Life Prediction Sensitivity Study - Residual Stress vs. Mean Stress Correction

SAE FDE Committee Meeting
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Date: Oct 16, 2014

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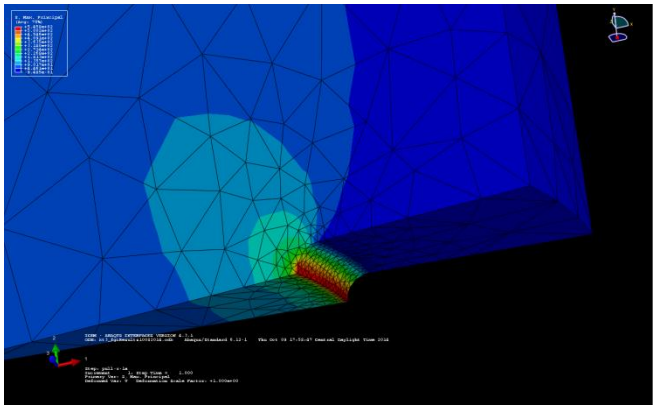
Agenda

- Study Objectives
- Model Inputs
- Residual Stress and Mean Stress Correction's Impact on B50 Life
- Residual Stress and Mean Stress Correction's Impact of % Failure Rate
- Summary

Study Objectives

- To understand the impact on fatigue life and % failure rate due to variations in residual stress and for different mean stress correction methods while keeping alternating stress constant.

Model Inputs



- Material – SAE 4130 Steel
  - UTS = 896MPa
  - YS = 778MPa
  - Se_{B50} = 400MPa at 1E6 cycles
- Loading COV = 5%
- Notched FE Model, Kt = 3.0
- Fatigue Analyzer – fesafe – Strain Life w/ UHCF Slope b/2 @ Se
- Constant Amplitude Stress in Notch = 286MPa
- Residual Stress / Mean Stress Variations: -450MPa, -225MPa, 0, 225MPa, 450MPa
- Mean Stress Correction Methods: SWT, Morrow, Goodman and Modified Goodman

