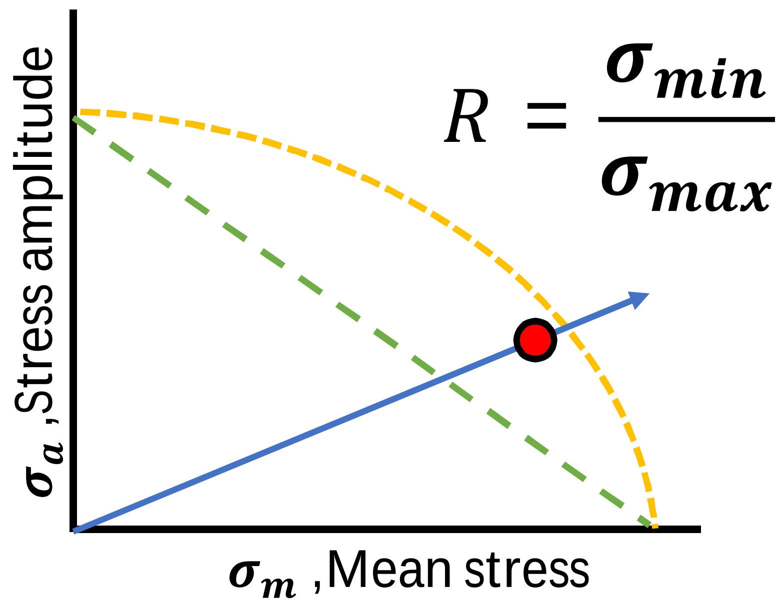
For some particular life…





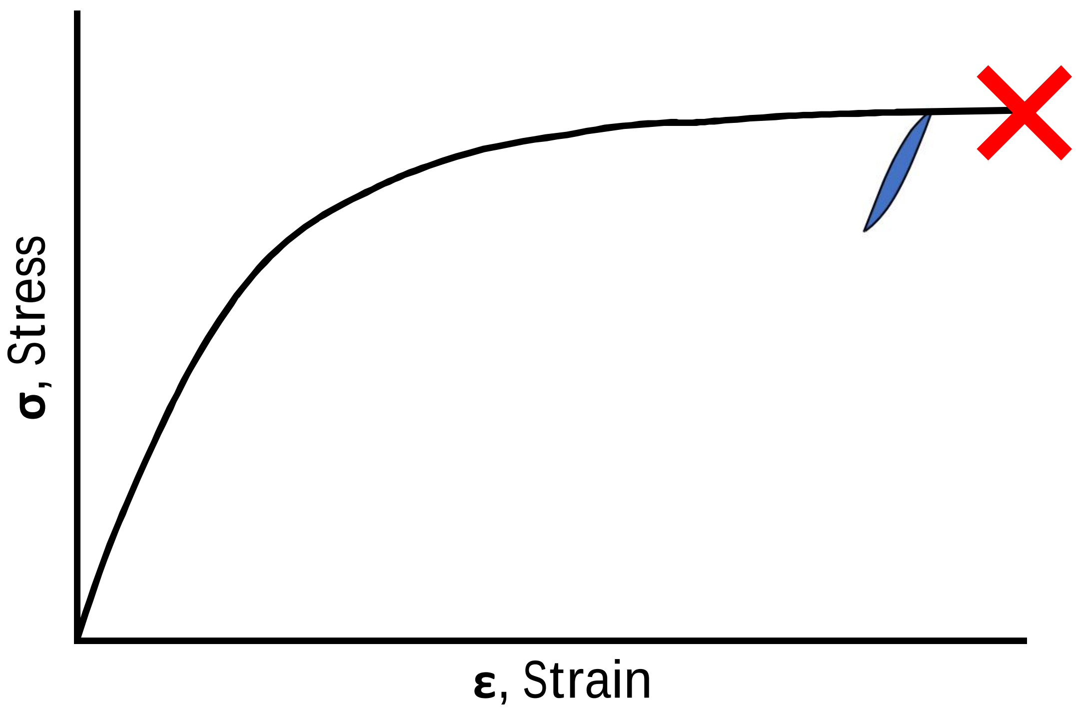
For some particular life…

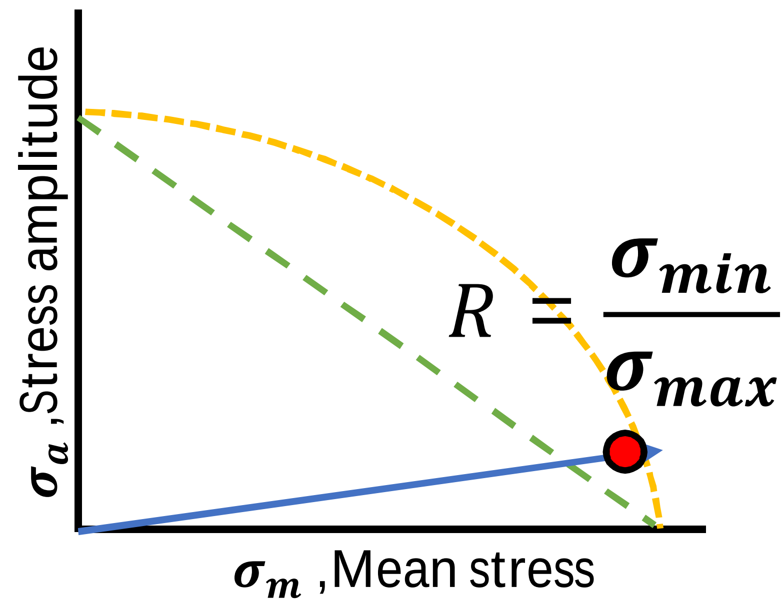




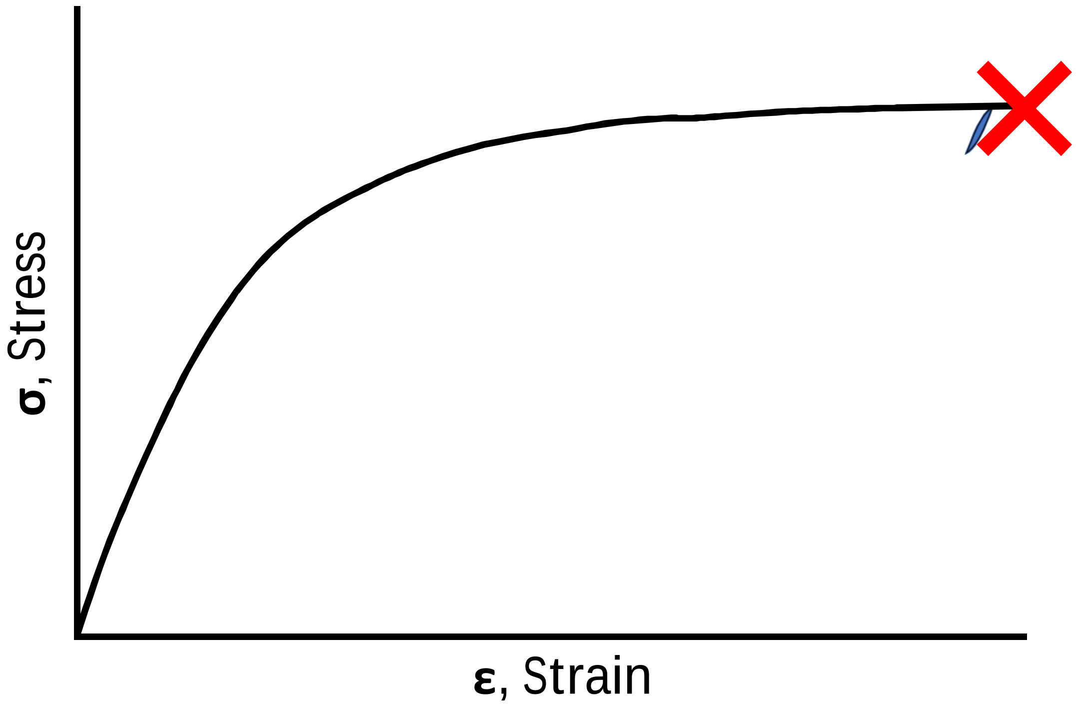
$$R = \frac{\sigma_{min}}{\sigma_{max}}$$

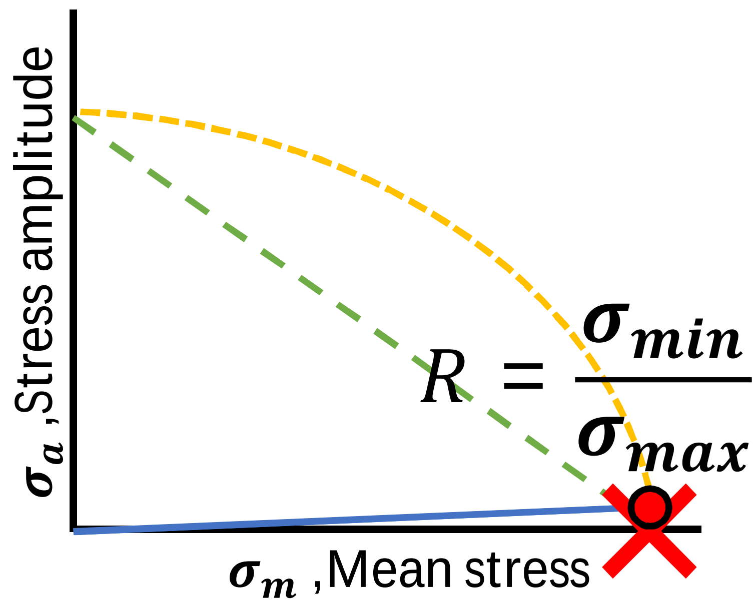
For some particular life…

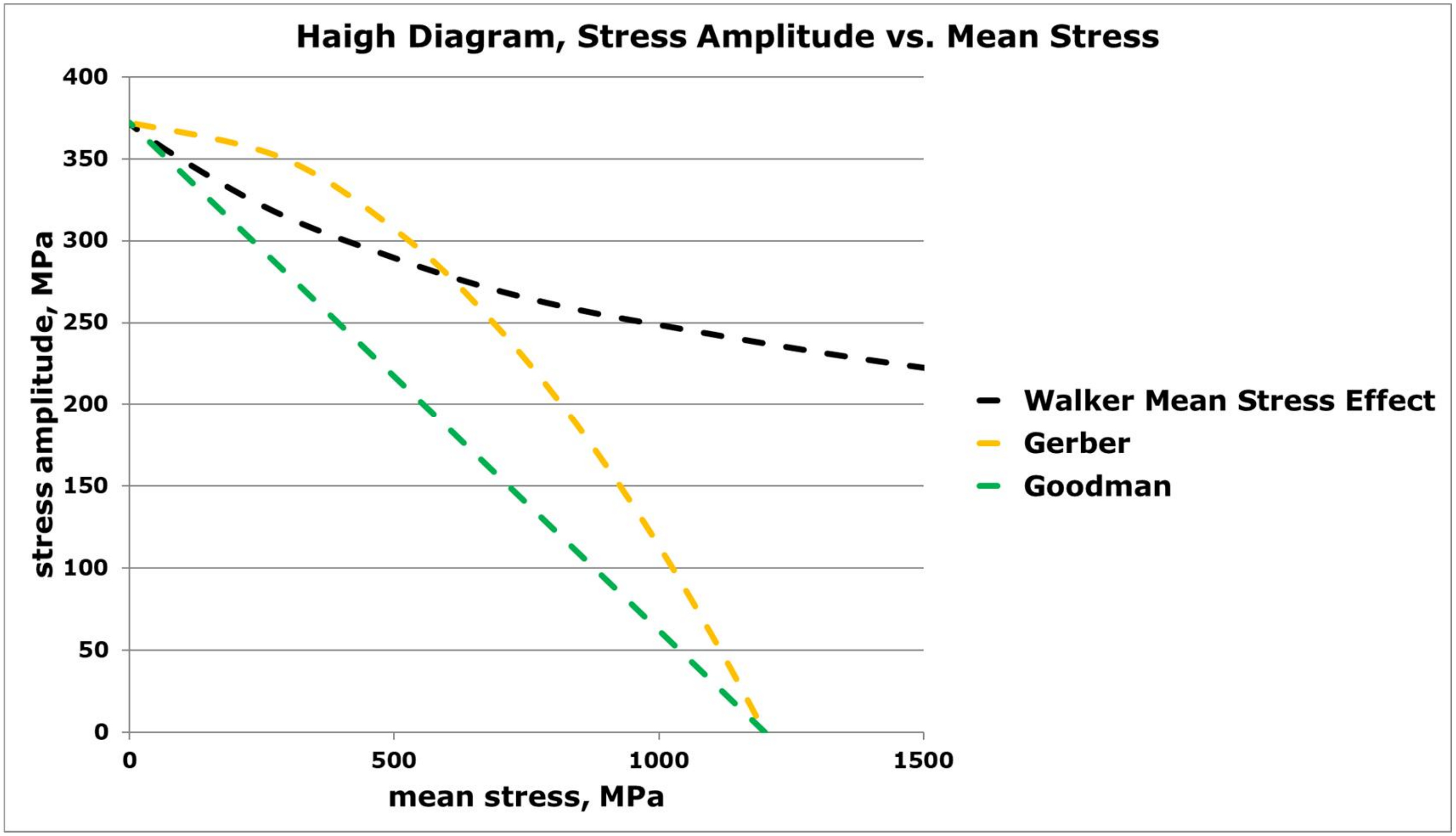




For some particular life…







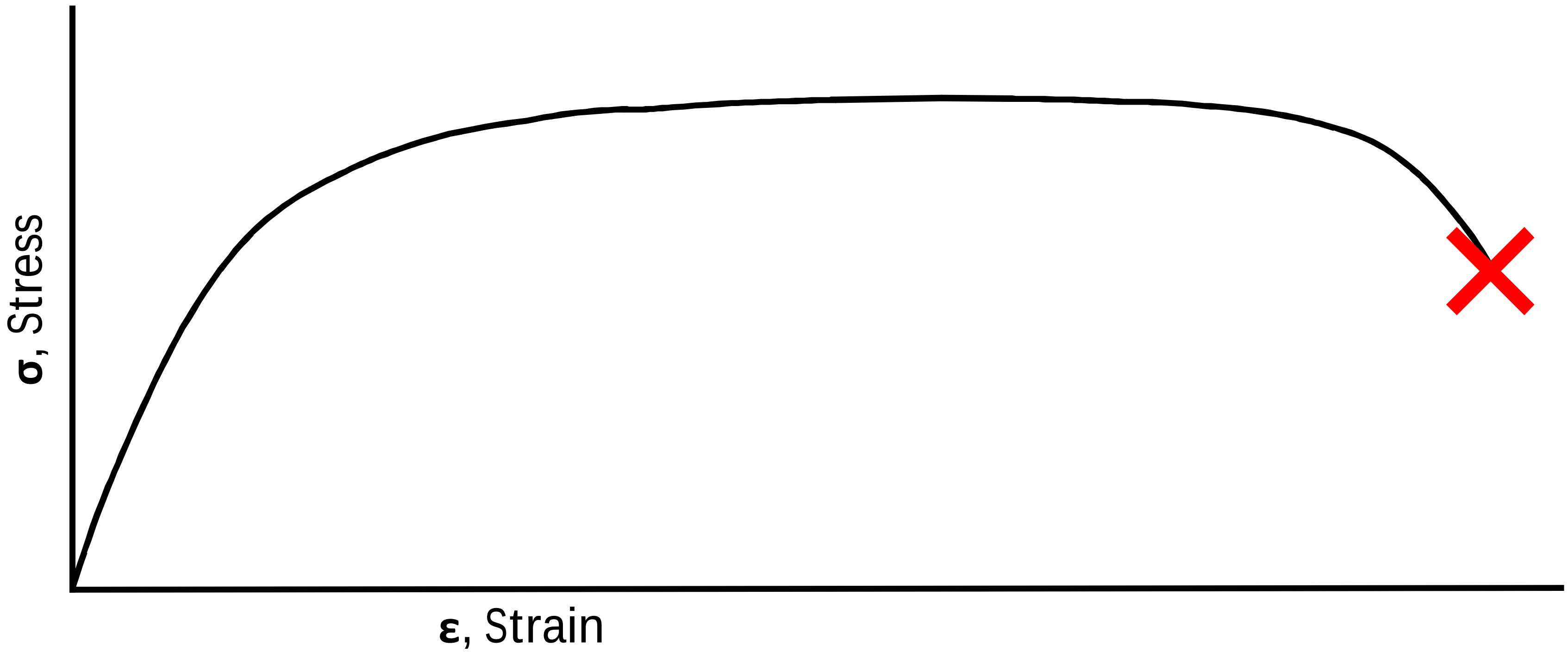
$$\sigma_a = \sigma_e \left[1 - \left(\frac{\sigma_m}{\sigma_{UTS}} \right)^2 \right]$$

$$\sigma_a = \sigma_e \left[1 - \frac{\sigma_m}{\sigma_{UTS}} \right]$$

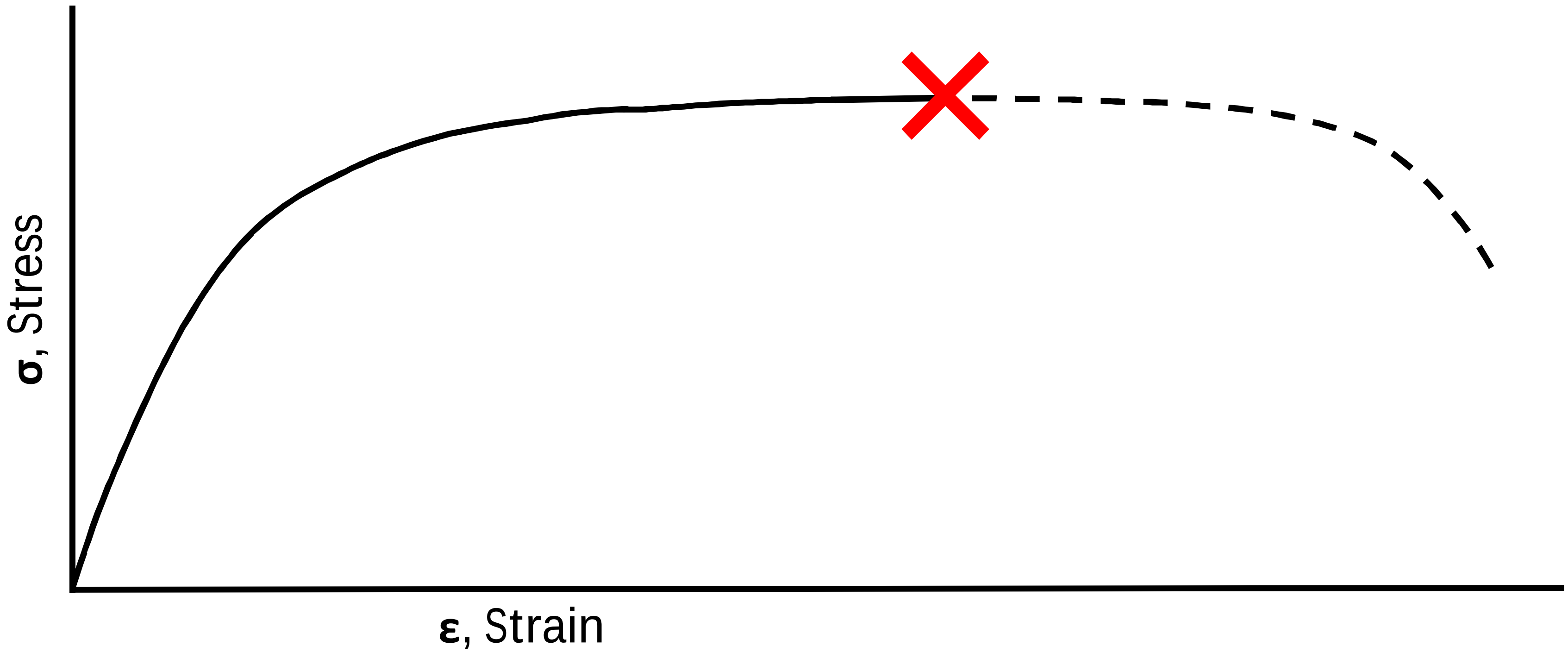
$$\sigma_{ar} = \sigma_{max}^{(1-\gamma)} \sigma_a^{\gamma}$$

(SWT)