SAE 4130 Material Props

SAFE TECHNOLOGY LTD MATERIAL DEFINITION FILE

COMMENT-1
Alloy Steel AISI4130 STEEL

COMMENT-2
TEMPERED MARTENSITE

CONSTANT-AMPLITUDE-ENDURANCE-LIMIT(2nf)
2e+030

POISSONS-RATIO
0.33

YOUNGS-MODULUS(MPa)
220640

0.2%-PROOF-STRESS(MPa)
779.1

ULTIMATE-TENSILE-STRENGTH(MPa)
896.4

K'-TENSILE-CYCLIC
1428

n'-TENSILE-CYCLIC
0.149

ef'-STRAIN-LIFE-CURVE
1.007

c-STRAIN-LIFE-CURVE
-0.651

Sf'-STRAIN-LIFE-CURVE
1315

b-STRAIN-LIFE-CURVE
-0.082

b2-STRAIN-LIFE-CURVE
-0.04

2nf-ABOVE-WHICH-b2-IS-USED
2e+006

S-N-CURVE

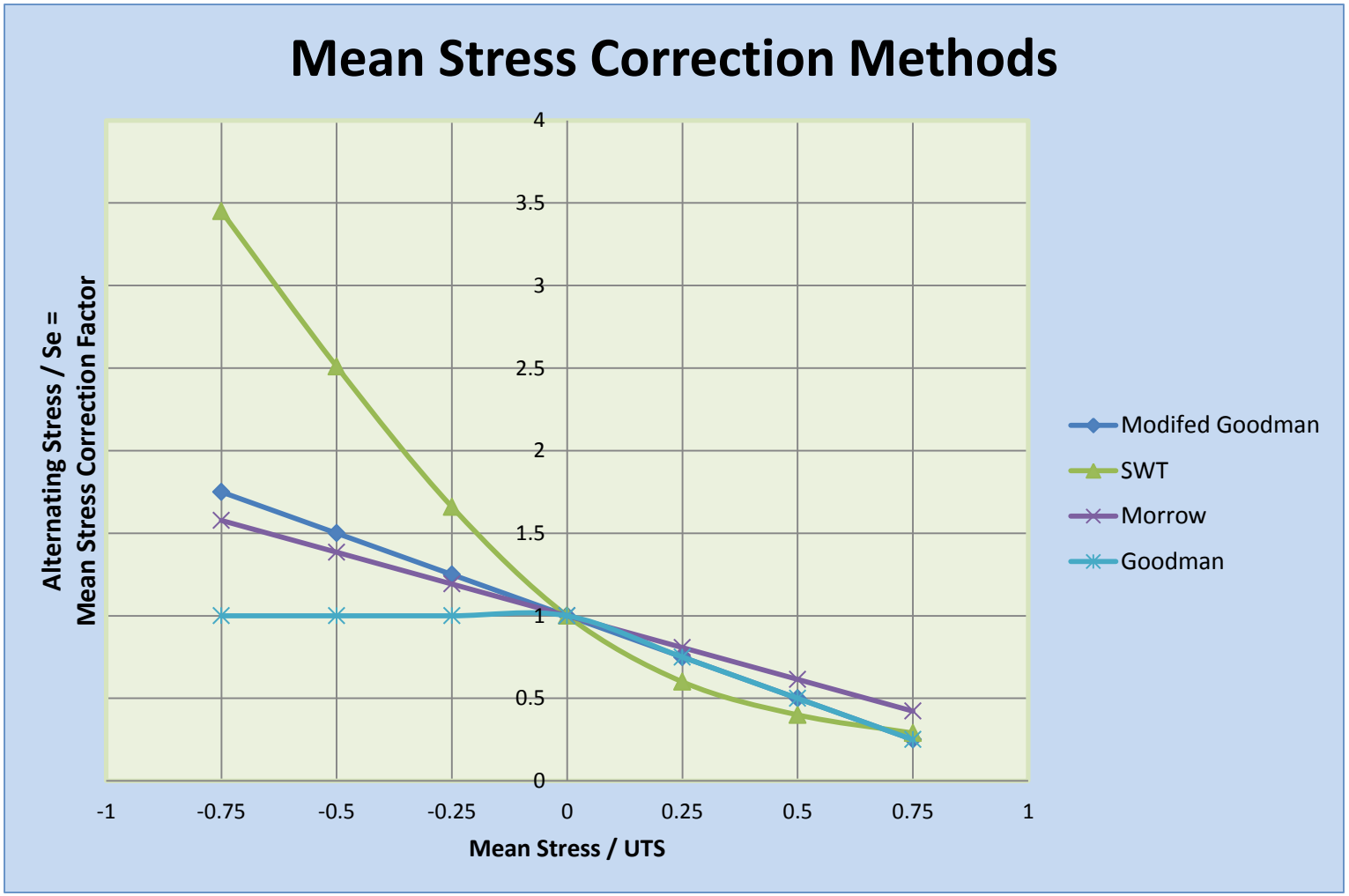
# Nf	S(MPa)
1E4	583.8
1E6	400.2

BF-PROBABILITY
3