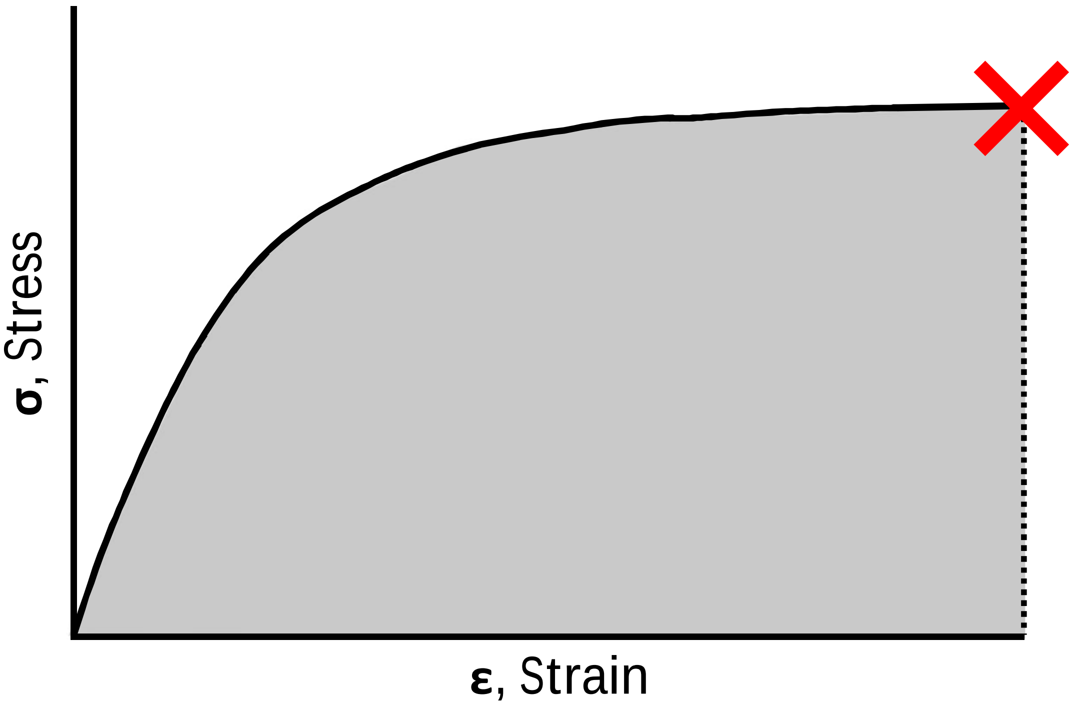
Actual overload failure



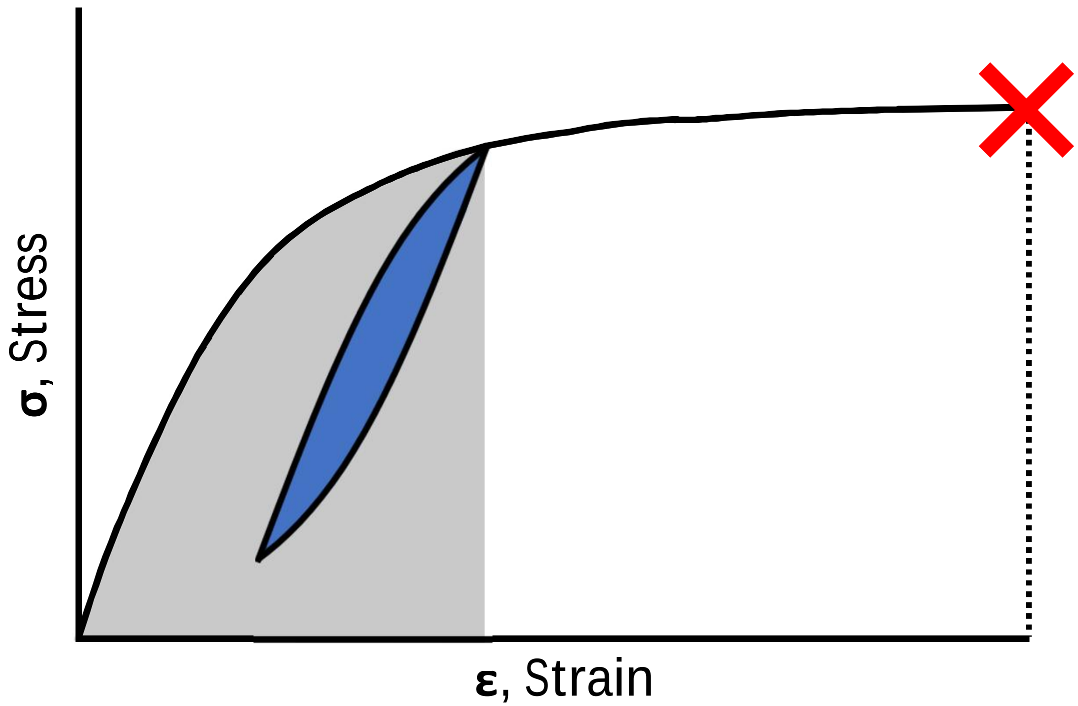
Practical overload failure



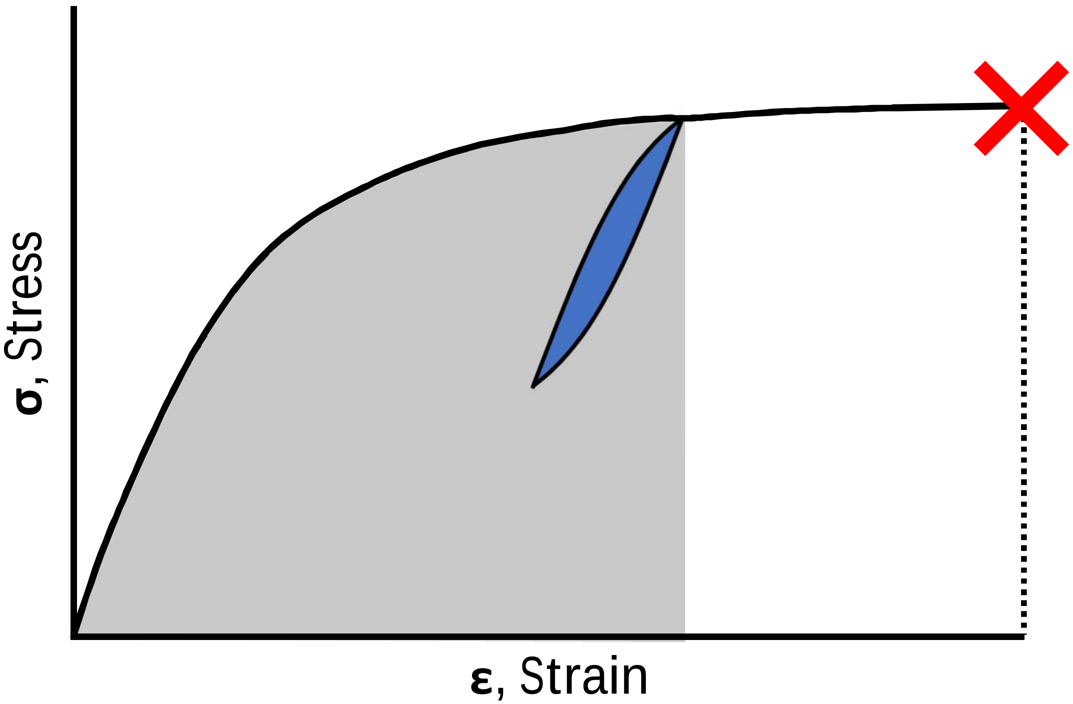
Strain energy related damage



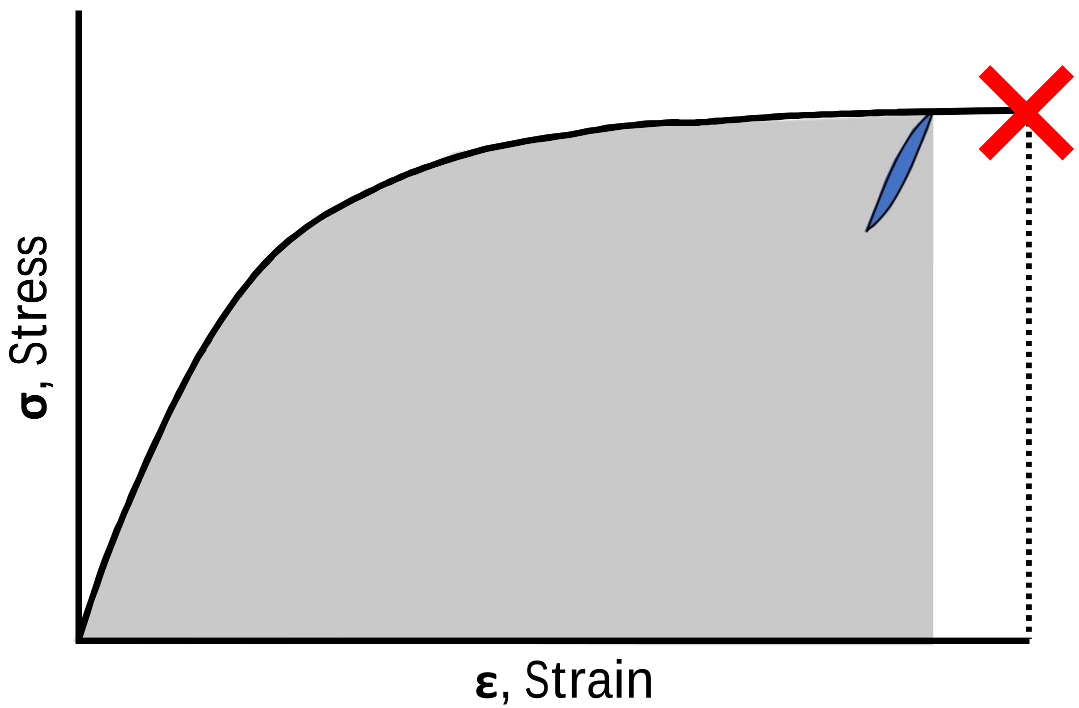
Only some of the damage is “left” for cycles



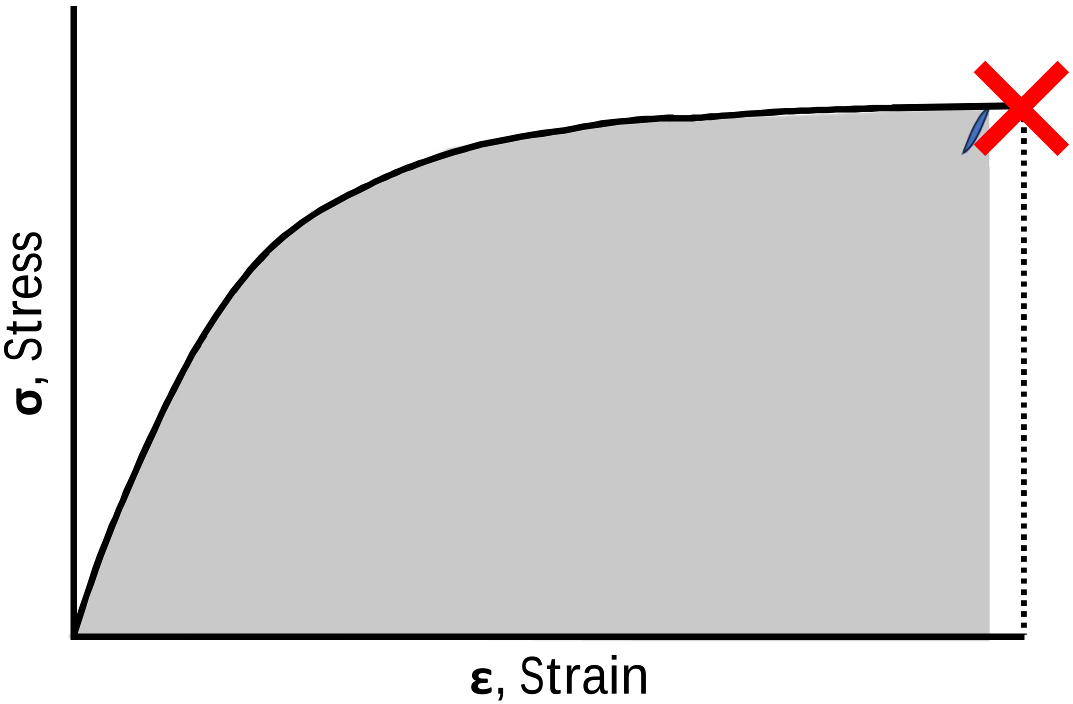
Only some of the damage is “left” for cycles



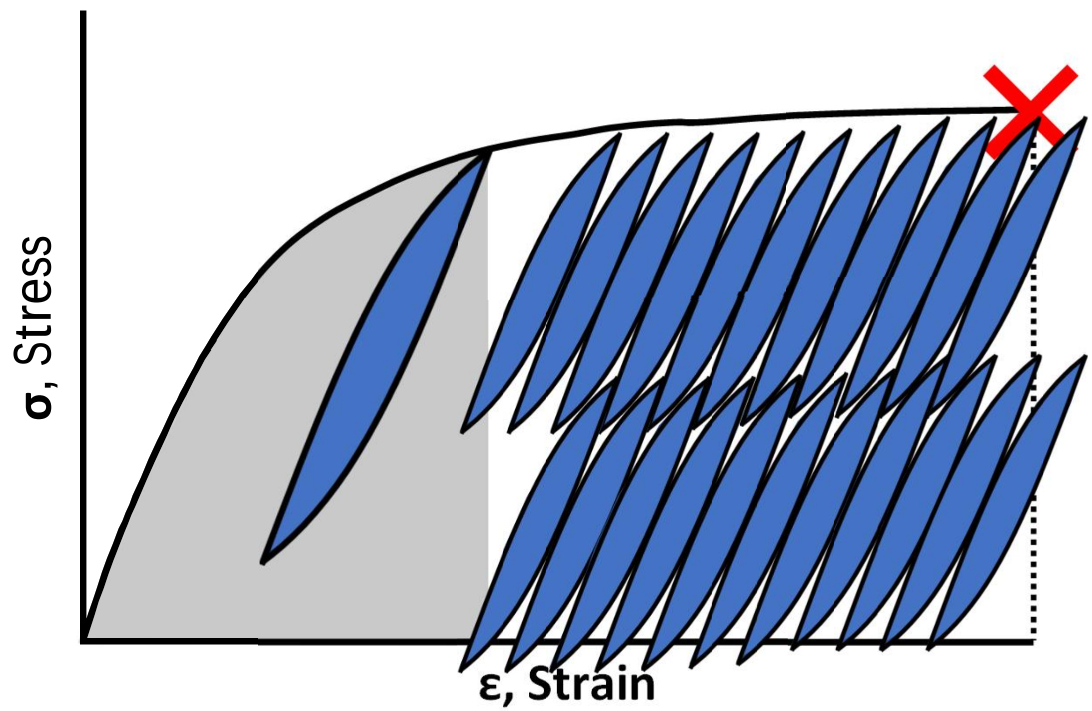
Only some of the damage is “left” for cycles



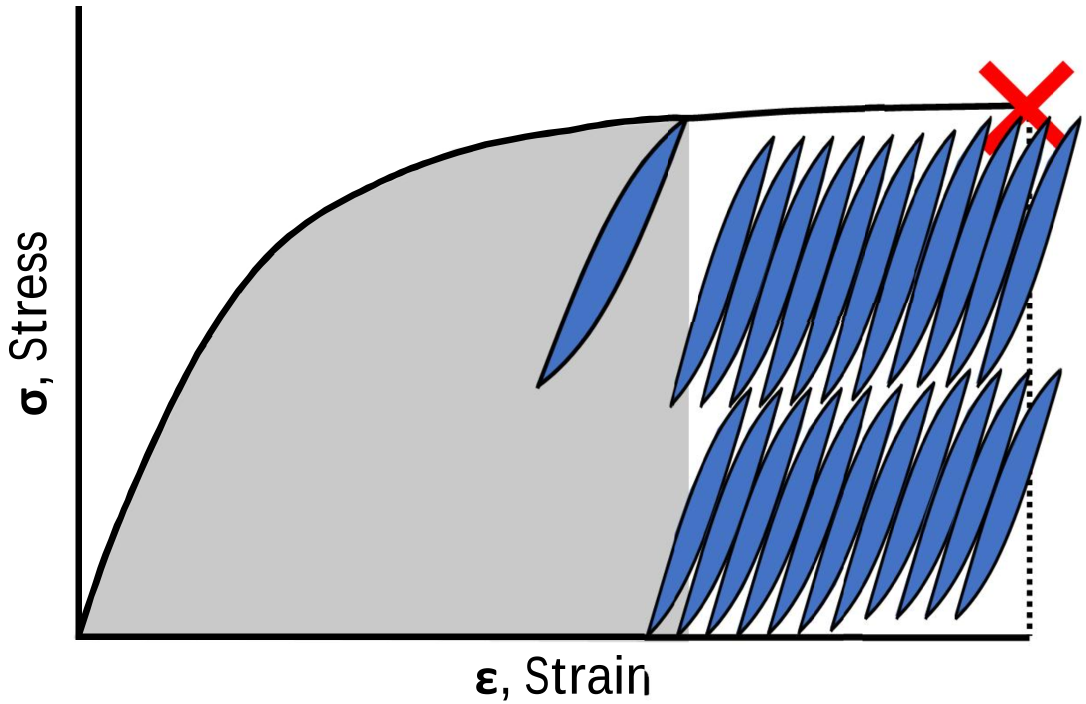
Only some of the damage is “left” for cycles



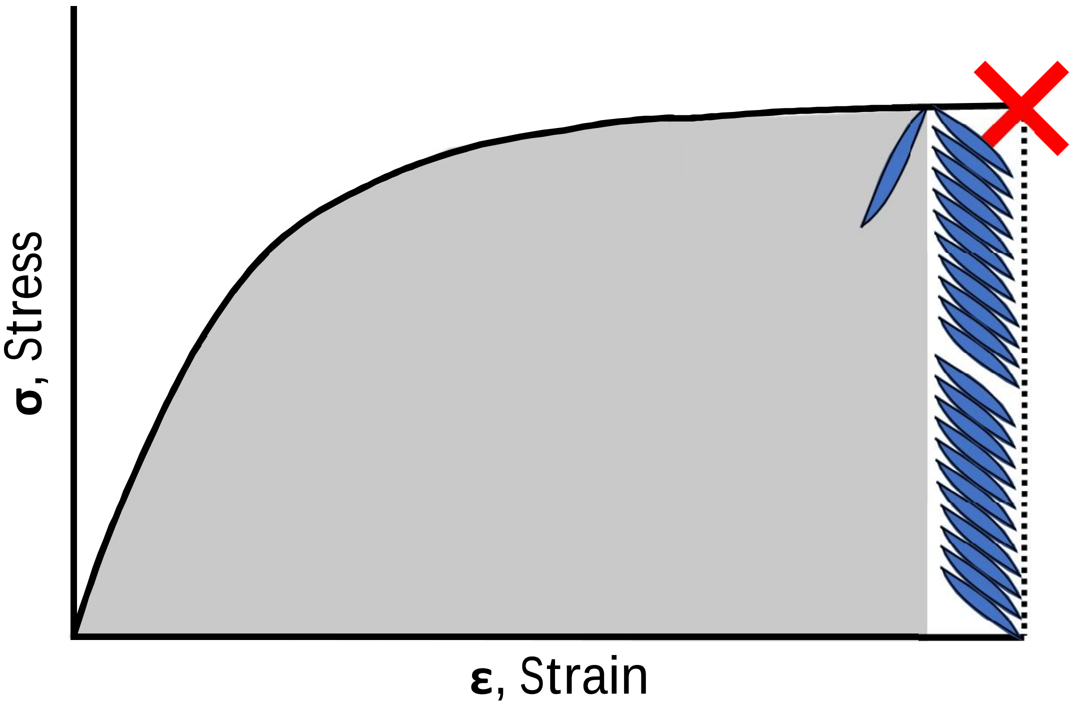
For some particular life goal,



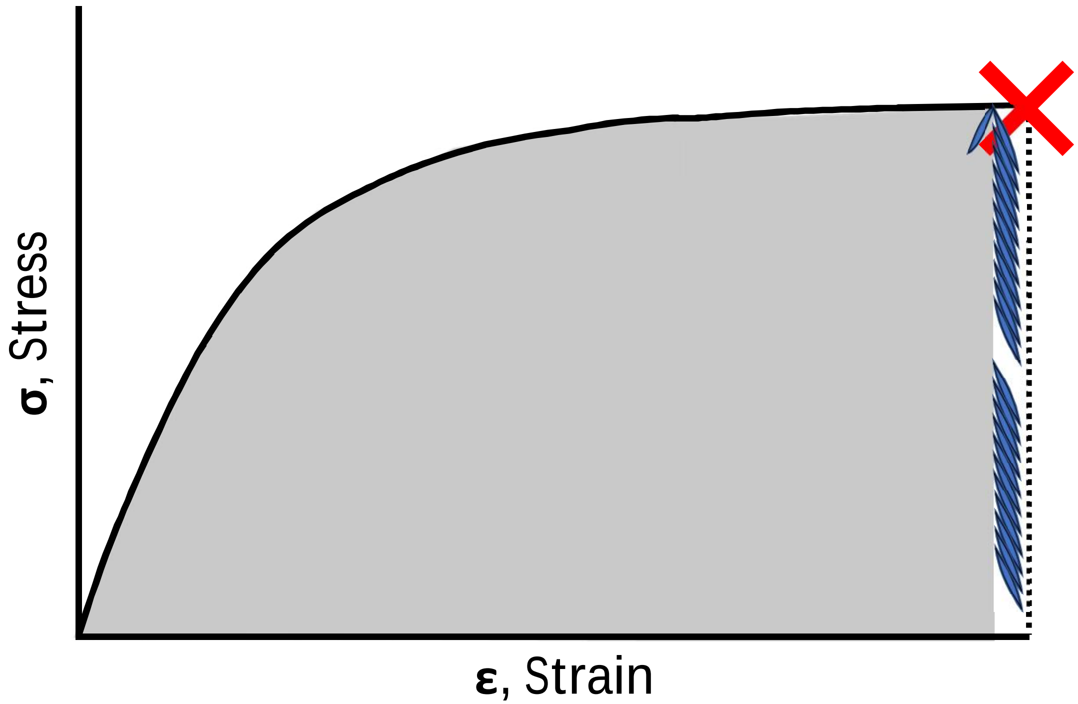
For some particular life goal,



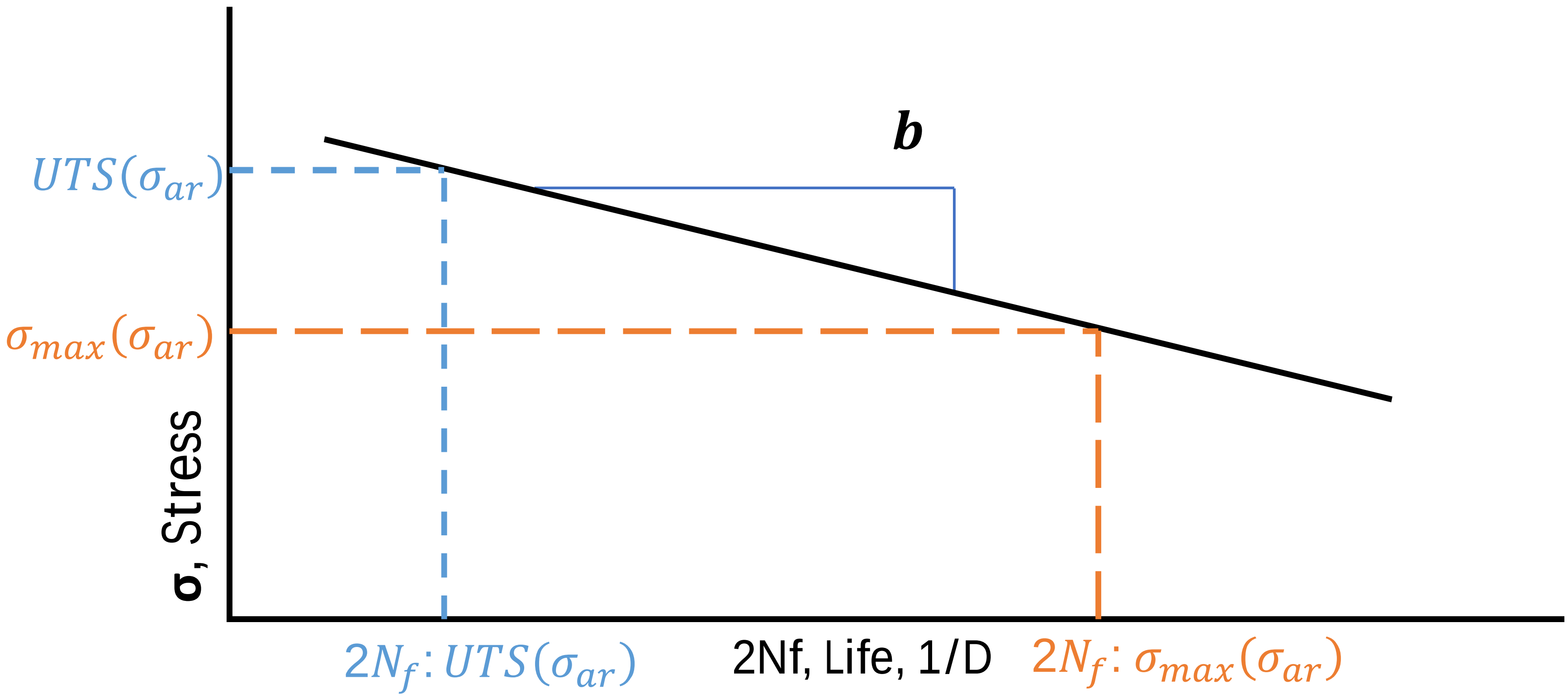
For some particular life goal,



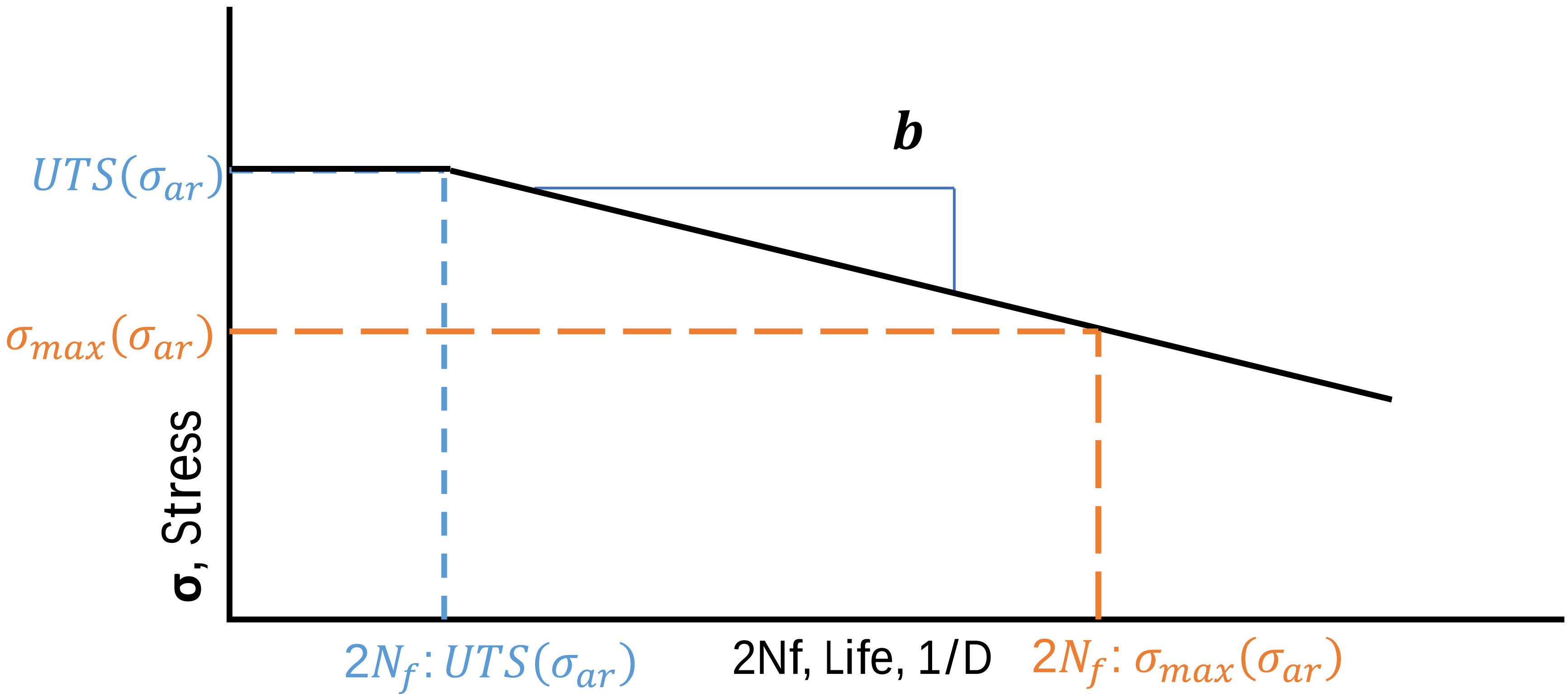
For some particular life goal,

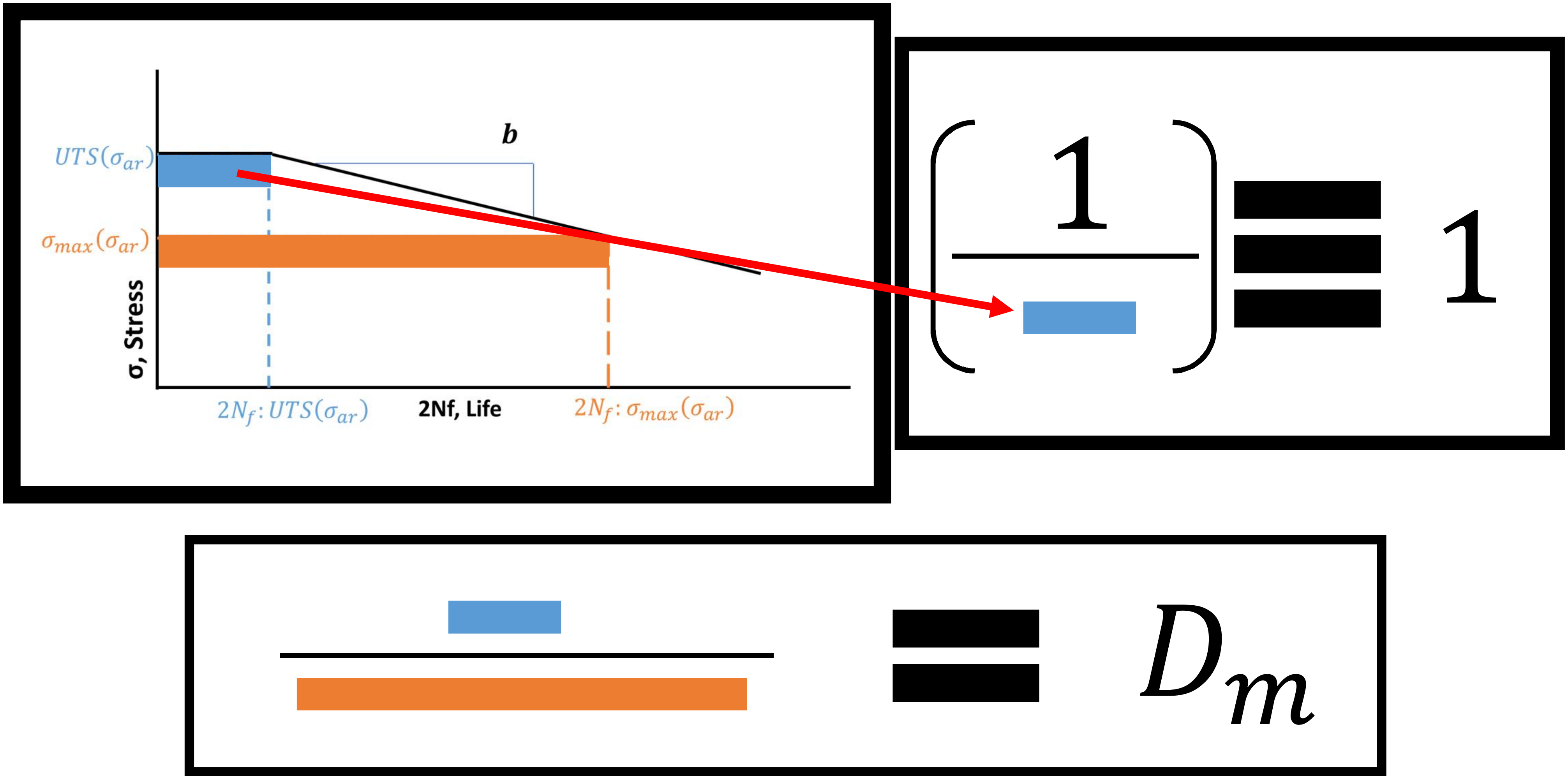


Calculating monotonic damage

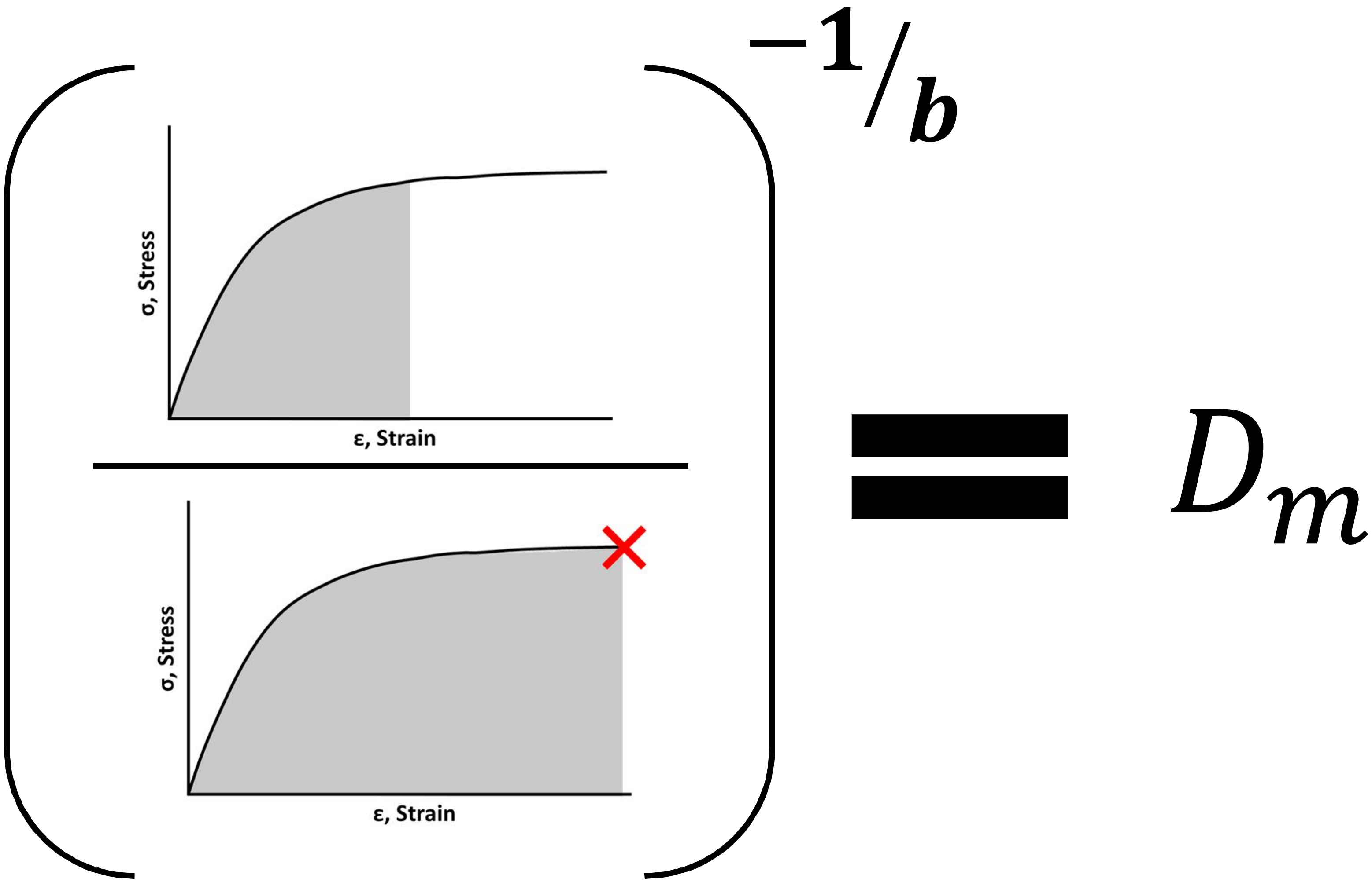


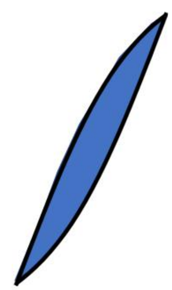
Set UTS to a damage of 1

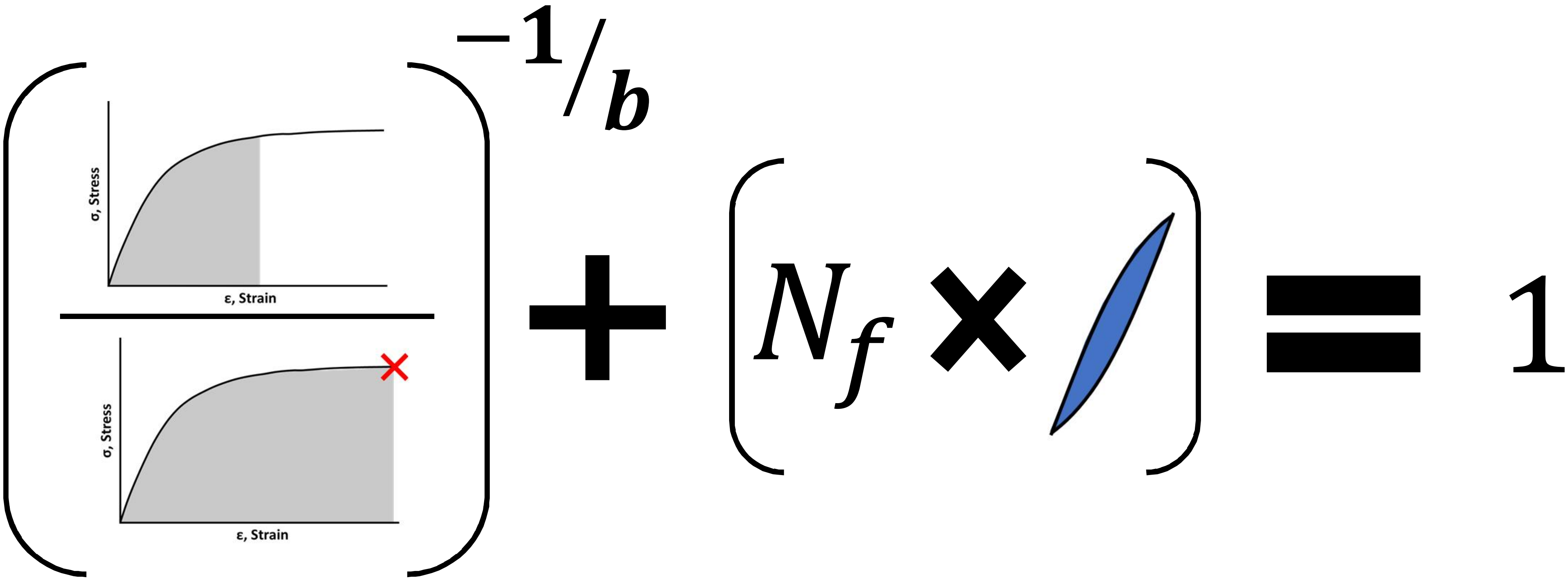


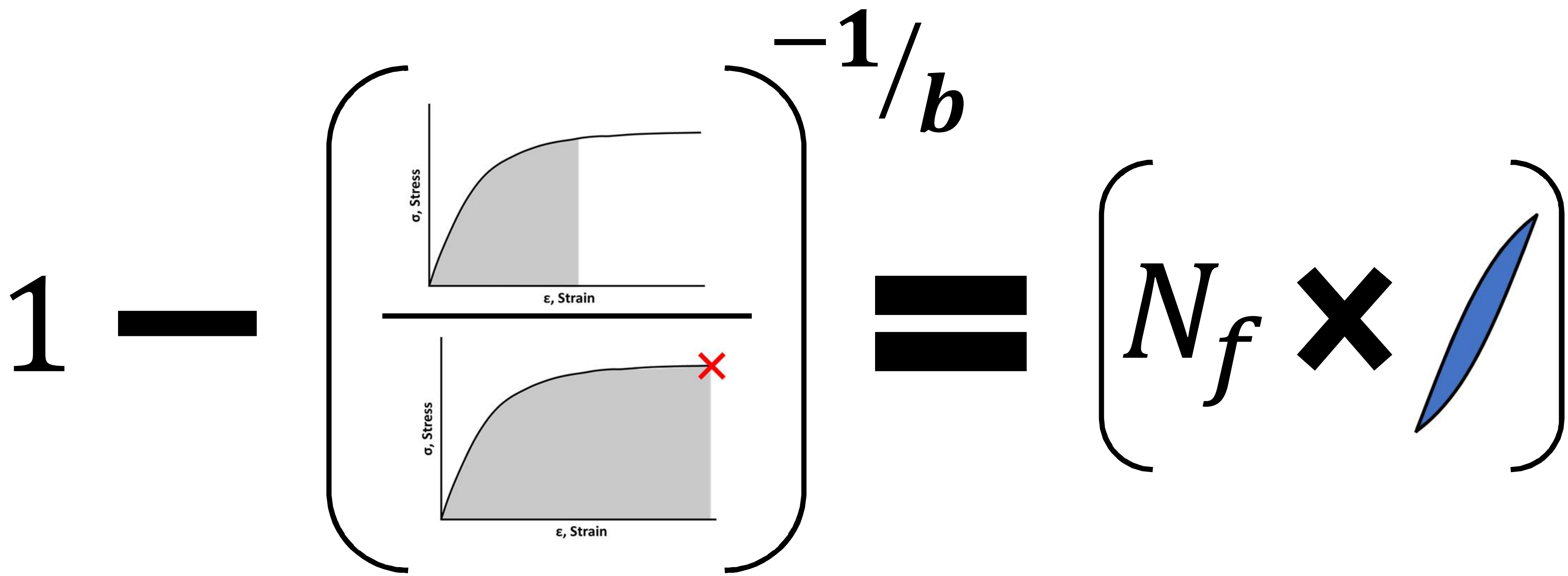


$UTS(\sigma_{ar})$
$\sigma_{max}(\sigma_{ar})$
b
σ, Stress
$2N_f: UTS(\sigma_{ar})$
2Nf, Life
$2N_f: \sigma_{max}(\sigma_{ar})$
1
1
D_m

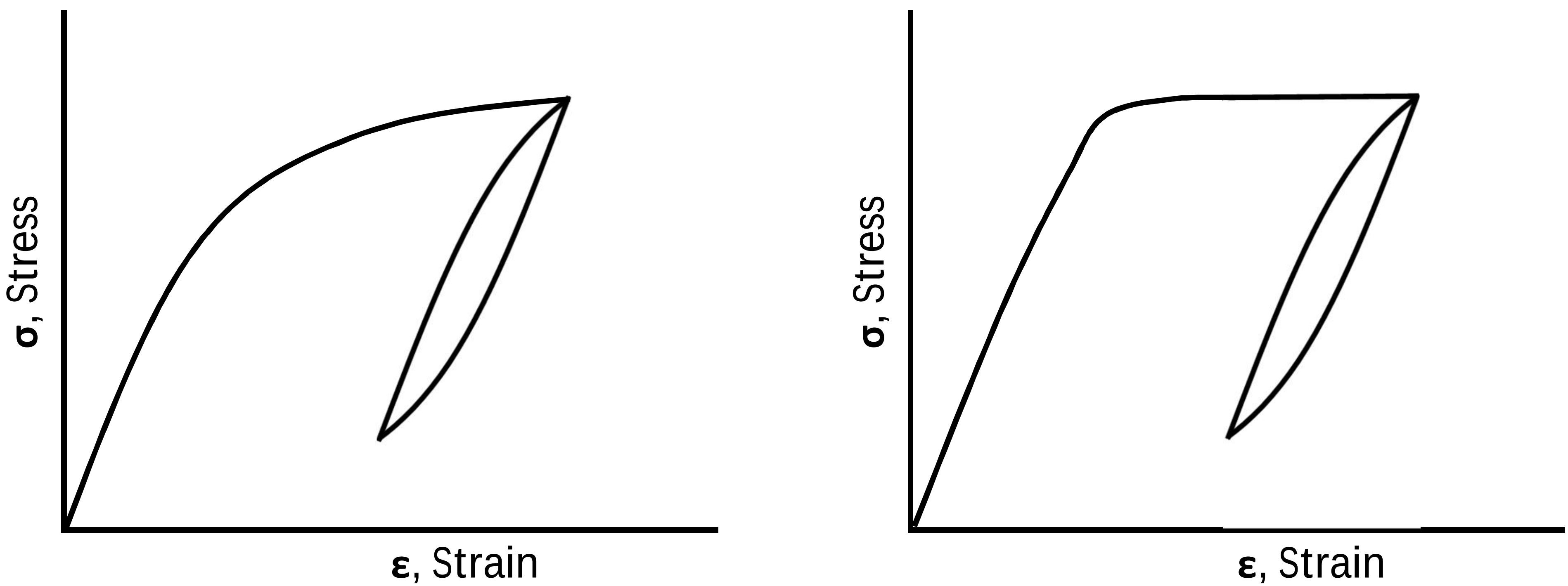

σ, Stress
ε, Strain
σ, Stress
ε, Strain
$-1/b$
$= D_m$

$$\left(N_f \times \right.$$  $$\left. \right) \neq 1$$

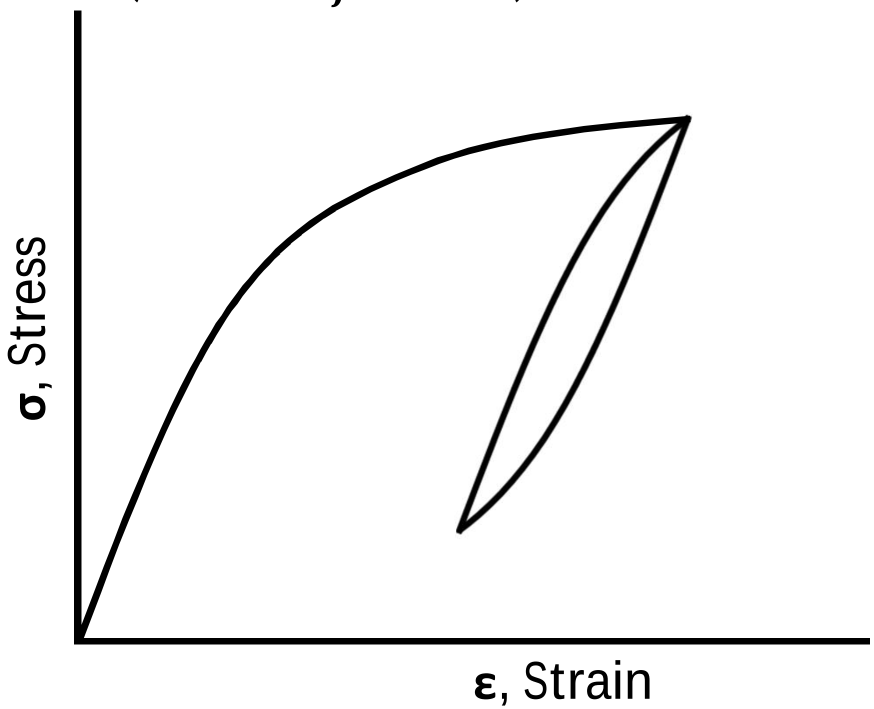

−1/b
σ, Stress
ε, Strain
σ, Stress
ε, Strain
+
N_f ×
= 1

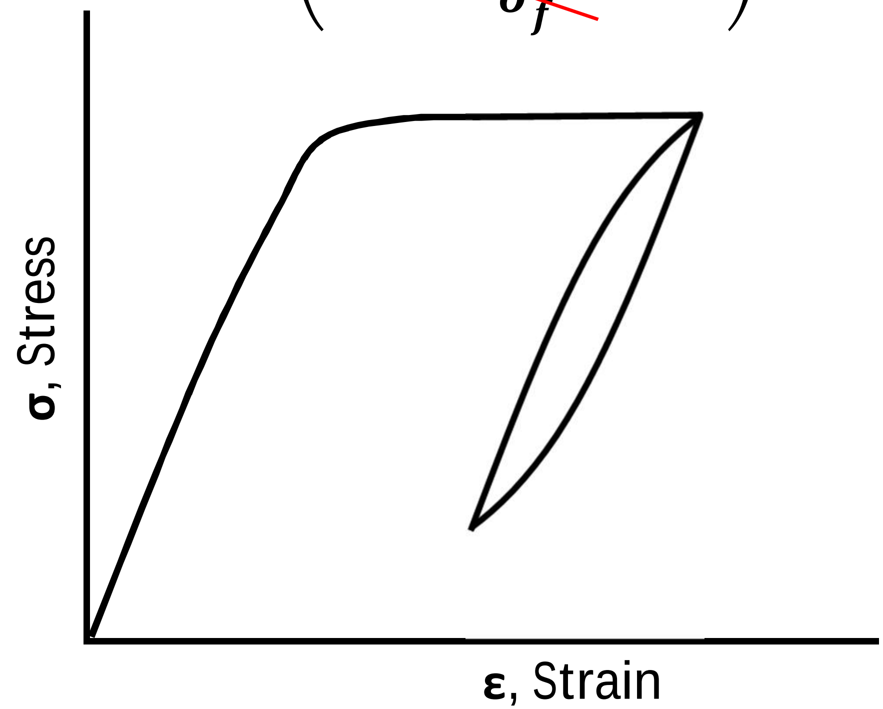

1 −
σ, Stress
ε, Strain
σ, Stress
ε, Strain
−1/b
=
N_f ×

Cyclic vs monotonic σ-ε

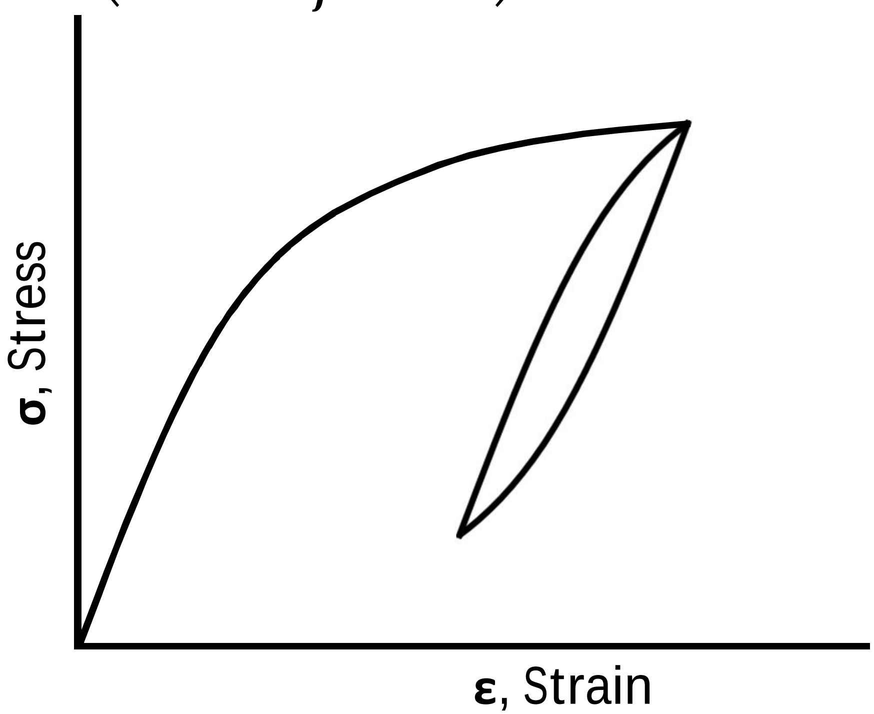


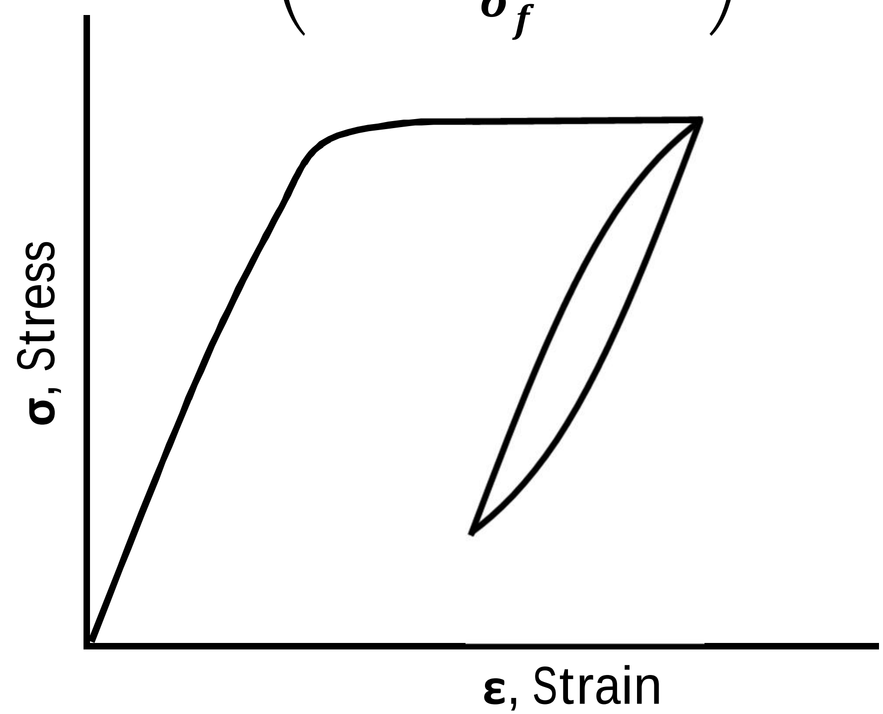
$$\frac{\left(\frac{\sigma_{max}^{(1-\gamma_c)}\left(\frac{\sigma_{max}}{2}\right)^{\gamma_c}}{\sigma_f'}\right)^{-1/b}}{\left(\frac{\sigma_{UTS}^{(1-\gamma_c)}\left(\frac{\sigma_{UTS}}{2}\right)^{\gamma_c}}{\sigma_f'}\right)^{-1/b}} = \left(\frac{\sigma_{max}}{\sigma_{UTS}}\right)^{-1/b} = \frac{\left(\frac{\sigma_{max}^{(1-\gamma_m)}\left(\frac{\sigma_{max}}{2}\right)^{\gamma_m}}{\sigma_f'}\right)^{-1/b}}{\left(\frac{\sigma_{UTS}^{(1-\gamma_m)}\left(\frac{\sigma_{UTS}}{2}\right)^{\gamma_m}}{\sigma_f'}\right)^{-1/b}}$$

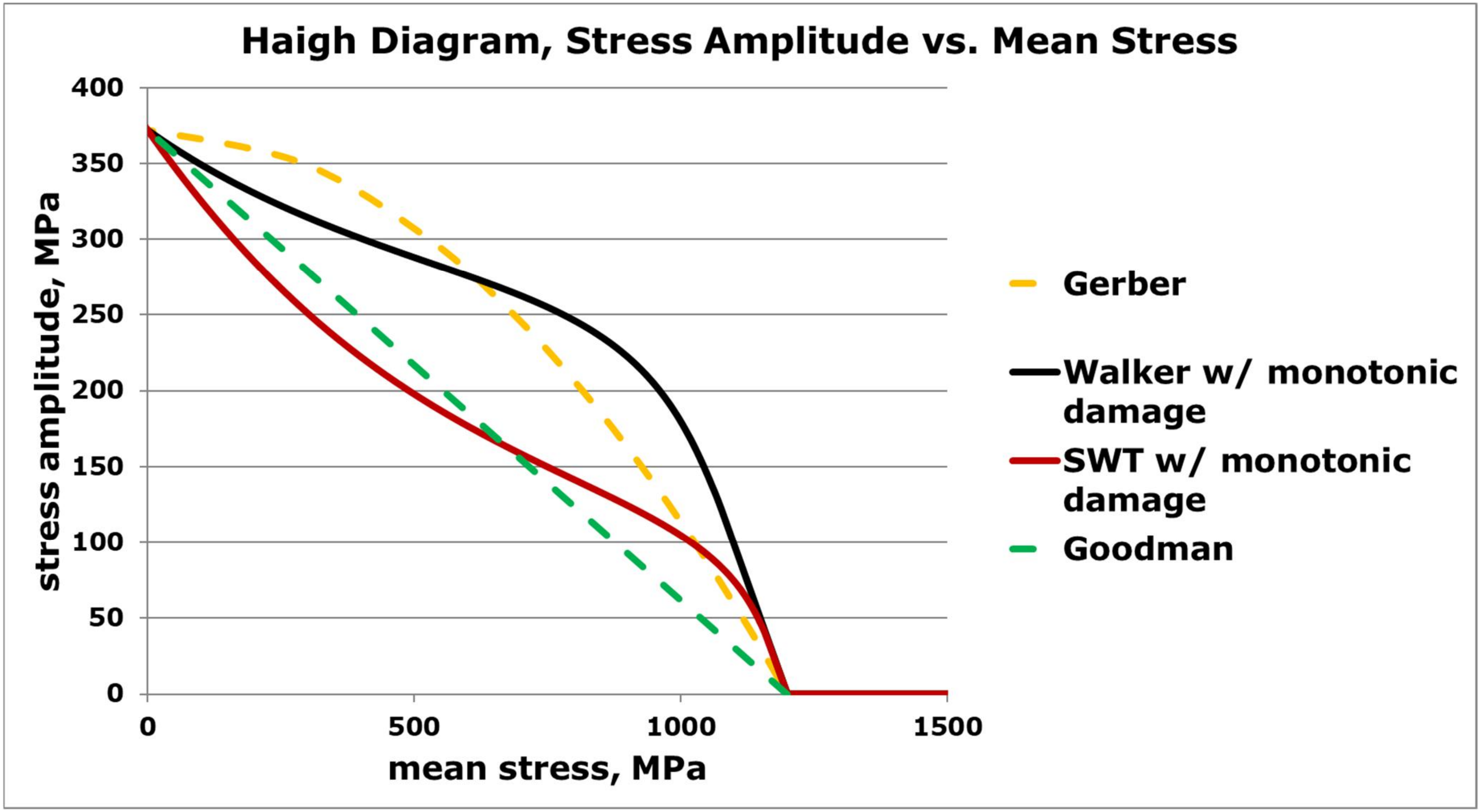


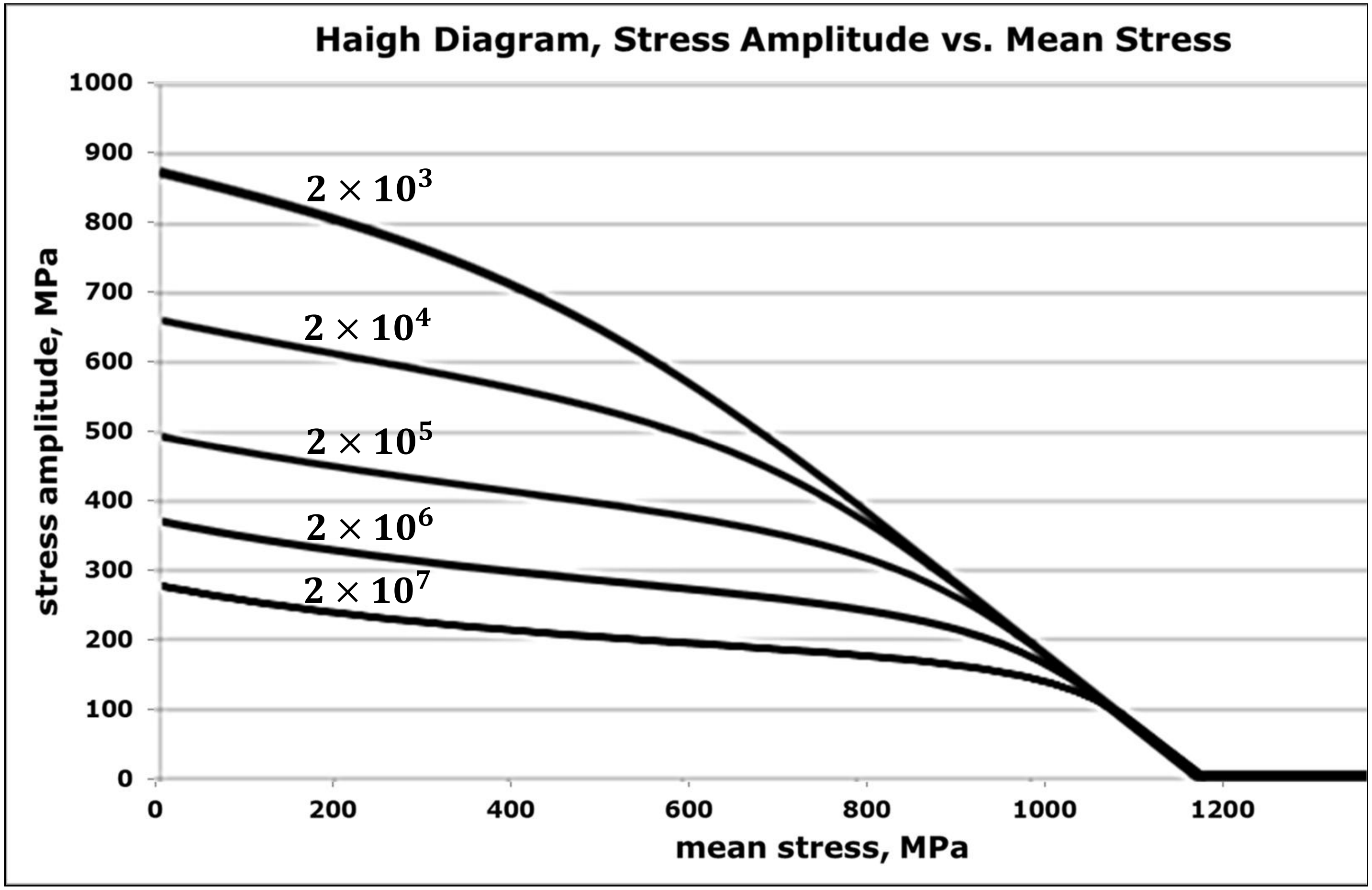


$$\frac{\left(\frac{\sigma_{max}^{(1-\gamma_c)}\left(\frac{\sigma_{max}}{2}\right)^{\gamma_c}}{\sigma'_f}\right)^{1/b}}{\left(\frac{\sigma_{UTS}^{(1-\gamma_c)}\left(\frac{\sigma_{UTS}}{2}\right)^{\gamma_c}}{\sigma'_f}\right)^{1/b}} \neq \left(\frac{\sigma_{ar,max}}{\sigma_{ar,UTS}}\right)^{-1/b_{mono}} = \frac{\left(\frac{\sigma_{max}^{(1-\gamma_m)}\left(\frac{\sigma_{max}}{2}\right)^{\gamma_m}}{\sigma'_f}\right)^{-1/b_{mono}}}{\left(\frac{\sigma_{UTS}^{(1-\gamma_m)}\left(\frac{\sigma_{UTS}}{2}\right)^{\gamma_m}}{\sigma'_f}\right)^{-1/b_{mono}}}$$

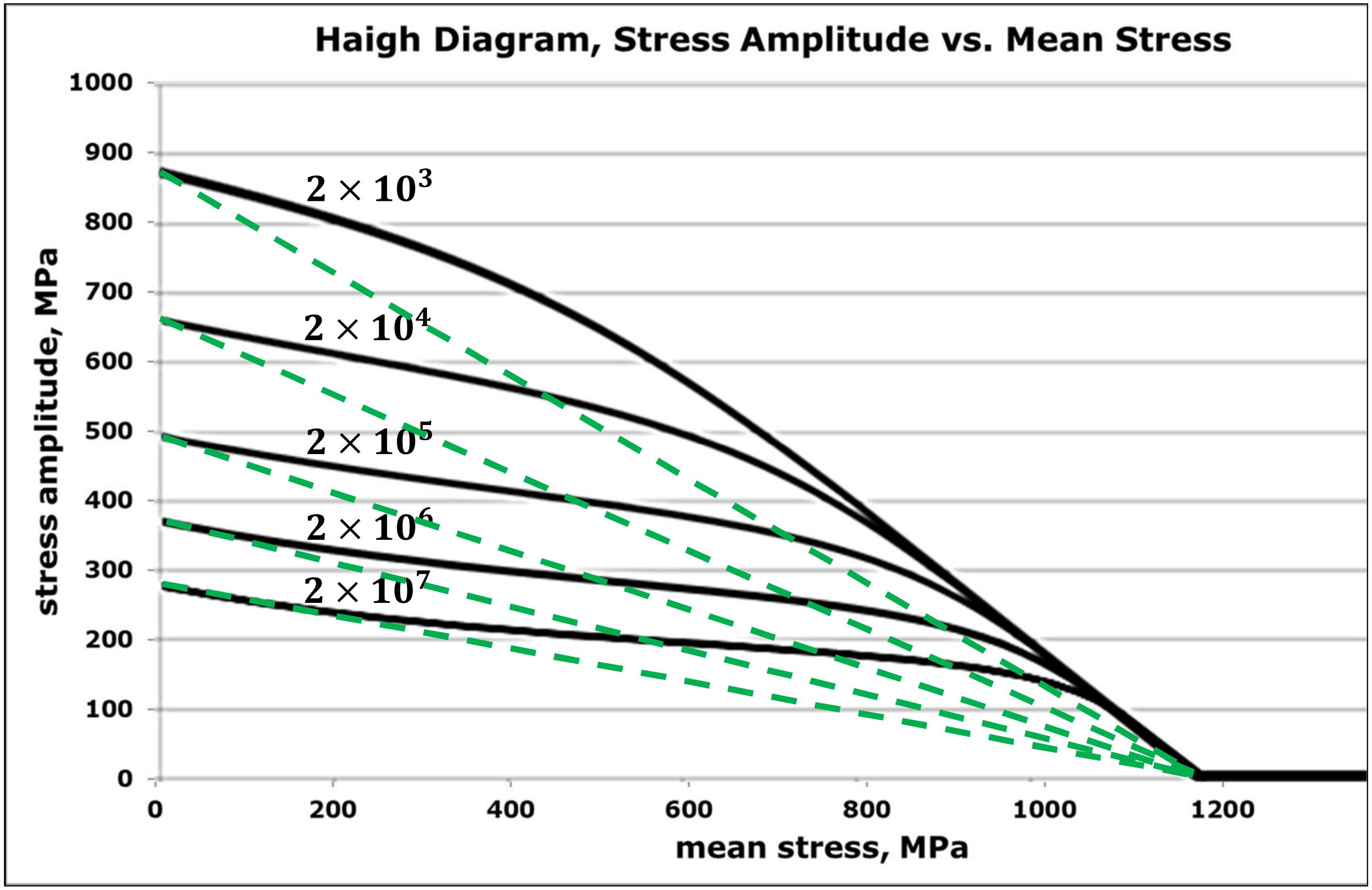




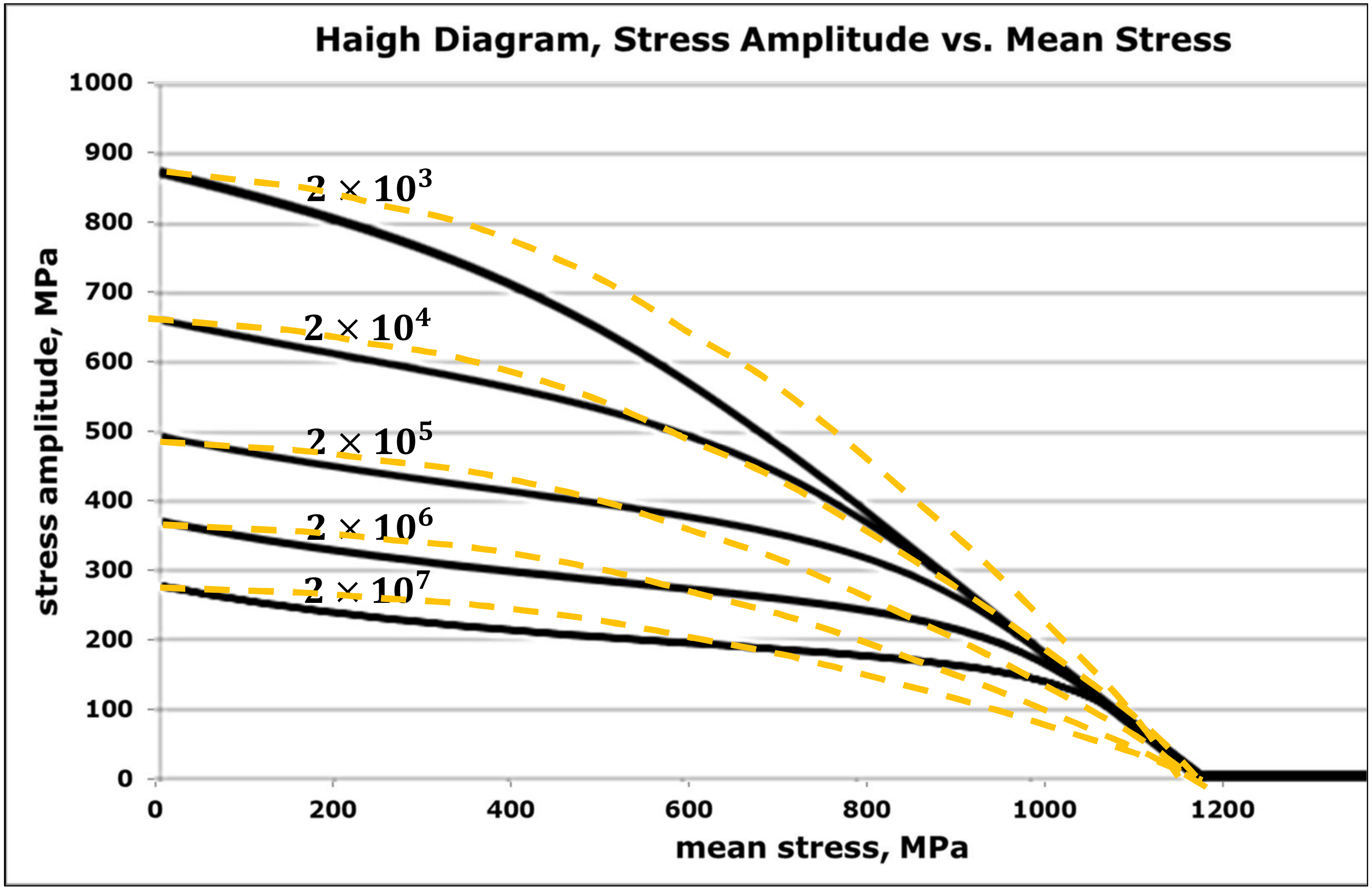

Haigh Diagram, Stress Amplitude vs. Mean Stress
stress amplitude, MPa
400
350
300
250
200
150
100
50
0
0
500
1000
1500
mean stress, MPa
Gerber
Walker w/ monotonic damage
SWT w/ monotonic damage
Goodman



Haigh Diagram, Stress Amplitude vs. Mean Stress
stress amplitude, MPa
mean stress, MPa
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
2×10^3
2×10^4
2×10^5
2×10^6
2×10^7

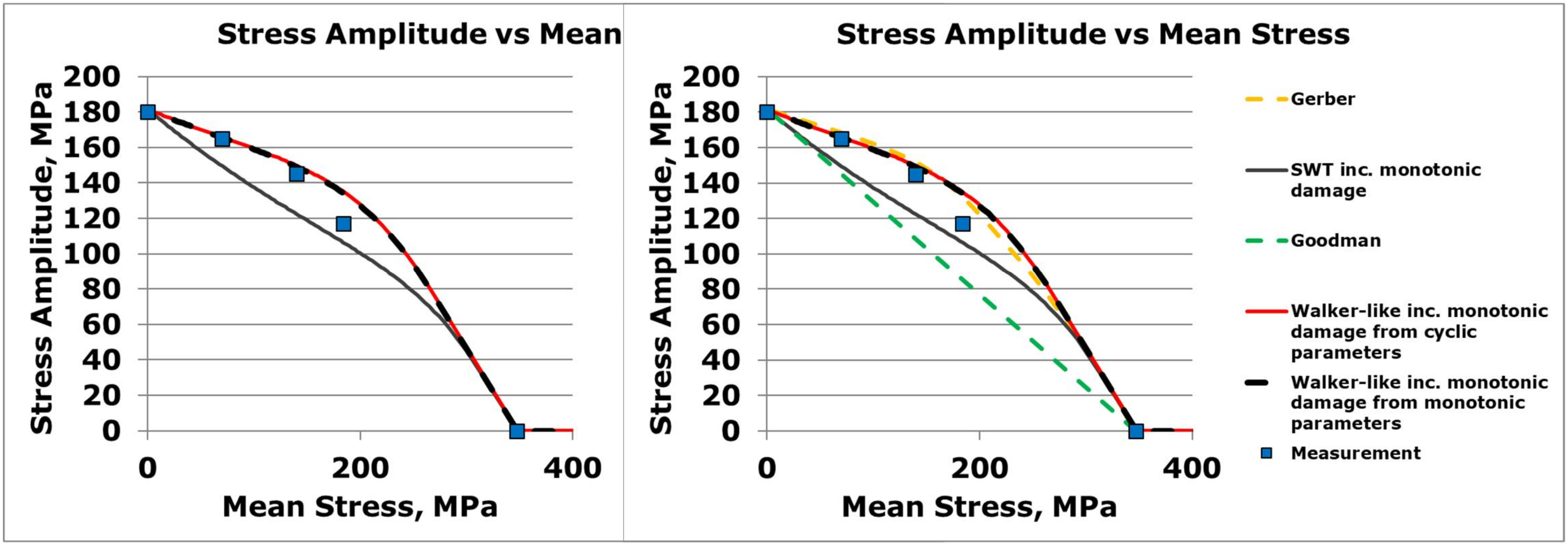


Haigh Diagram, Stress Amplitude vs. Mean Stress
1000
900
800
700
600
500
400
300
200
100
0
stress amplitude, MPa
2×10^3
2×10^4
2×10^5
2×10^6
2×10^7
0
200
400
600
800
1000
1200
mean stress, MPa



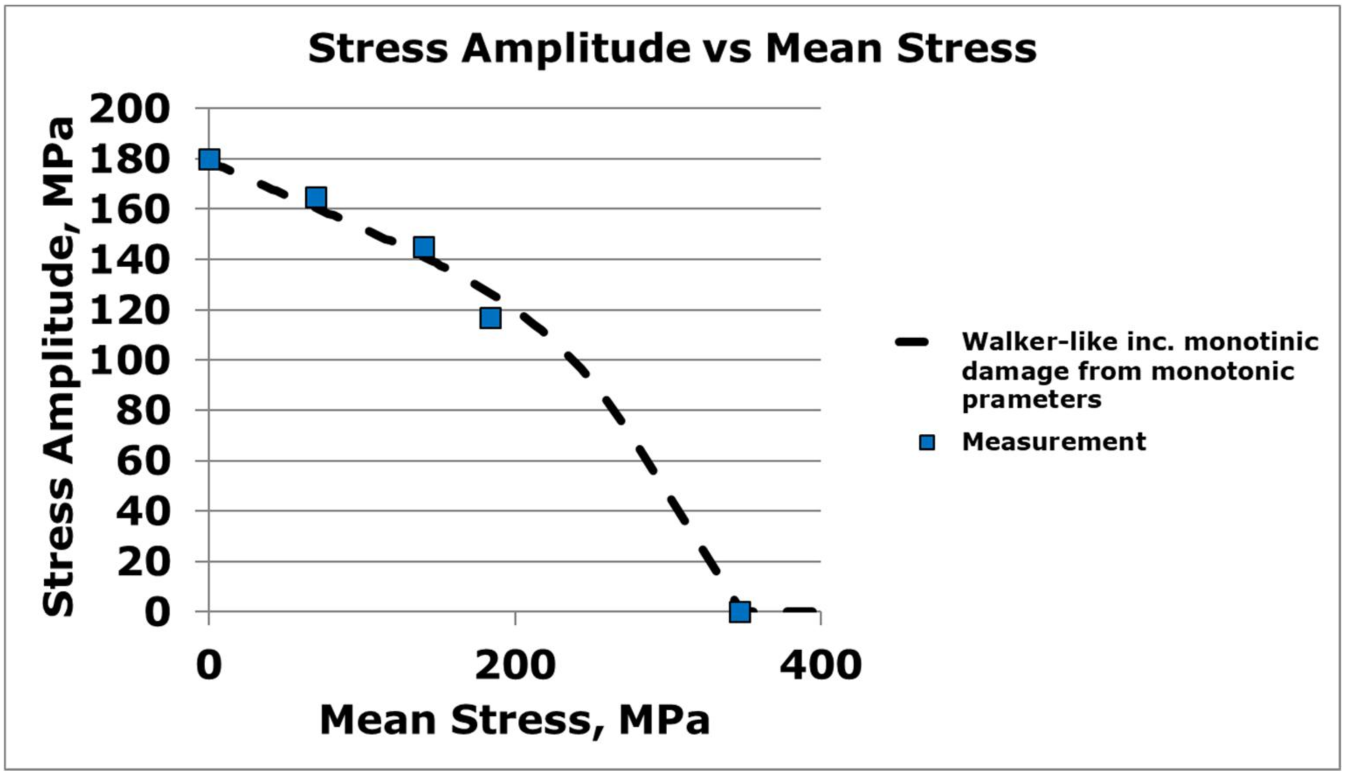
Haigh Diagram, Stress Amplitude vs. Mean Stress
stress amplitude, MPa
mean stress, MPa
0
100
200
300
400
500
600
700
800
900
1000
0
200
400
600
800
1000
1200
2×10^3
2×10^4
2×10^5
2×10^6
2×10^7

.13 carbon



Development of the positive mean stress diagrams using genetic algorithm approach Sekercioglu, Canyurt

.13 carbon b_{mono} fit



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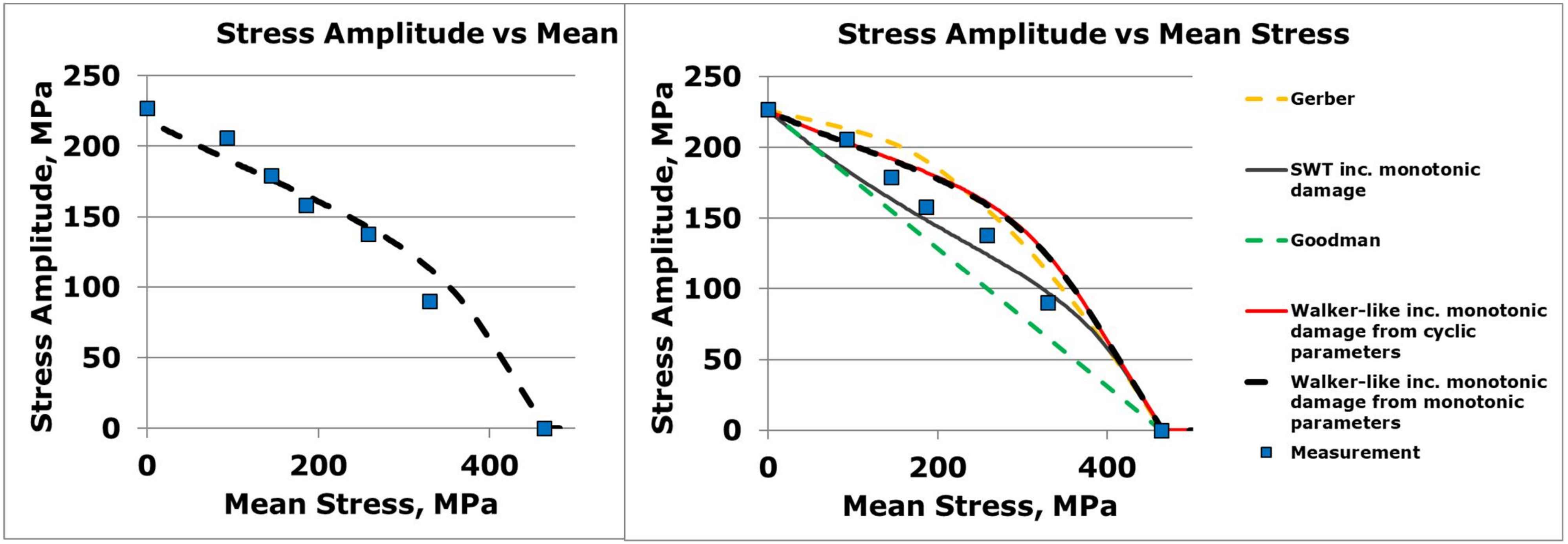
.29 carbon



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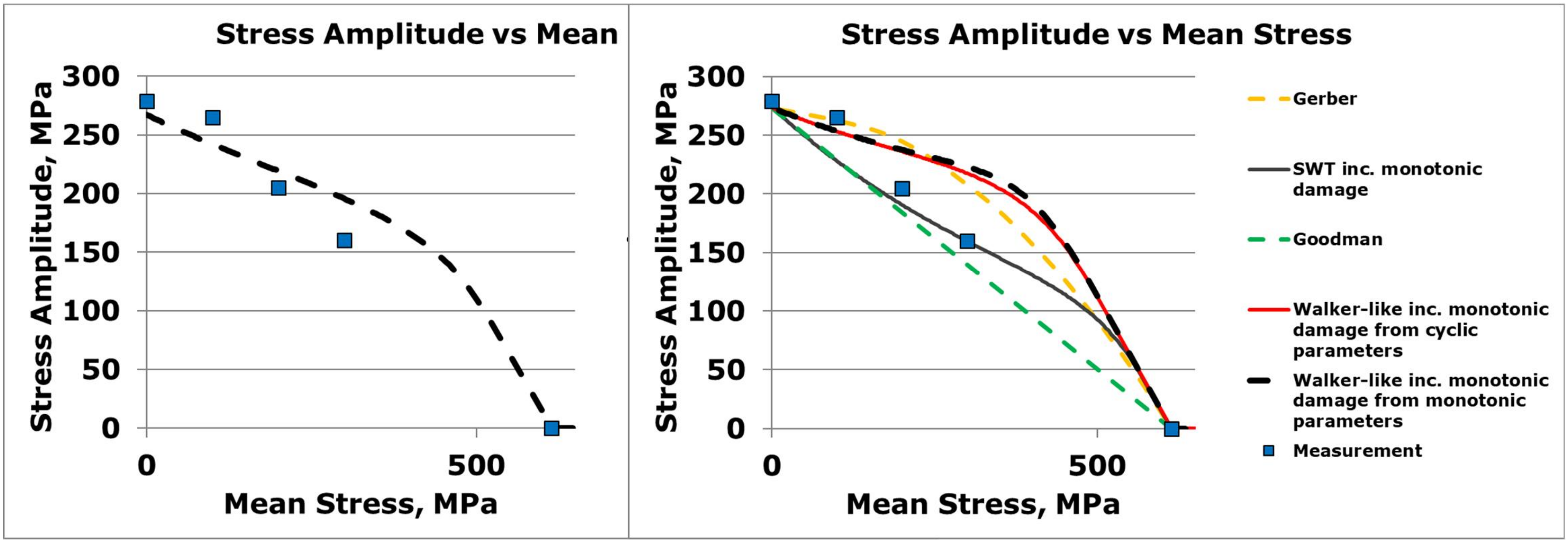
0.09 dual phase



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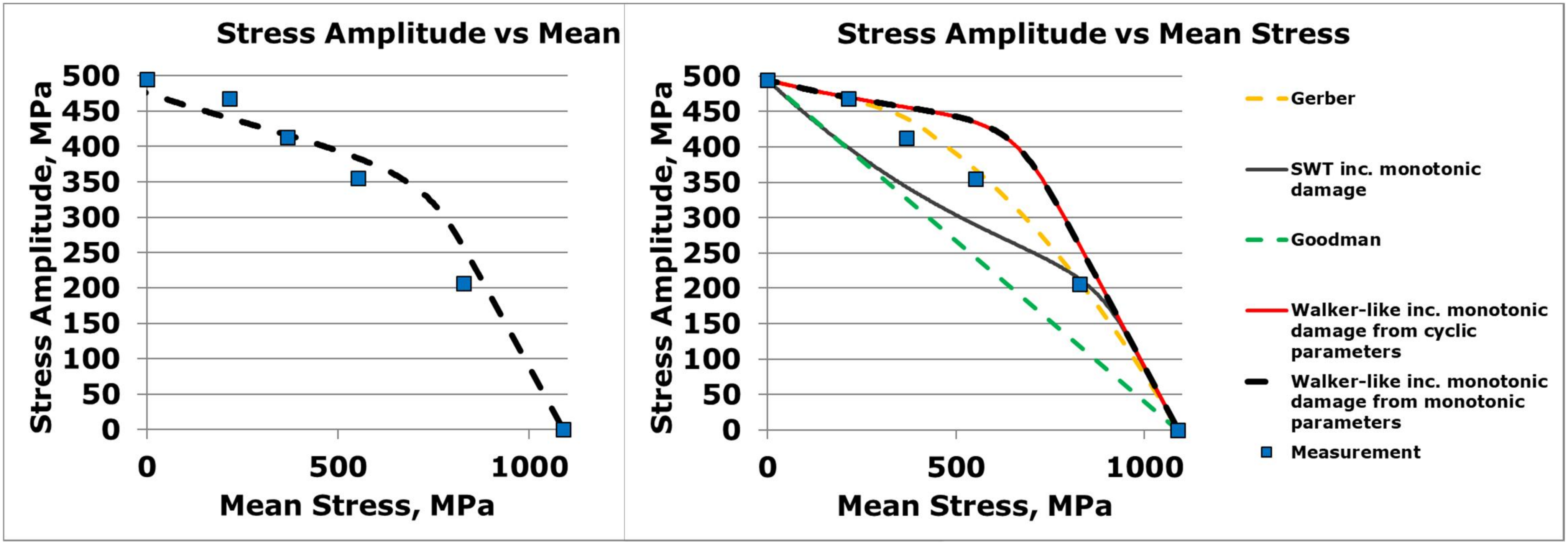
4340



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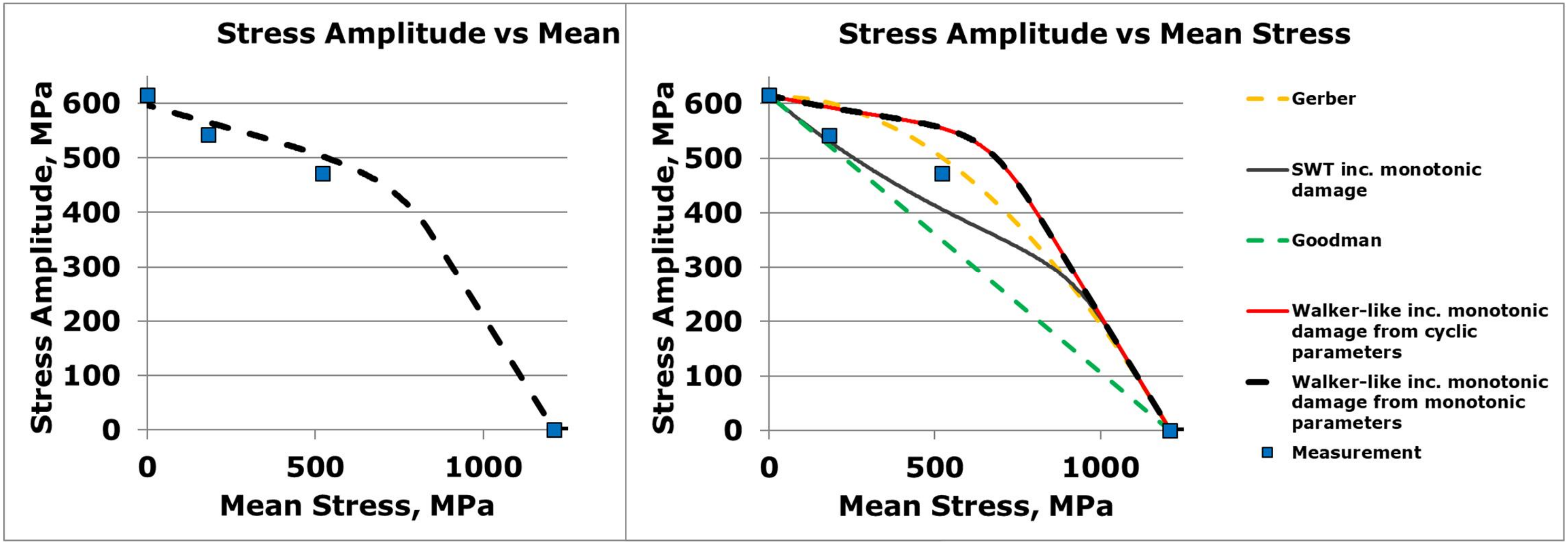
34CrNiMo6



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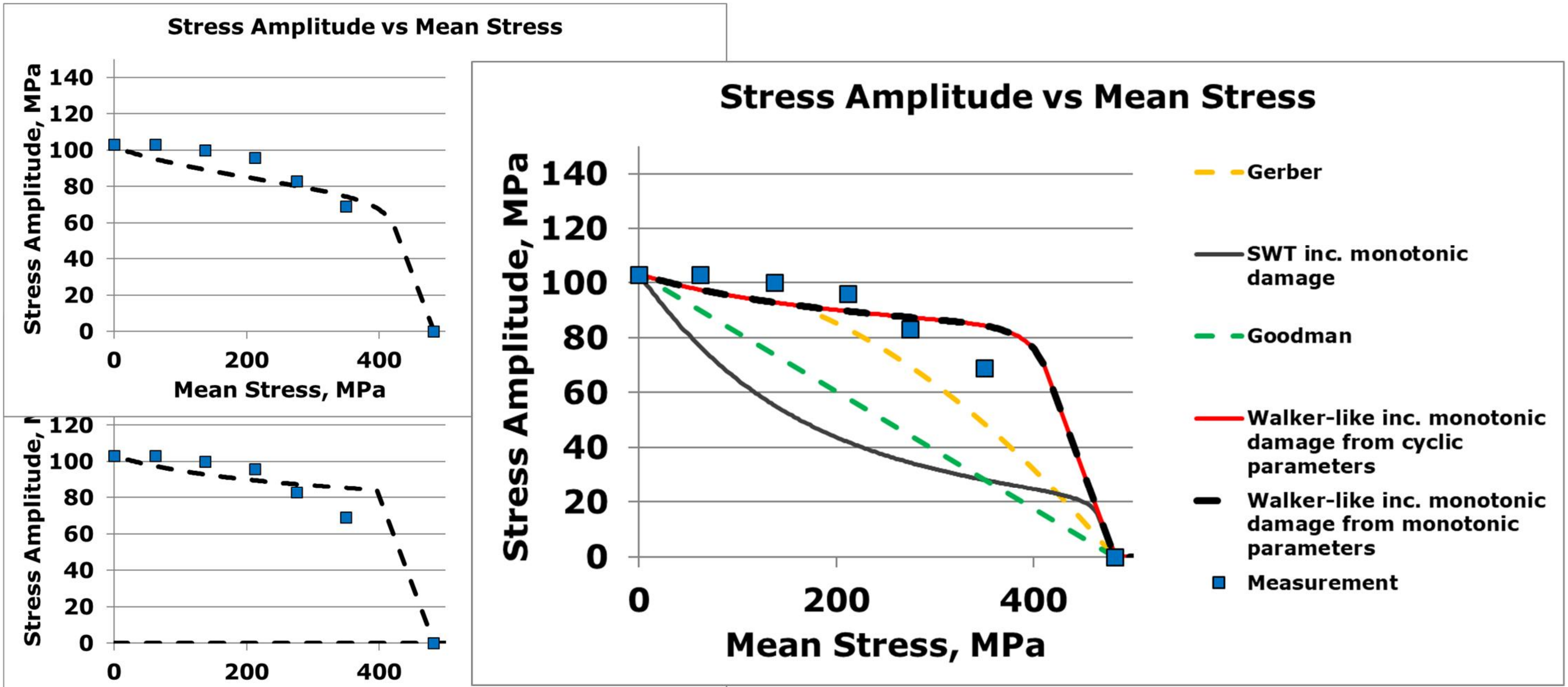
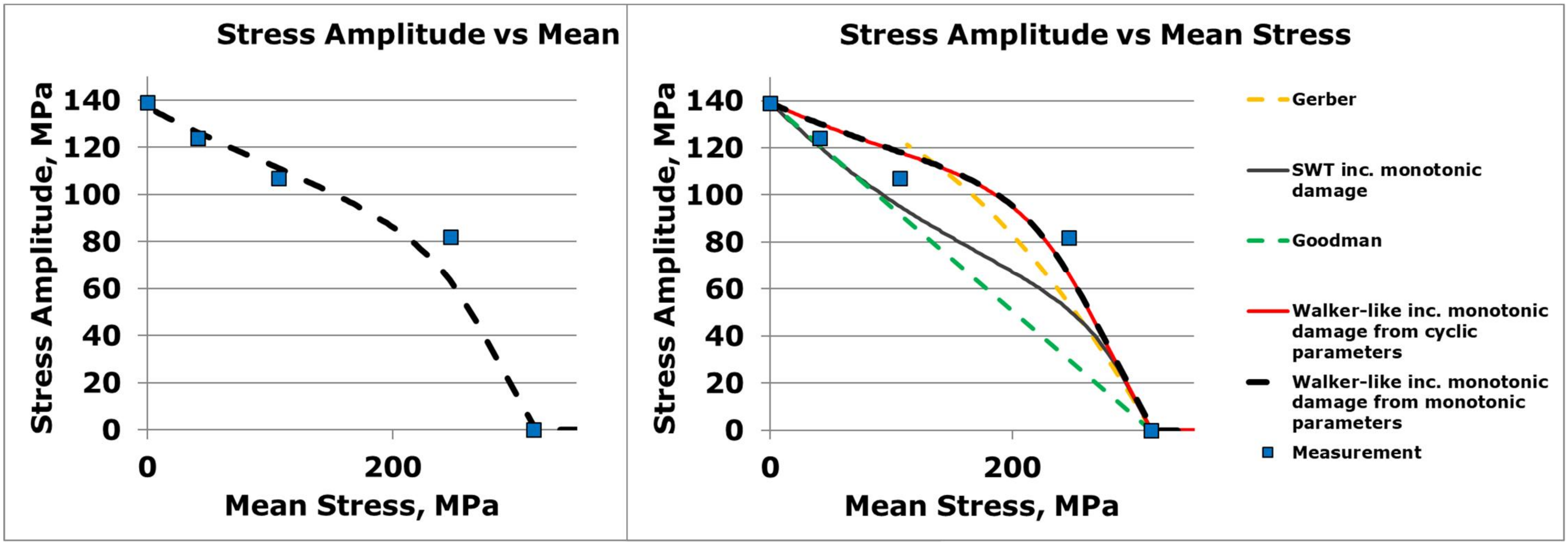
2014-T6 Al-alloy



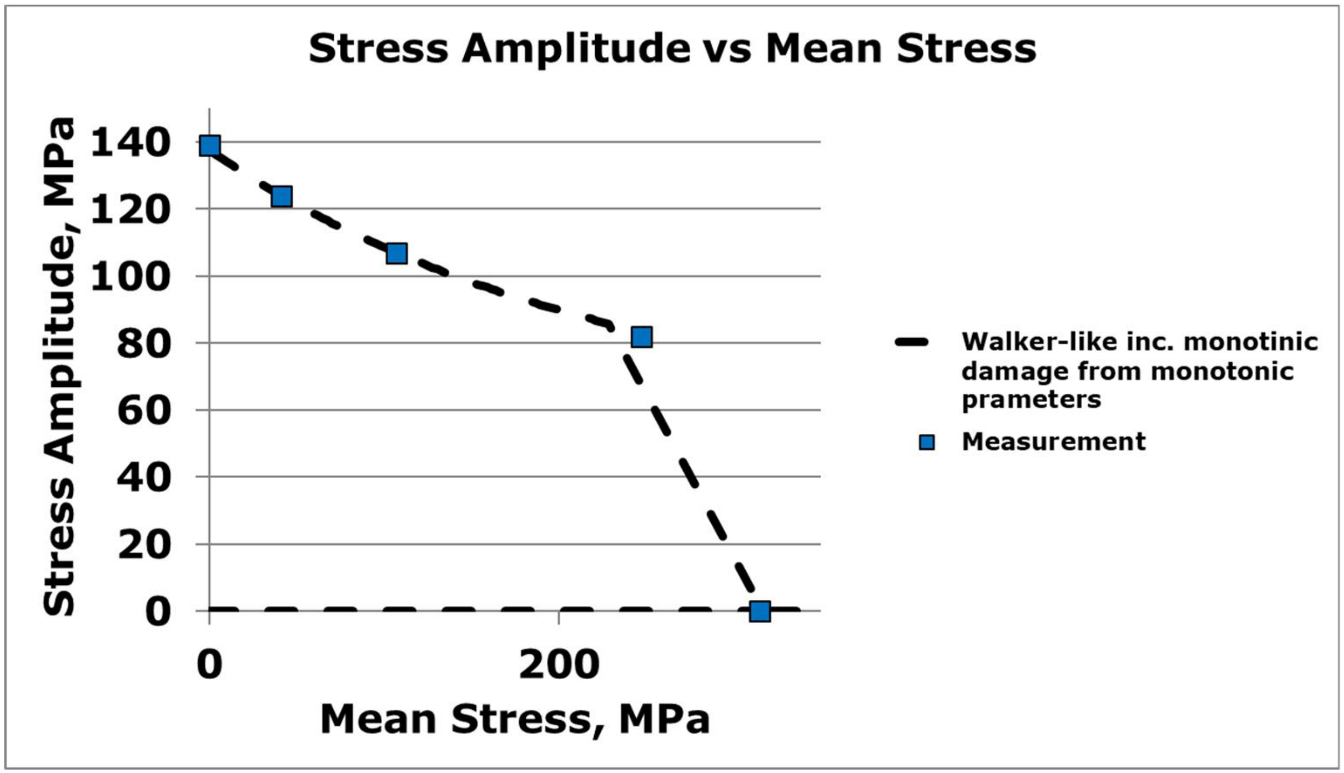
Development of the positive mean stress diagrams using genetic algorithm approach Sekercioglu, Canyurt

6061-T6 Al-alloy

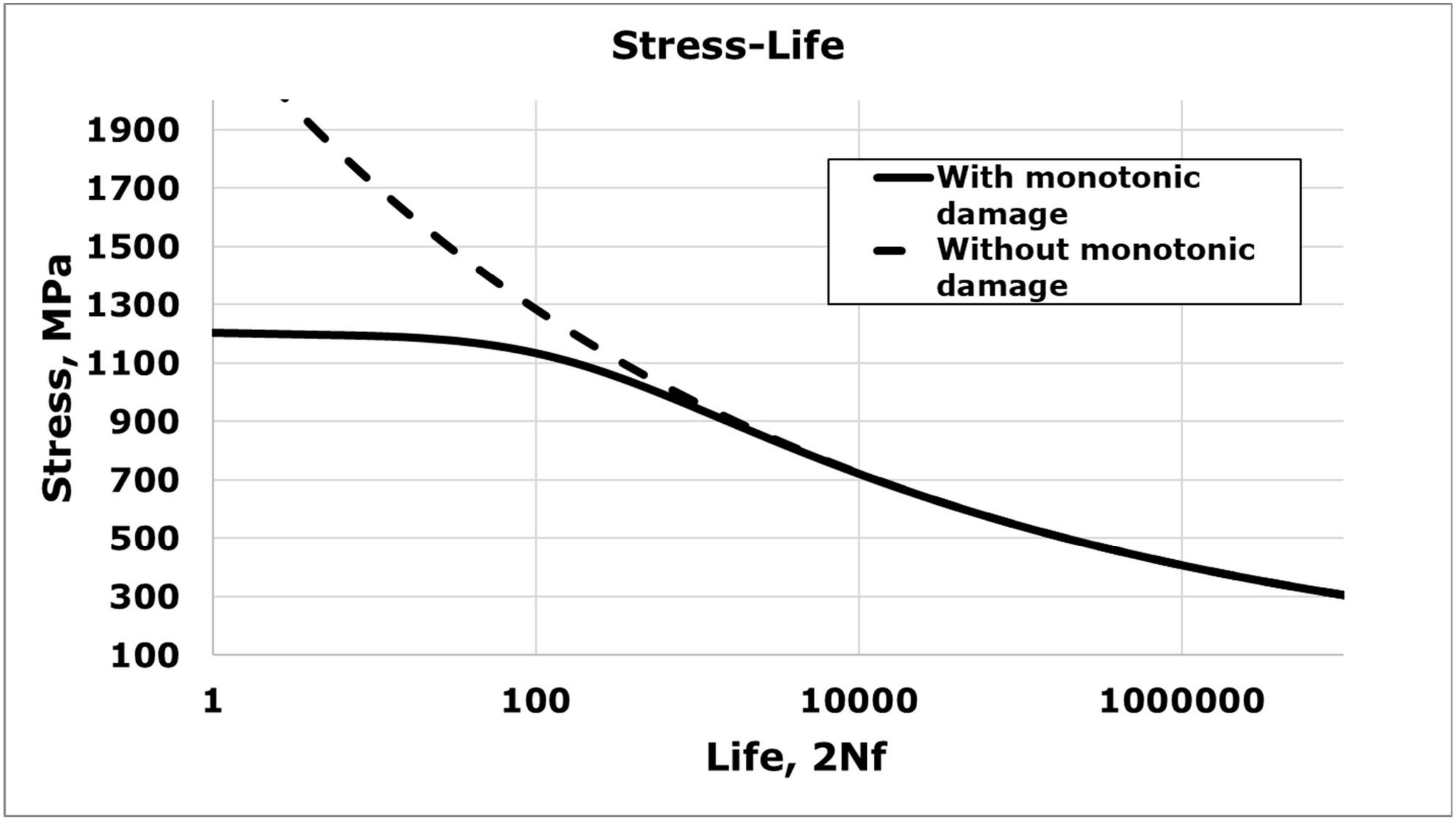


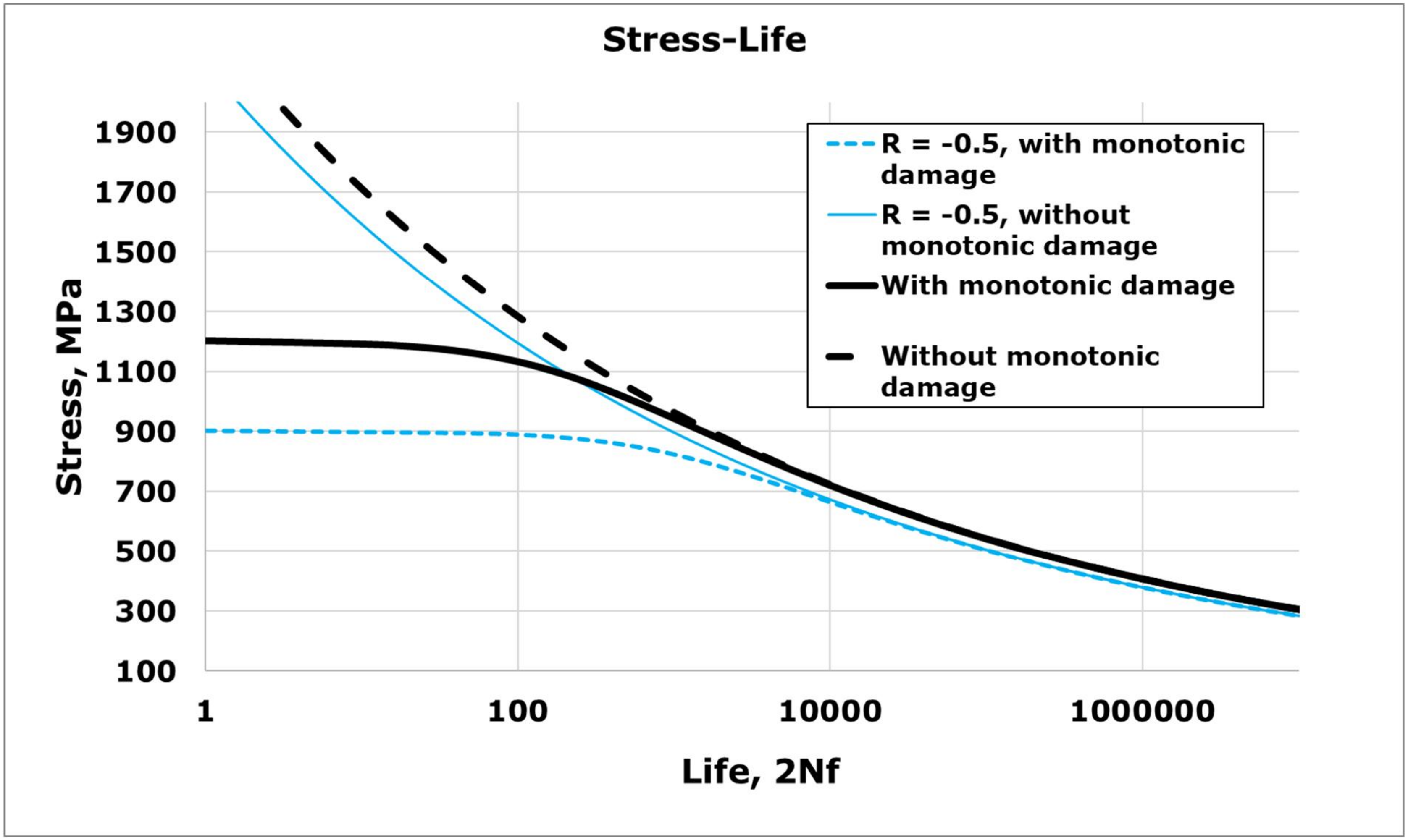
Development of the positive mean stress diagrams using genetic algorithm approach Sekercioglu, Canyurt

“Free fit”

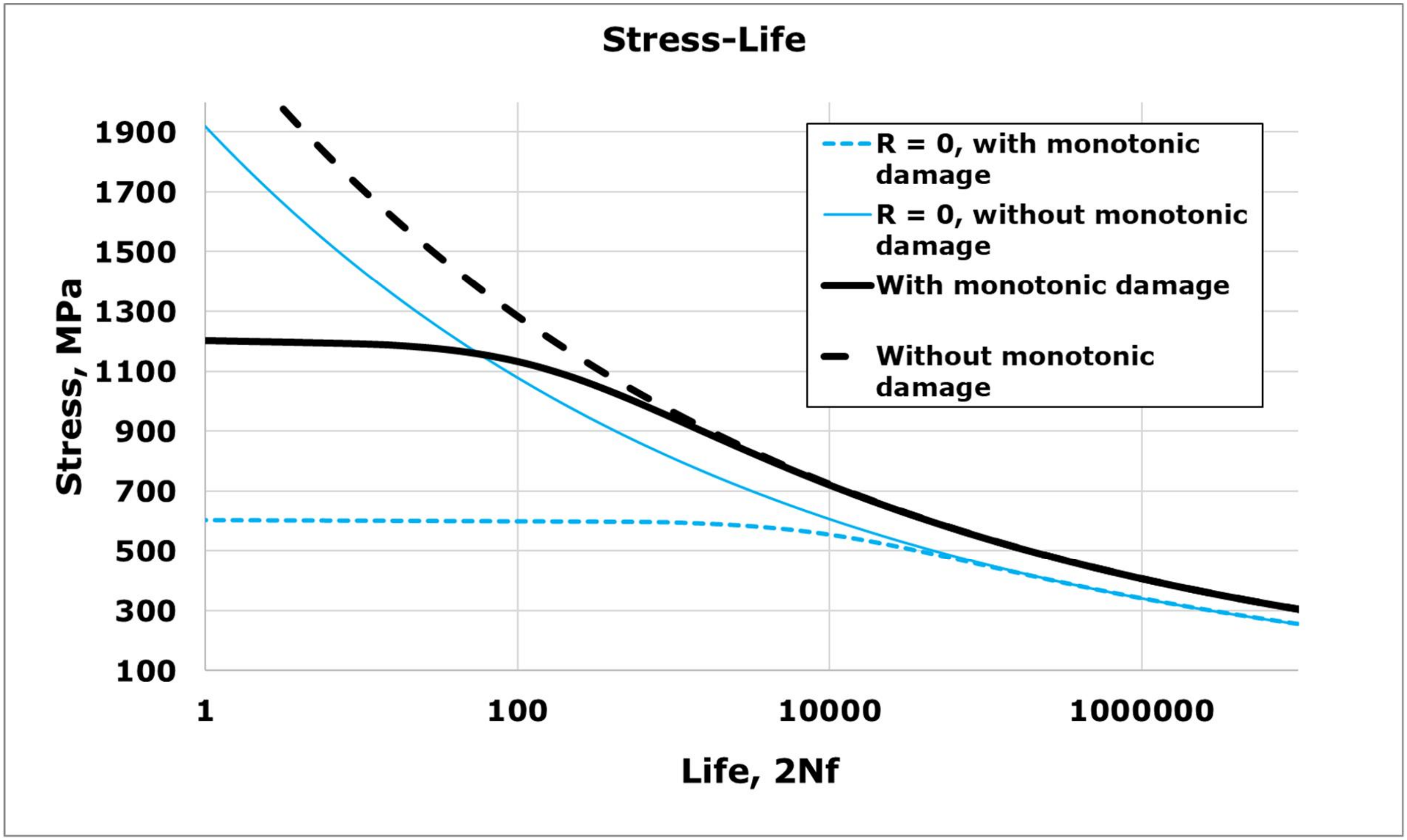


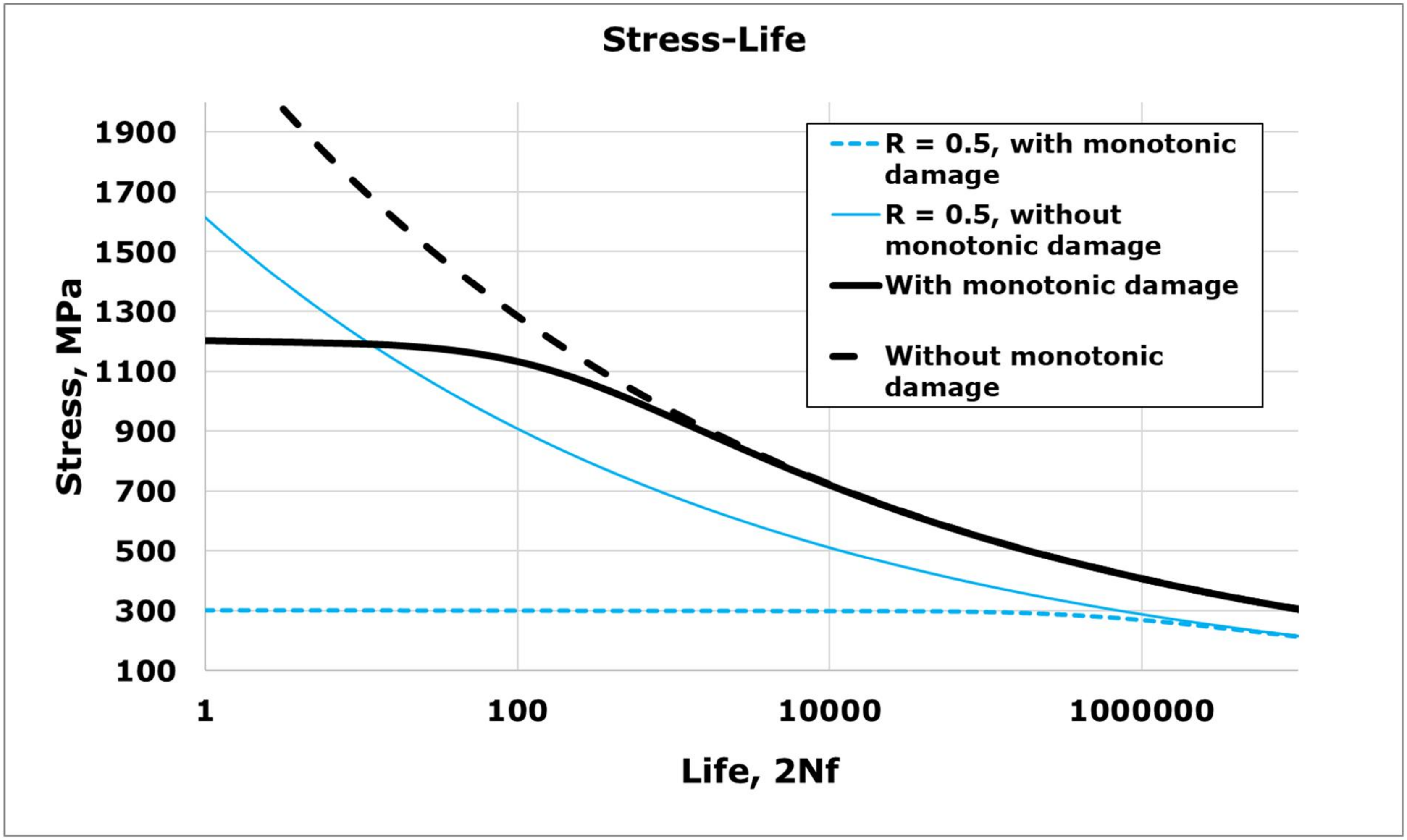
Development of the positive mean stress diagrams using genetic algorithm approach Sekercioglu, Canyurt

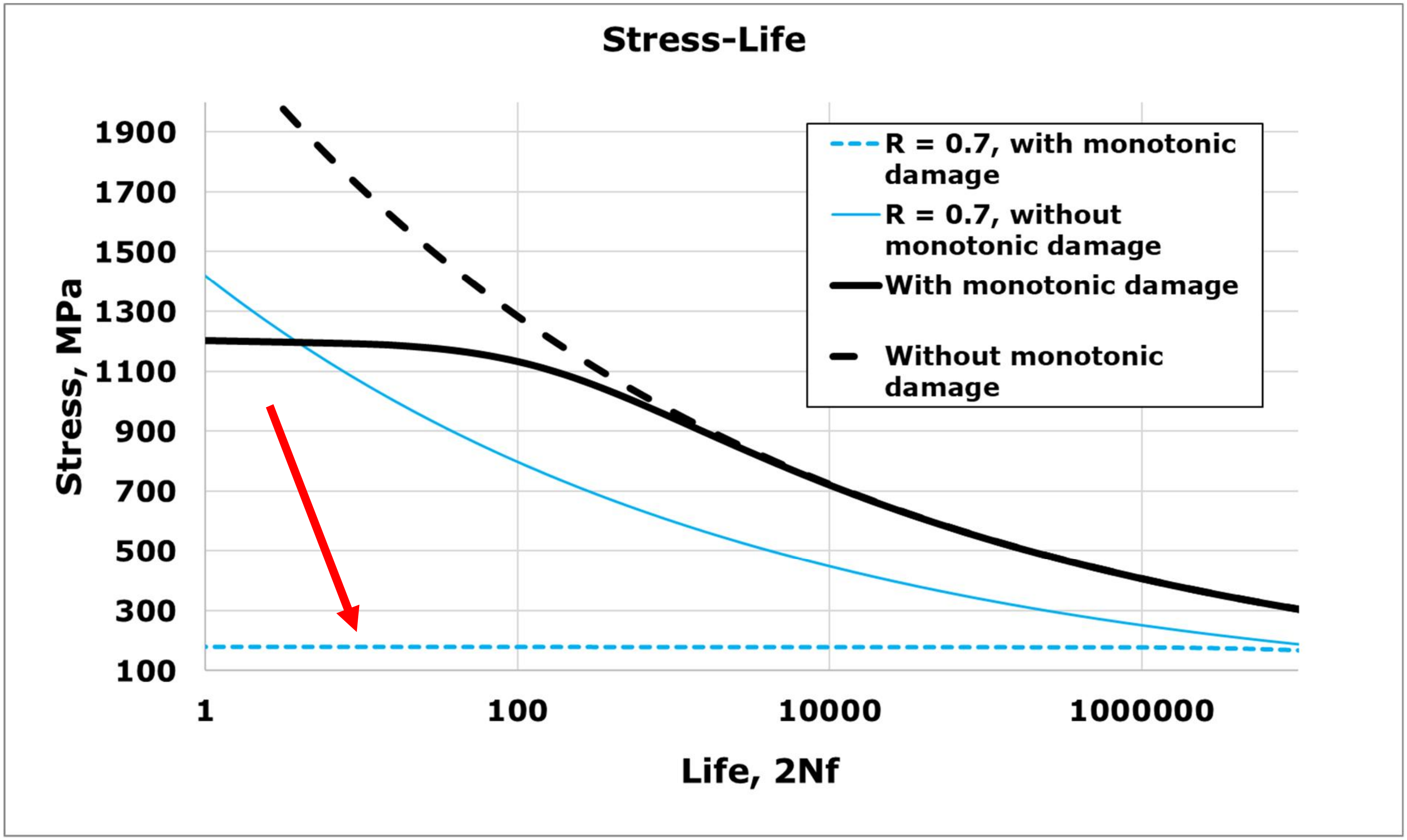

Stress-Life
1900
1700
1500
1300
1100
900
700
500
300
100
Stress, MPa
1
100
10000
1000000
Life, 2Nf
With monotonic damage
Without monotonic damage

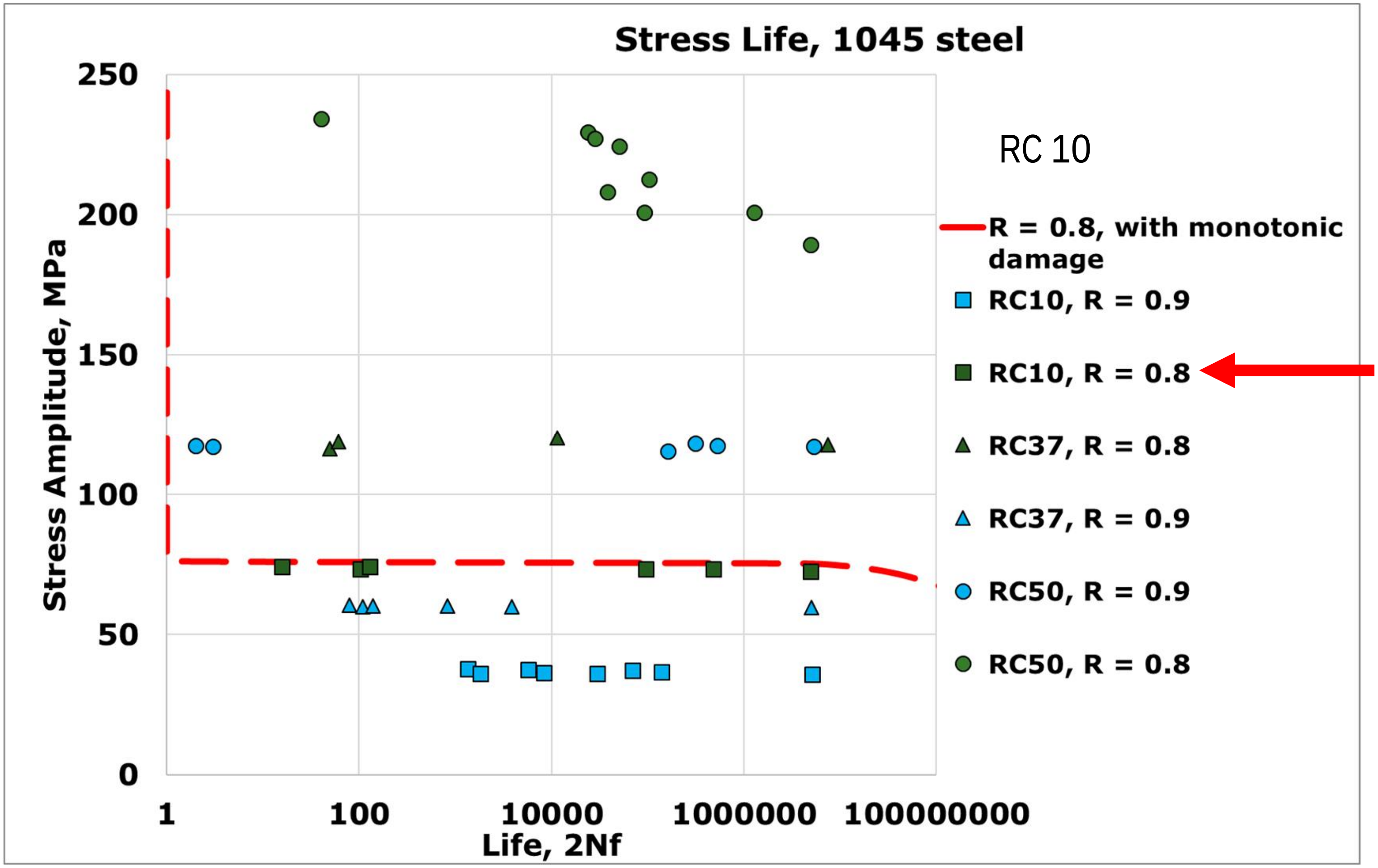


Stress-Life
R = -0.5, with monotonic damage
R = -0.5, without monotonic damage
With monotonic damage
Without monotonic damage
Stress, MPa
1900
1700
1500
1300
1100
900
700
500
300
100
1
100
10000
1000000
Life, 2Nf

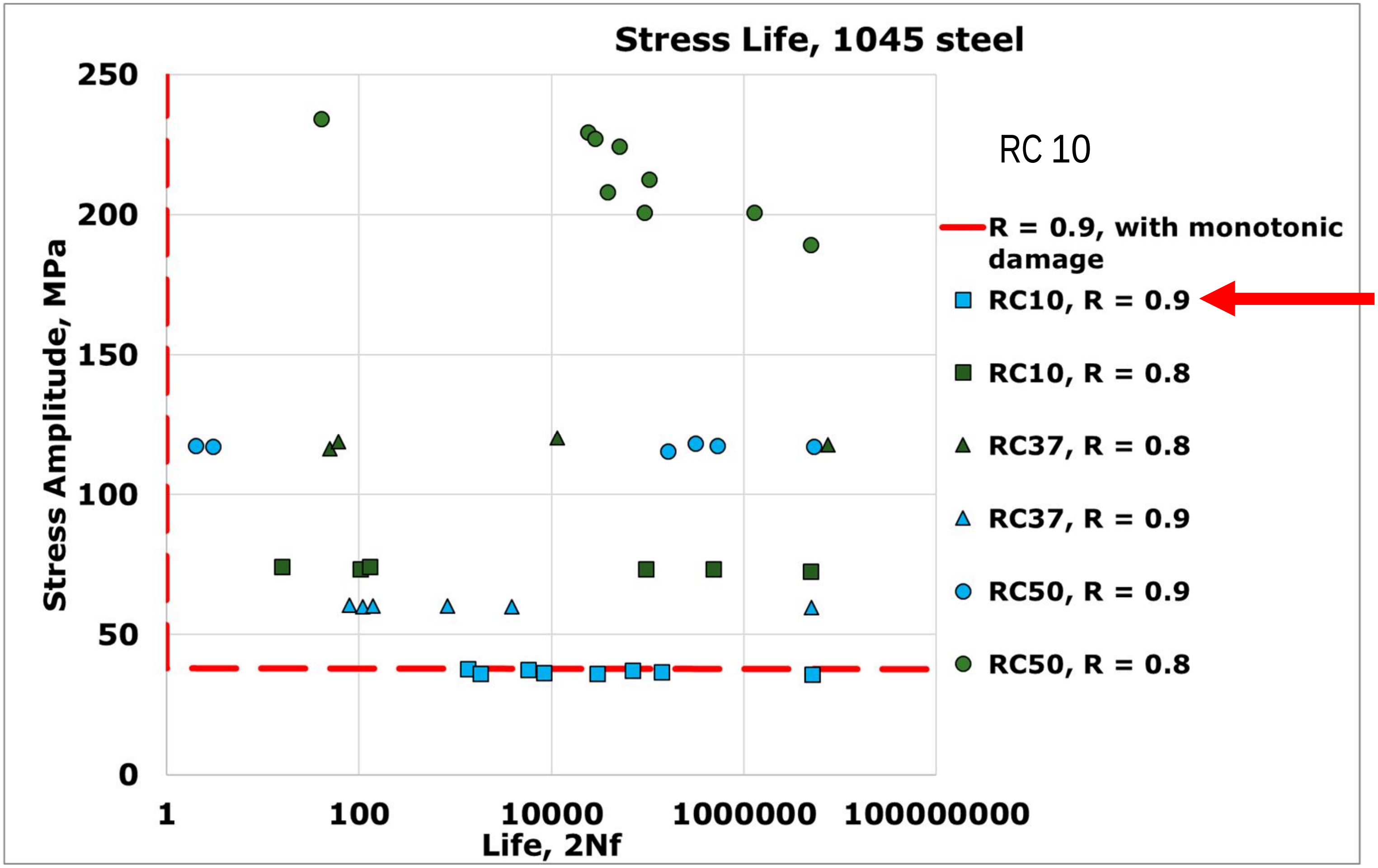

Stress-Life
1900
1700
1500
1300
1100
900
700
500
300
100
Stress, MPa
1
100
10000
1000000
Life, 2Nf
R = 0, with monotonic damage
R = 0, without monotonic damage
With monotonic damage
Without monotonic damage


Stress-Life
Stress, MPa
1900
1700
1500
1300
1100
900
700
500
300
100
1
100
10000
1000000
Life, 2Nf
R = 0.5, with monotonic damage
R = 0.5, without monotonic damage
With monotonic damage
Without monotonic damage


Stress-Life
Stress, MPa
1900
1700
1500
1300
1100
900
700
500
300
100
1
100
10000
1000000
Life, 2Nf
R = 0.7, with monotonic damage
R = 0.7, without monotonic damage
With monotonic damage
Without monotonic damage



The influence of high R ratio on unnotched fatigue behavior of 1045 steel with three different heat treatments, Karadag, Stephens



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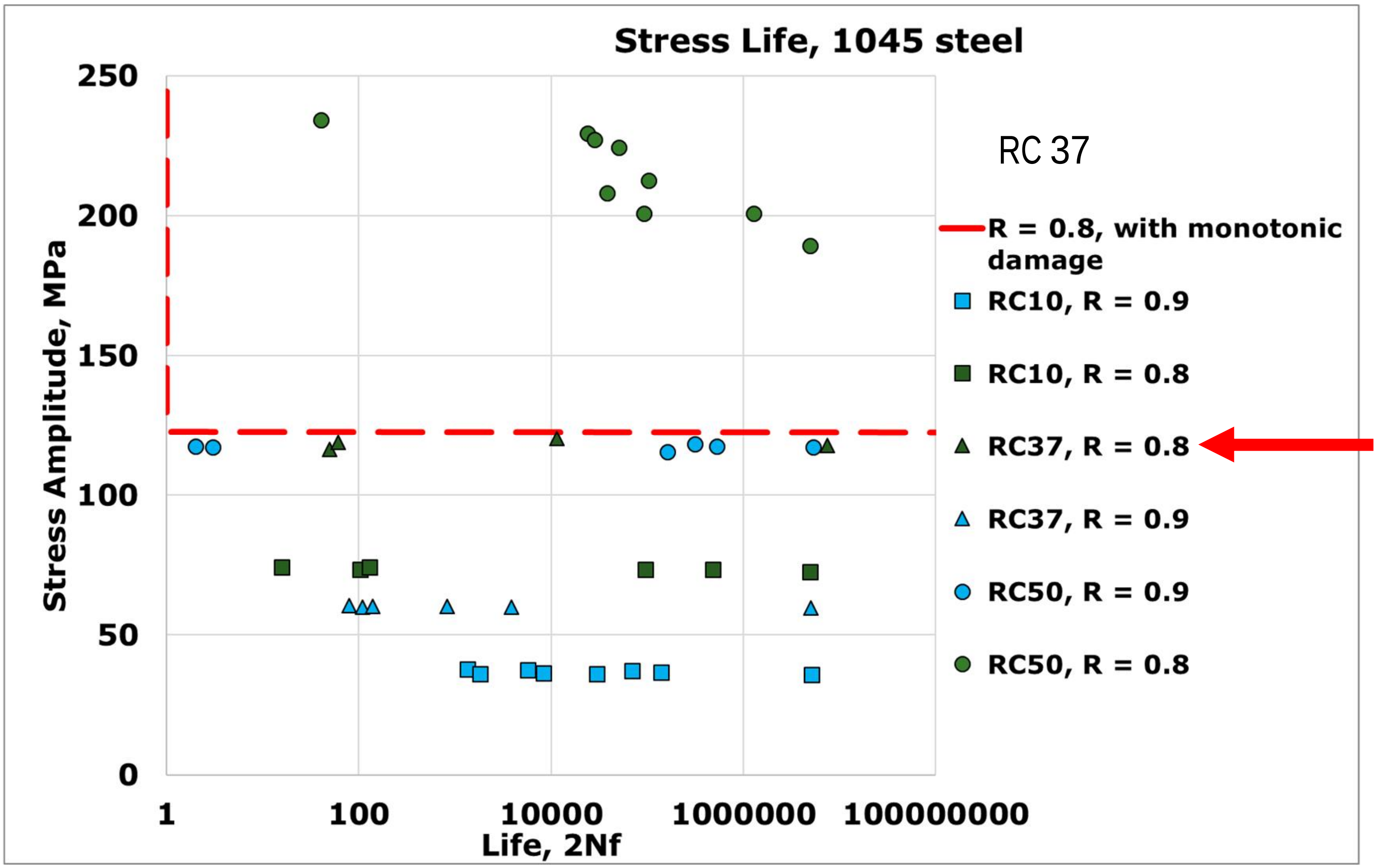
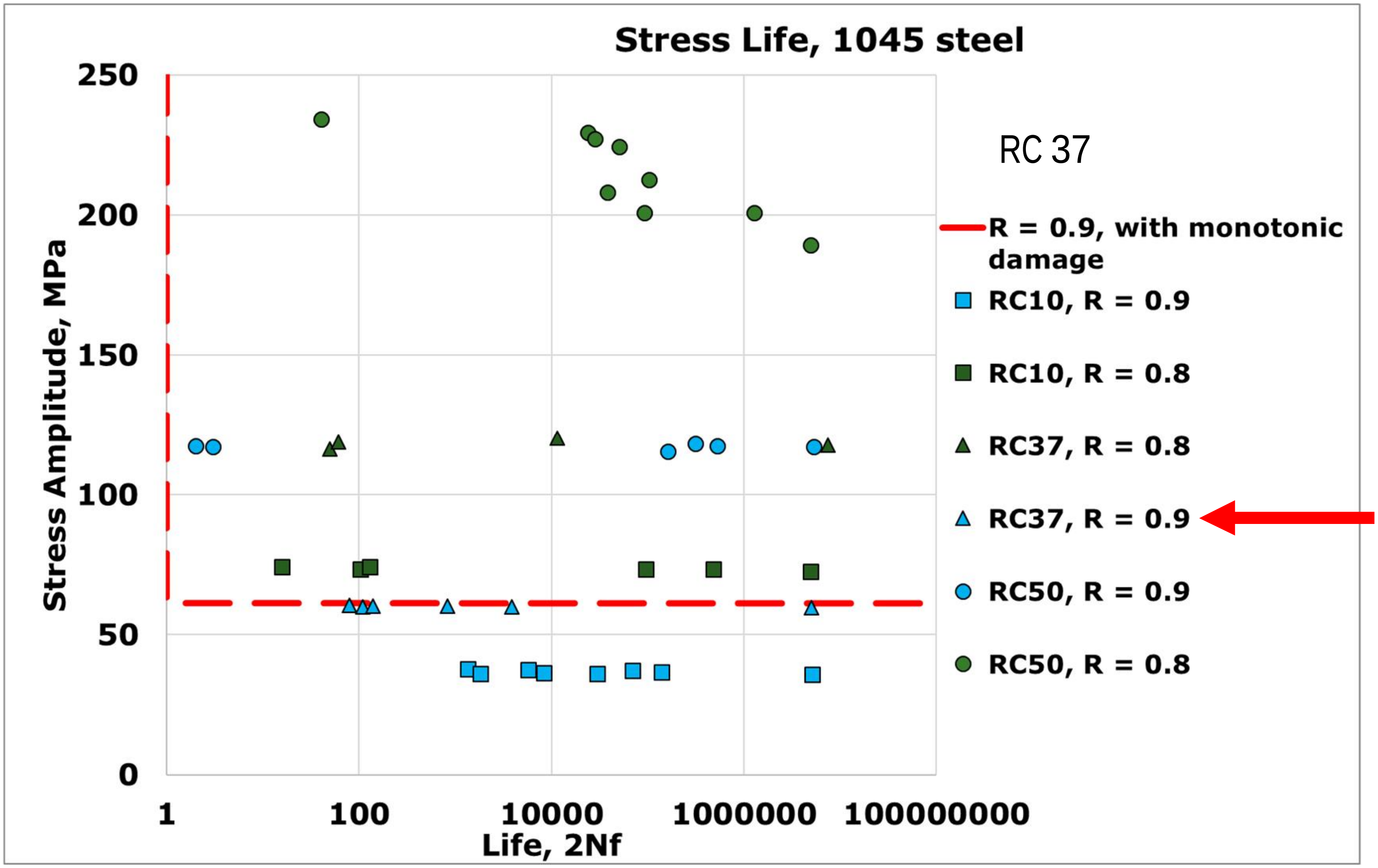
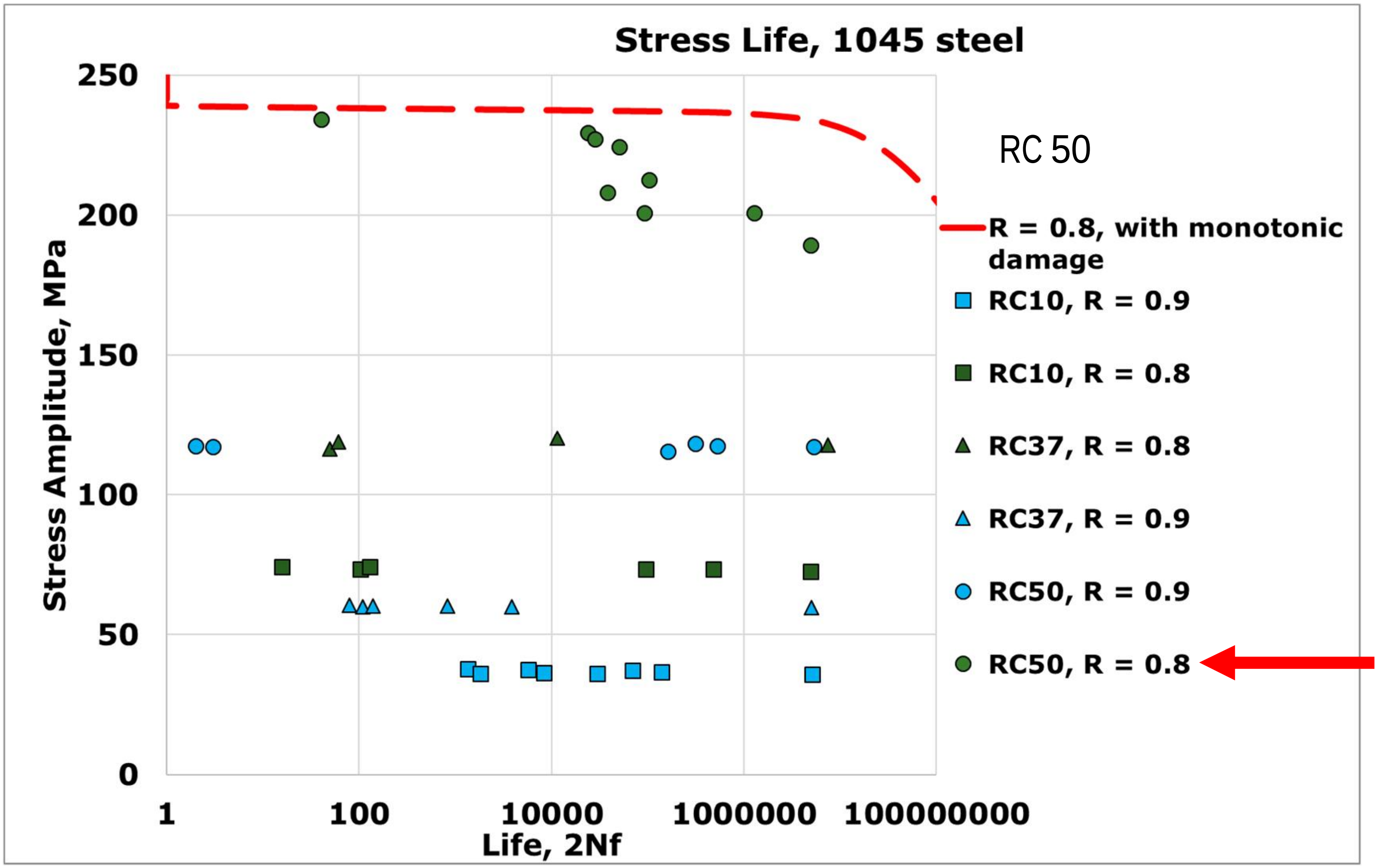


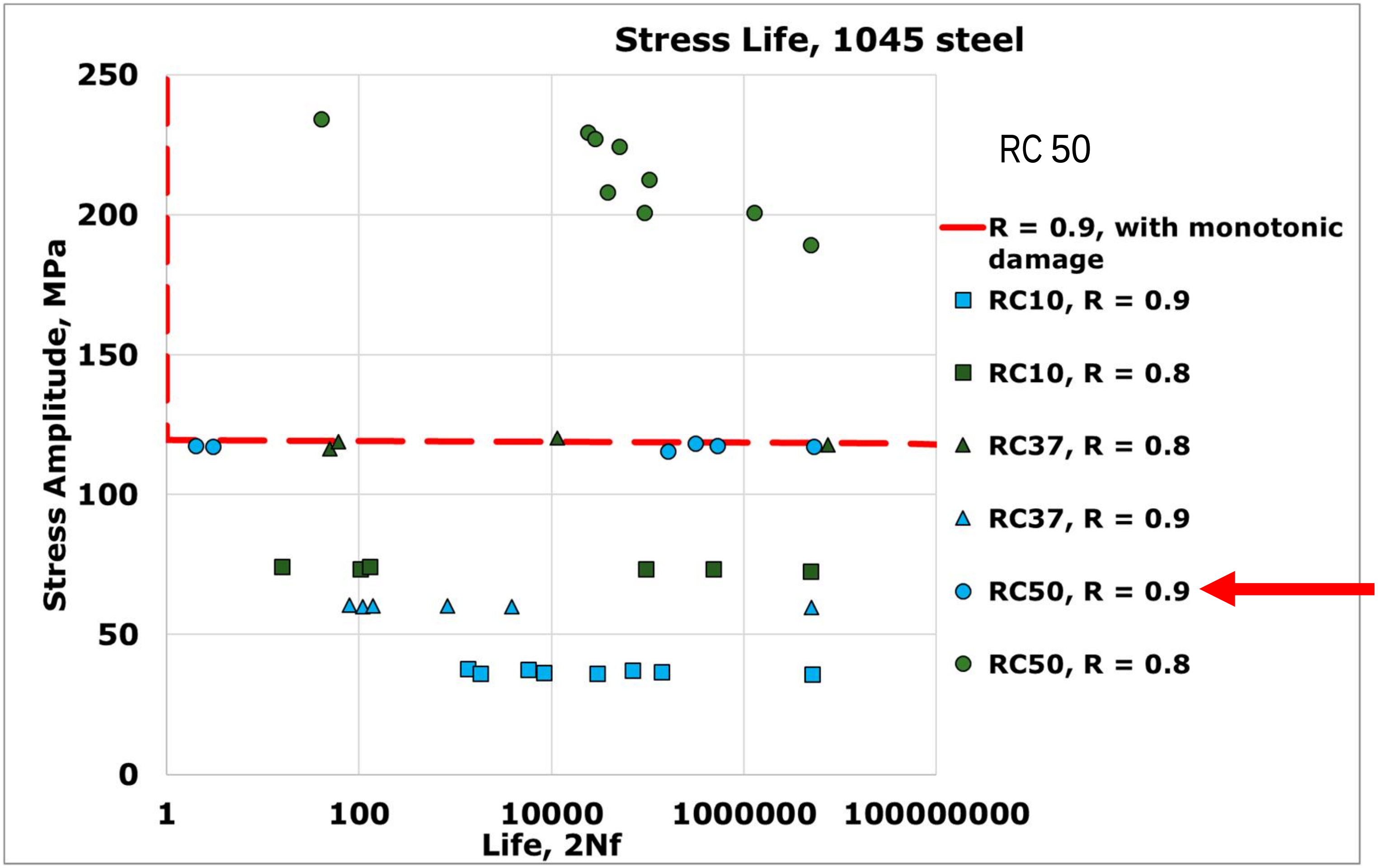
The influence of high R ratio on unnotched fatigue behavior of 1045 steel with three different heat treatments, Karadag, Stephens



The influence of high R ratio on unnotched fatigue behavior of 1045 steel with three different heat treatments, Karadag, Stephens

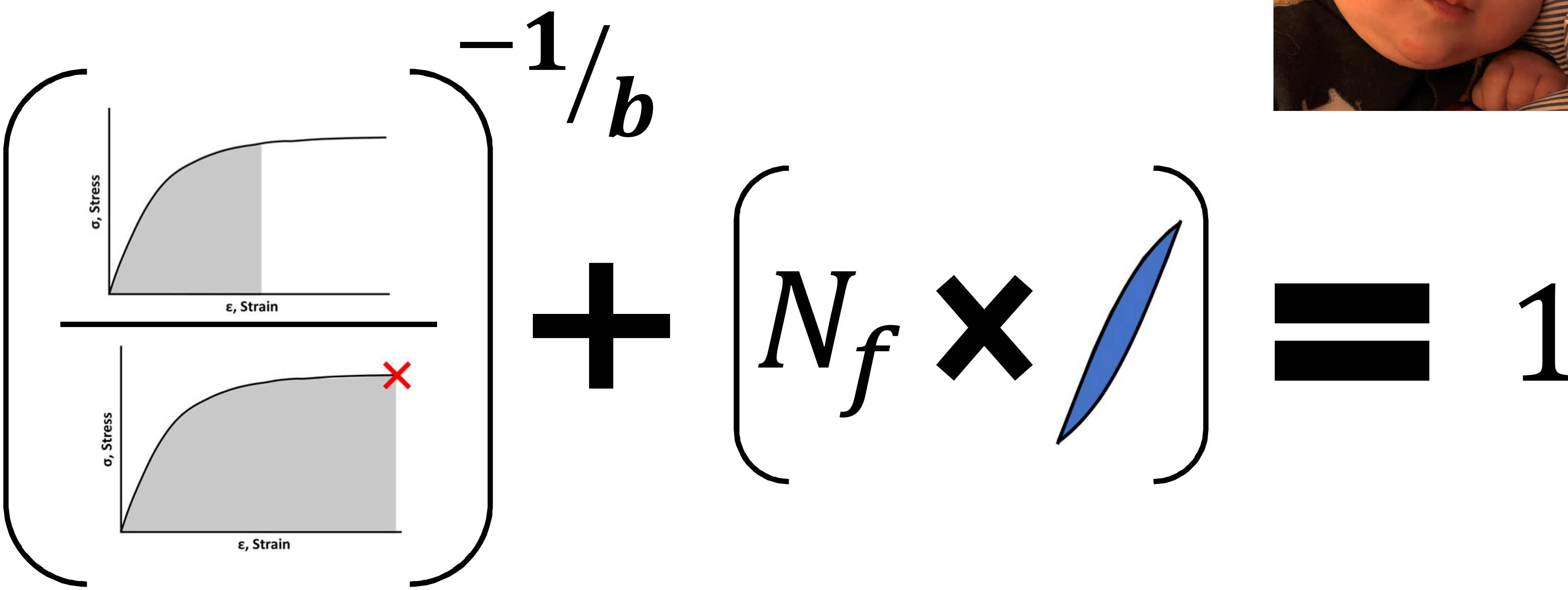


The influence of high R ratio on unnotched fatigue behavior of 1045 steel with three different heat treatments, Karadag, Stephens

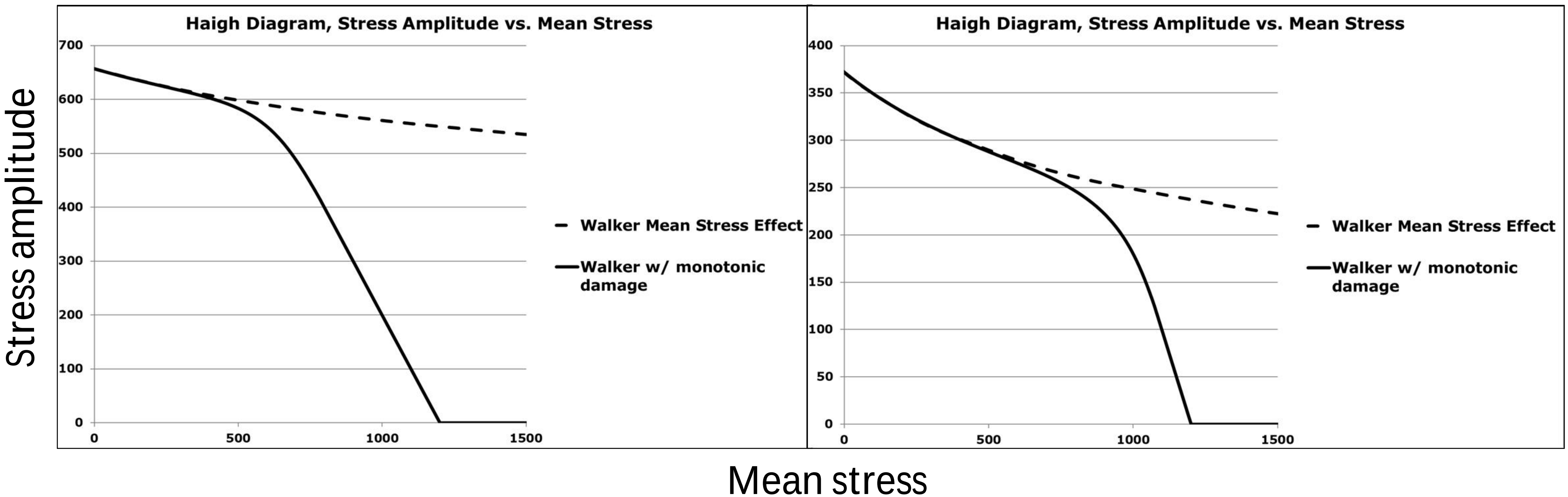


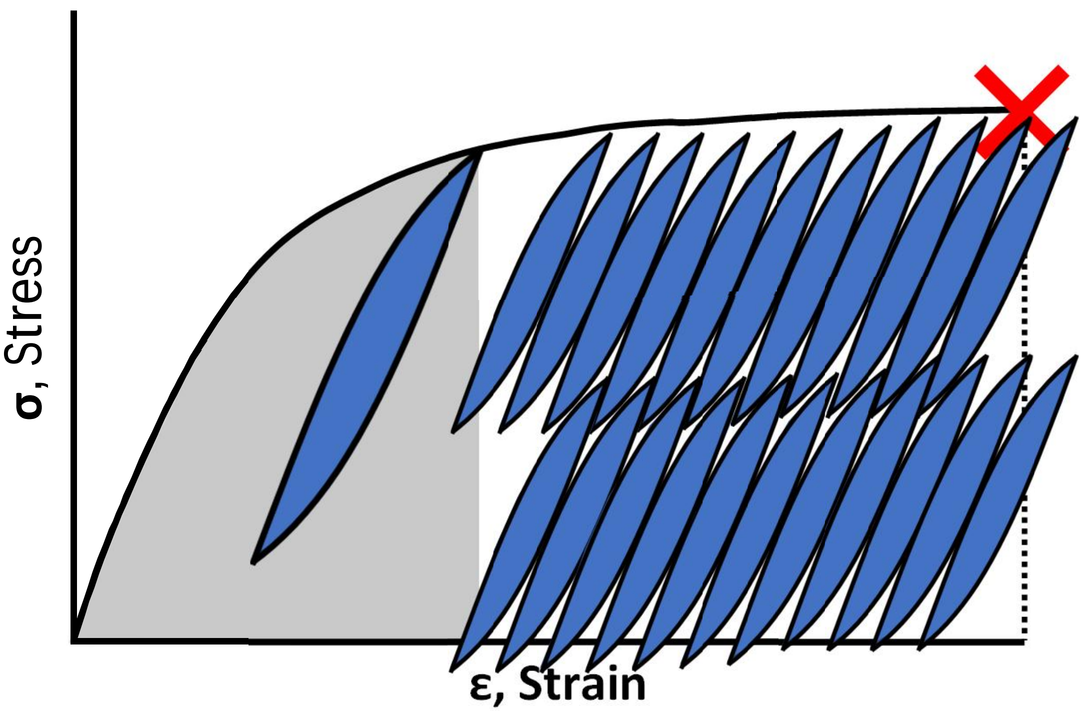
The influence of high R ratio on unnotched fatigue behavior of 1045 steel with three different heat treatments, Karadag, Stephens

Questions?

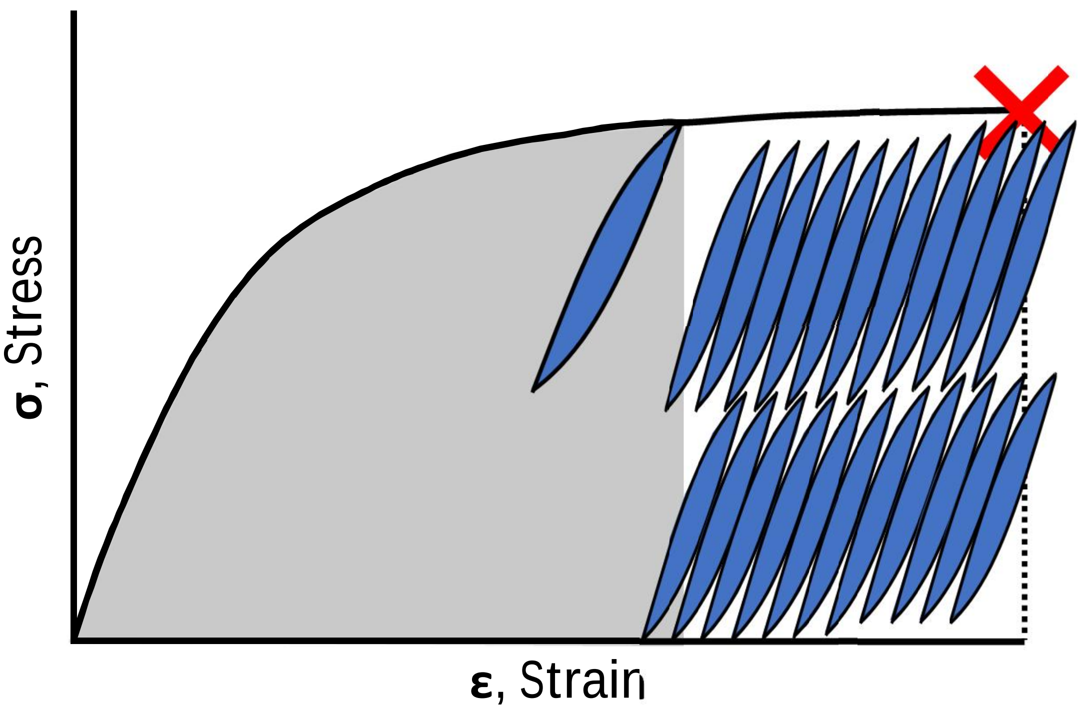


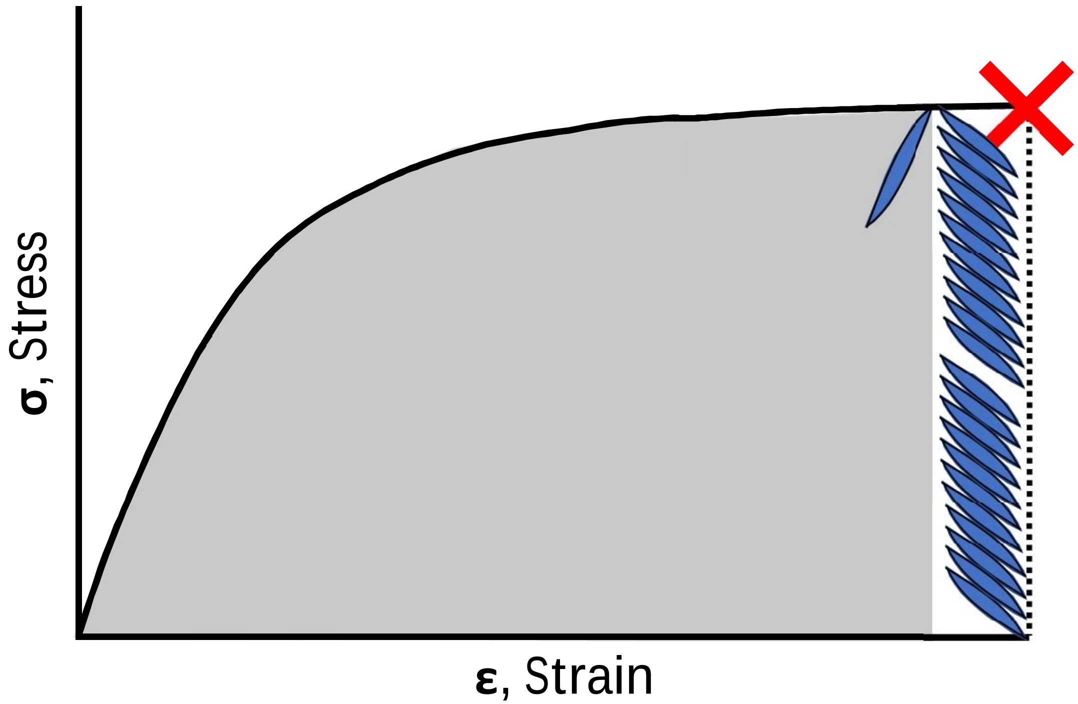
$n' = 0.1$ $n' = 0.2$

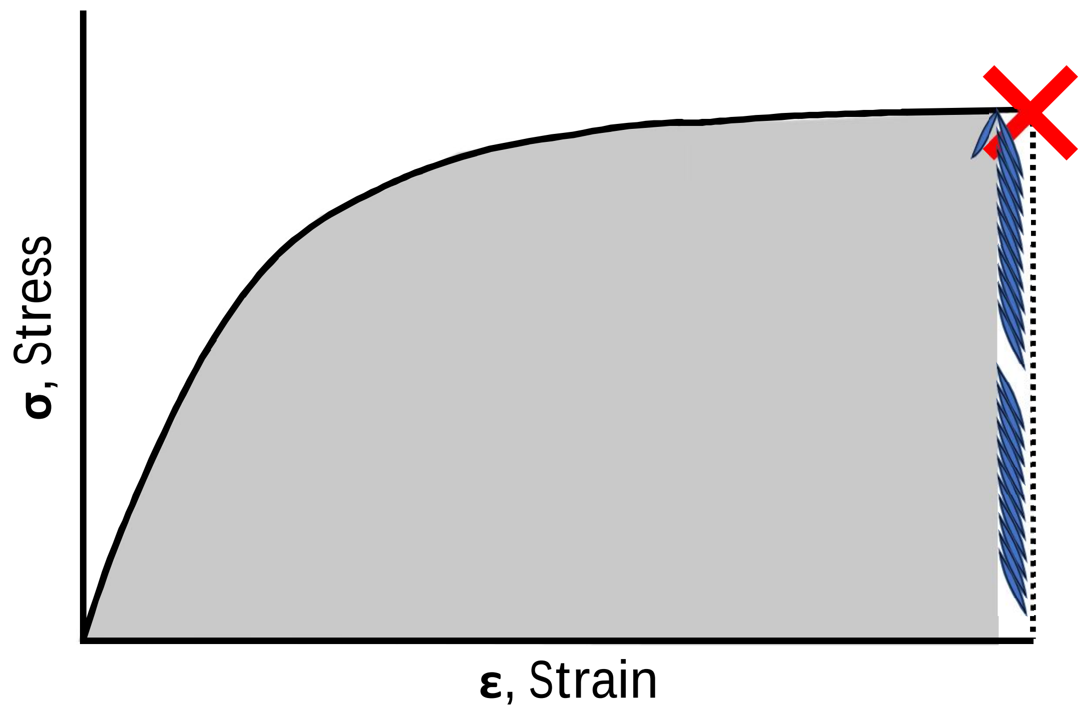

Haigh Diagram, Stress Amplitude vs. Mean Stress
Walker Mean Stress Effect
Walker w/ monotonic damage
Haigh Diagram, Stress Amplitude vs. Mean Stress
Walker Mean Stress Effect
Walker w/ monotonic damage
Stress amplitude
Mean stress

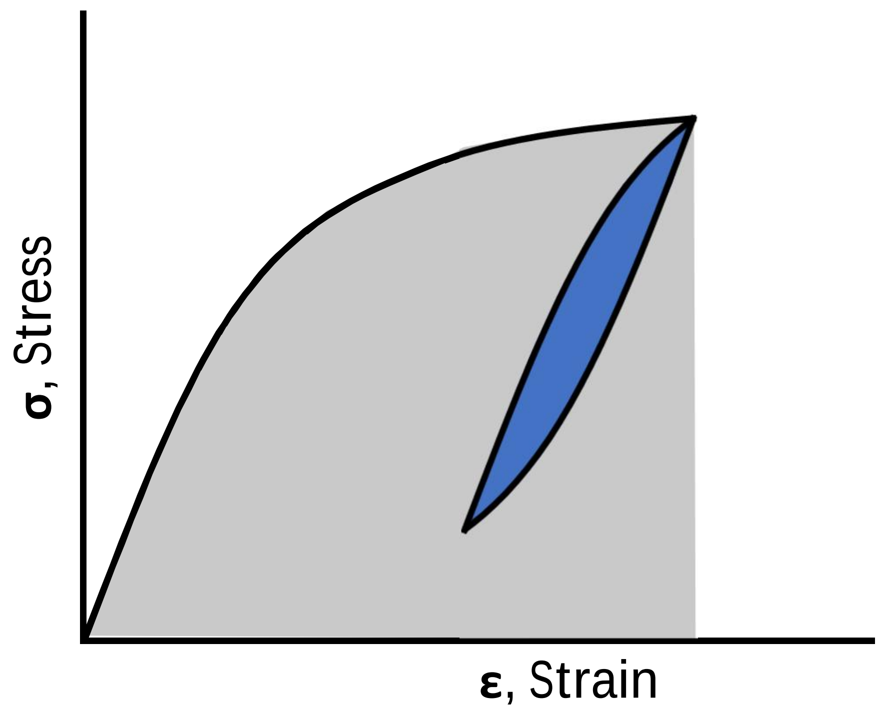


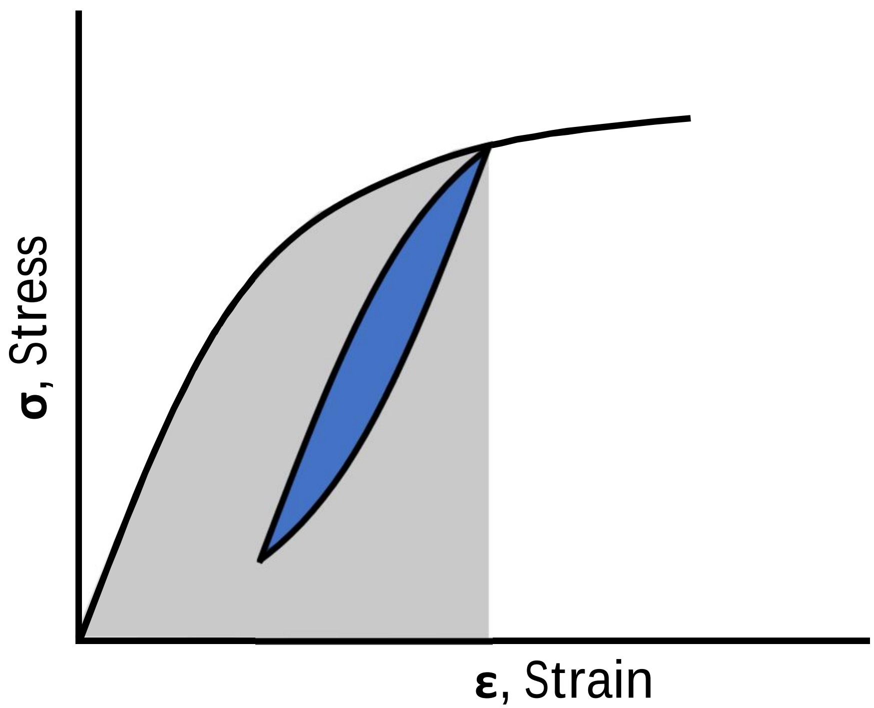
σ, Stress
ε, Strain

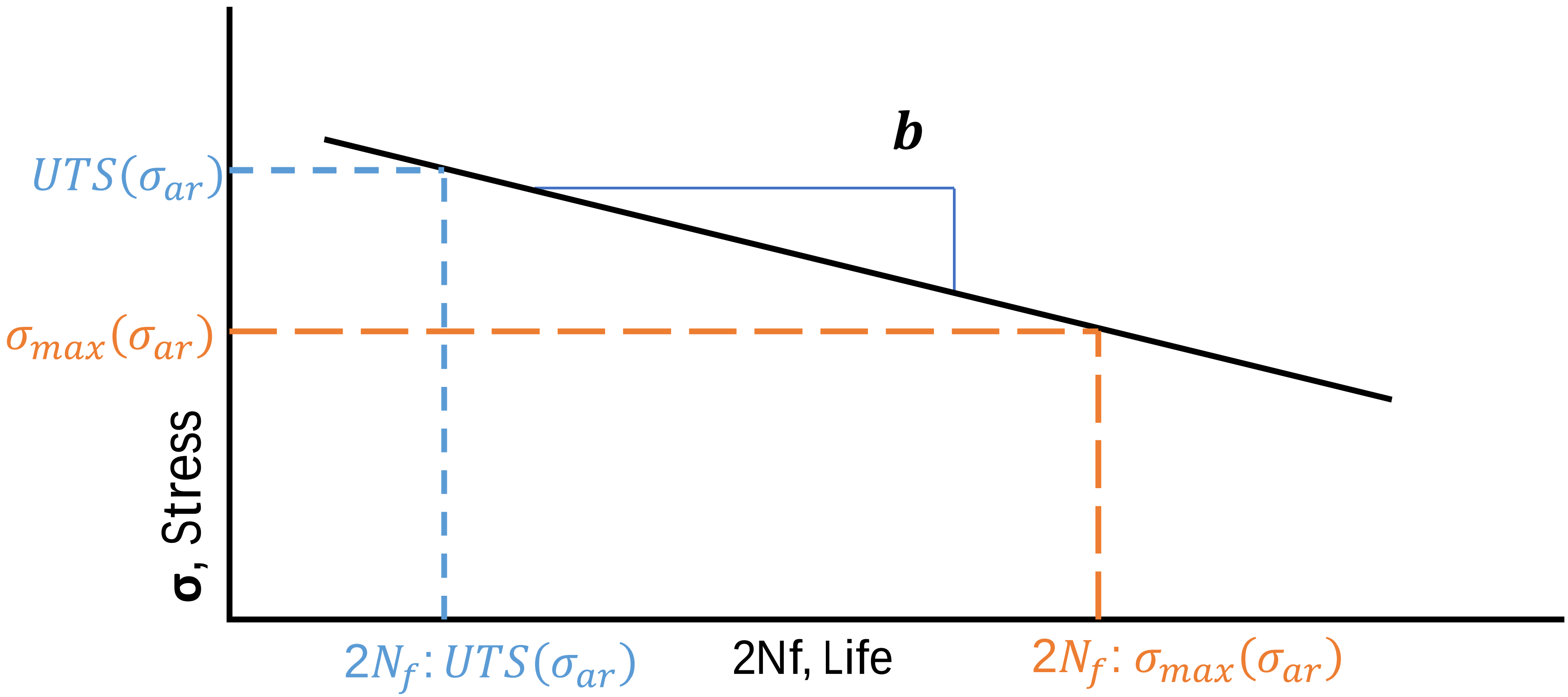

σ, Stress
ε, Strain


σ, Stress
ε, Strain


σ, Stress
ε, Strain

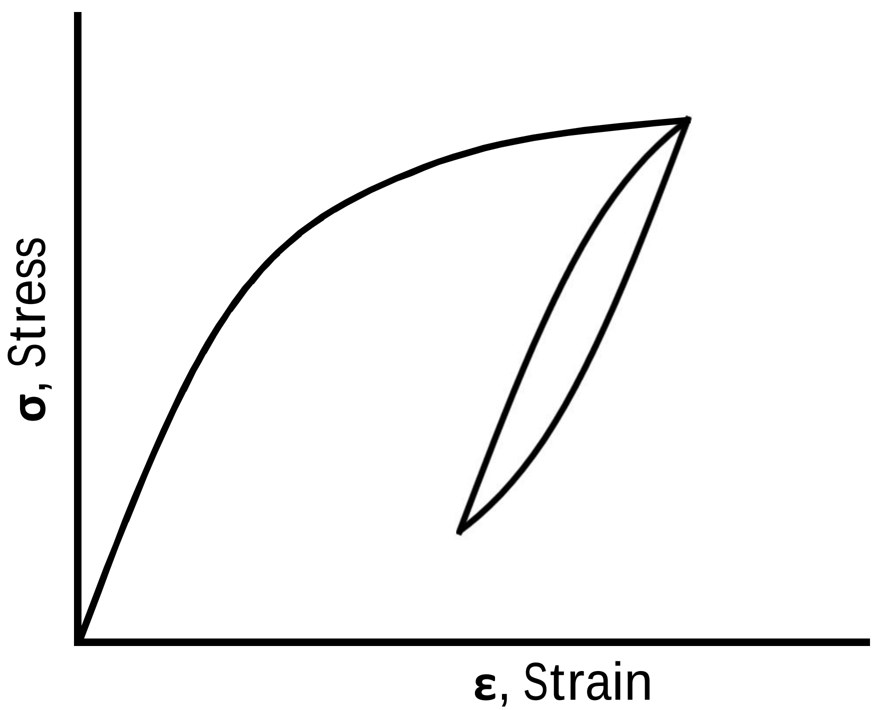

σ, Stress
ε, Strain

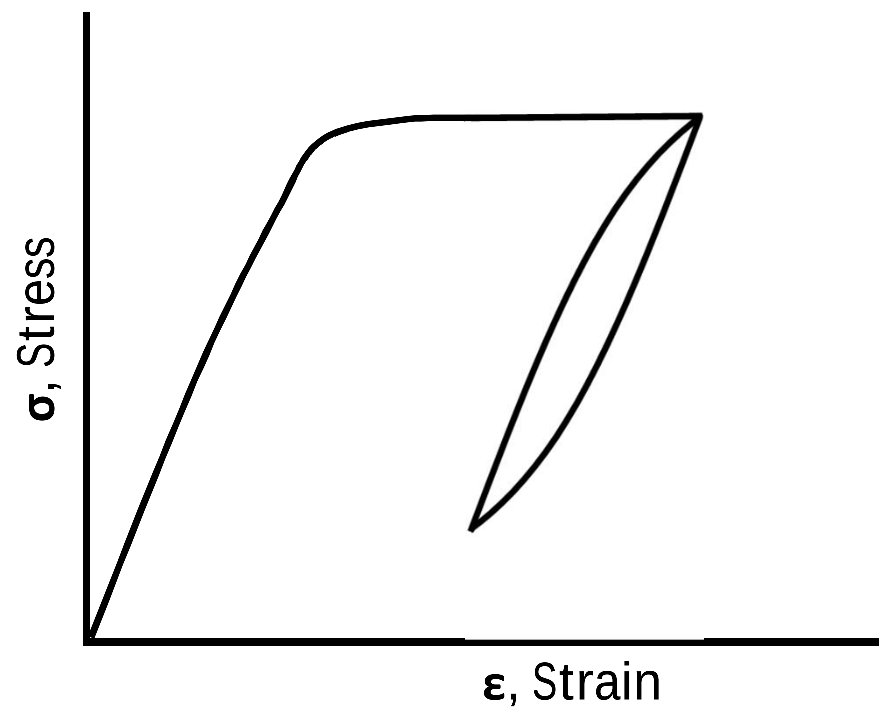

σ, Stress
ε, Strain



b
$UTS(\sigma_{ar})$
$\sigma_{max}(\sigma_{ar})$
σ, Stress
$2N_f: UTS(\sigma_{ar})$
2Nf, Life
$2N_f: \sigma_{max}(\sigma_{ar})$

Cyclic vs monotonic σ-ε





Lower $\boldsymbol{b_{mono}}$

Higher $\boldsymbol{b_{mono}}$