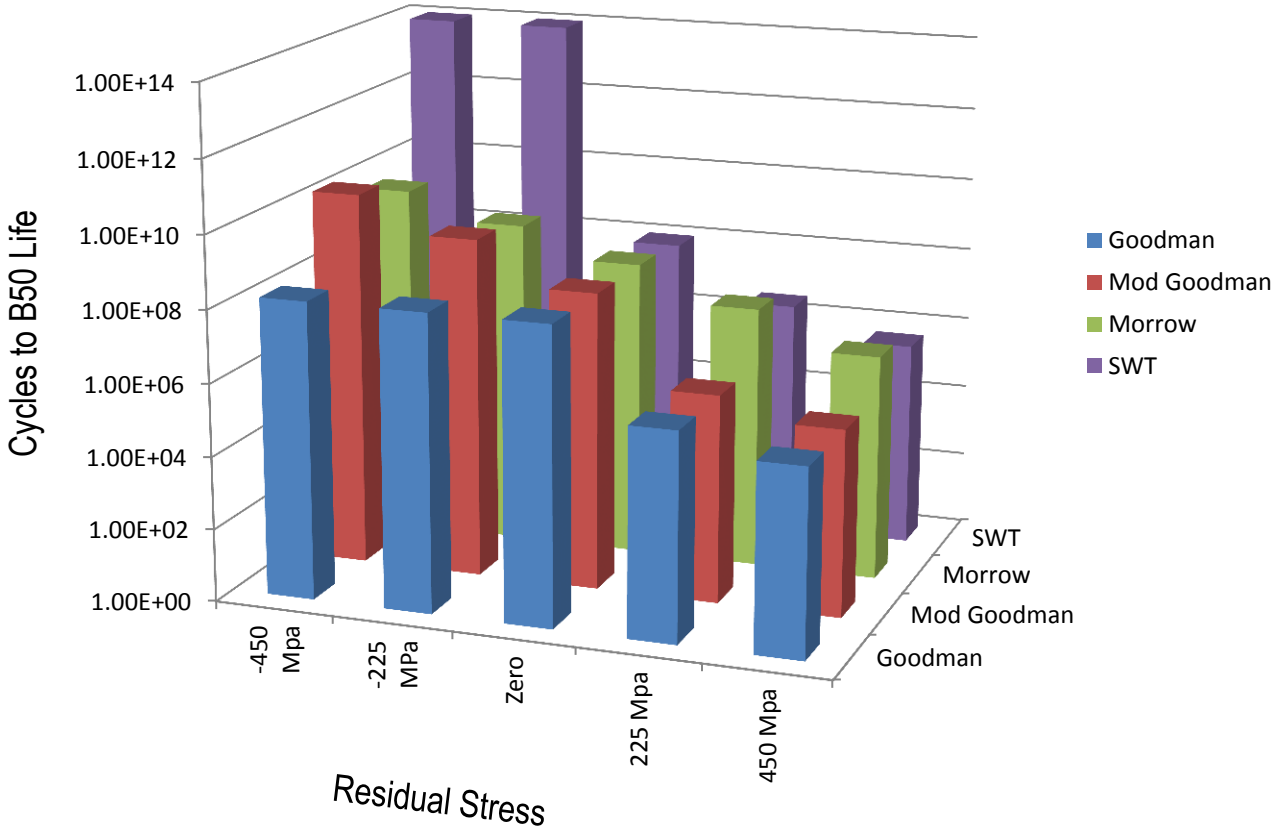
QMUF-PROBABILITY
0.5

Mean Stress Correction Method

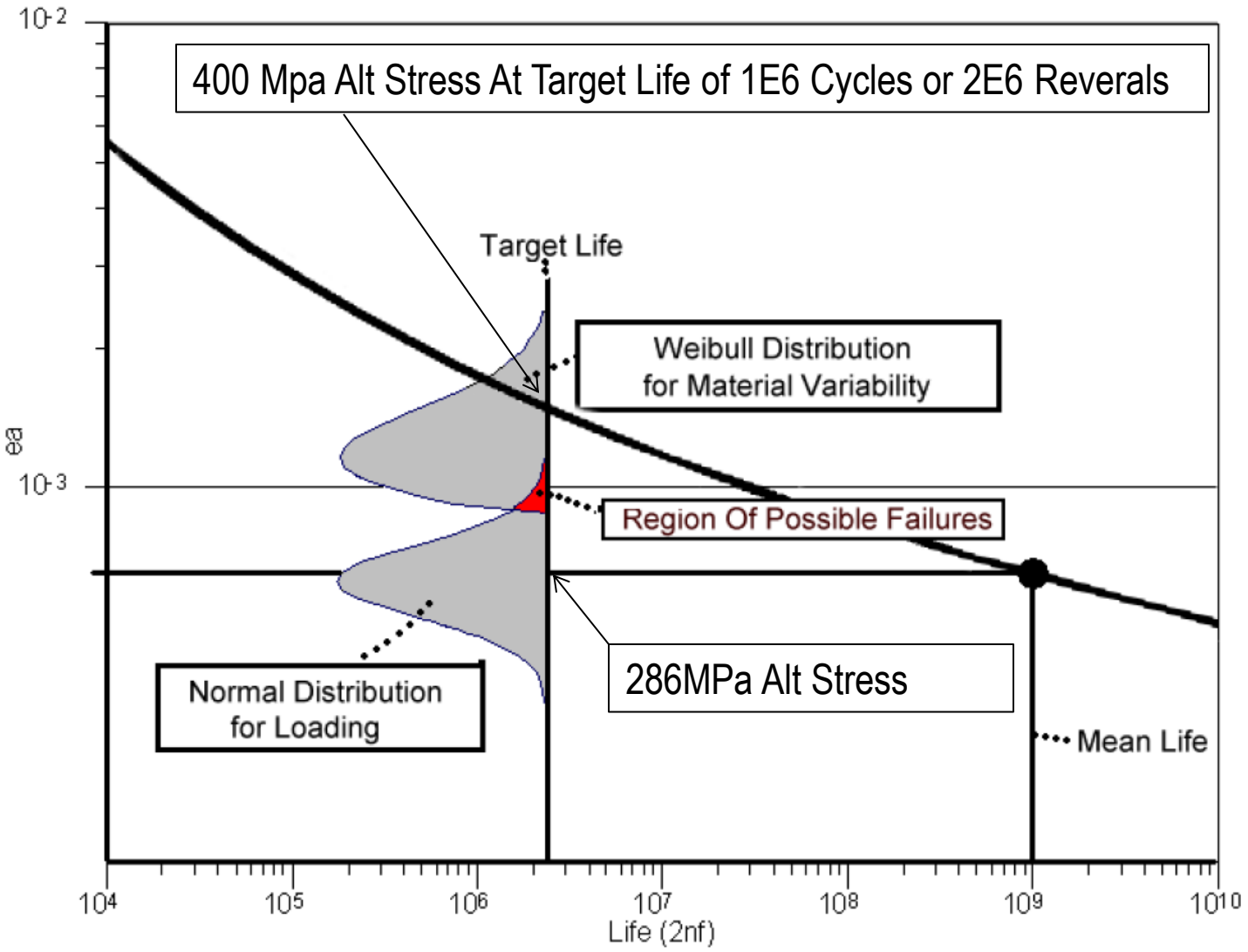
Equivalent Stress = Alt Stress / Mean Stress Correction Factor



B50 Life - Residual Stress vs. Mean Correction



Comparing B50 Life Changes from Residual Stress vs Mean Stress Correction for a Constant Amplitude Stress of 286MPa					
Residual Stress	-450 Mpa	-225 MPa	Zero	225 Mpa	450 Mpa
Goodman	1.54E+08	1.54E+08	1.54E+08	5.38E+05	1.40E+05
Mod Goodman	2.12E+10	2.29E+09	1.54E+08	5.38E+05	1.40E+05
Morrow	5.39E+09	1.02E+09	1.54E+08	1.70E+07	1.64E+06
SWT	1.00E+20	1.00E+20	9.61E+07	3.12E+06	4.46E+05


400 Mpa Alt Stress At Target Life of 1E6 Cycles or 2E6 Reverals
Target Life
Weibull Distribution
for Material Variability
Region Of Possible Failures
286MPa Alt Stress
Normal Distribution
for Loading
Mean Life
ea
10-2
10-3
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹
10¹⁰
Life (2nf)

% Failure Rate at Zero Mean Stress

Mode

Parameter	User Inputs	Unit	Sensitivity Swing +/-
Stress	286.00	Mpa	10 %
Stress SD (%)	5.000	%	10 %
Fatigue Strength	400.00	MPa	10 %
Minimum Value	50.00	%	10 %
Weibull Slope	3.000	-	10 %
Failure Rate	**5.754**	%	**10** %

Calculate

Export Results

Generic Material - Typical Fatigue Properties for 1E6 Cycles

Flake Graphite Iron - High Grade

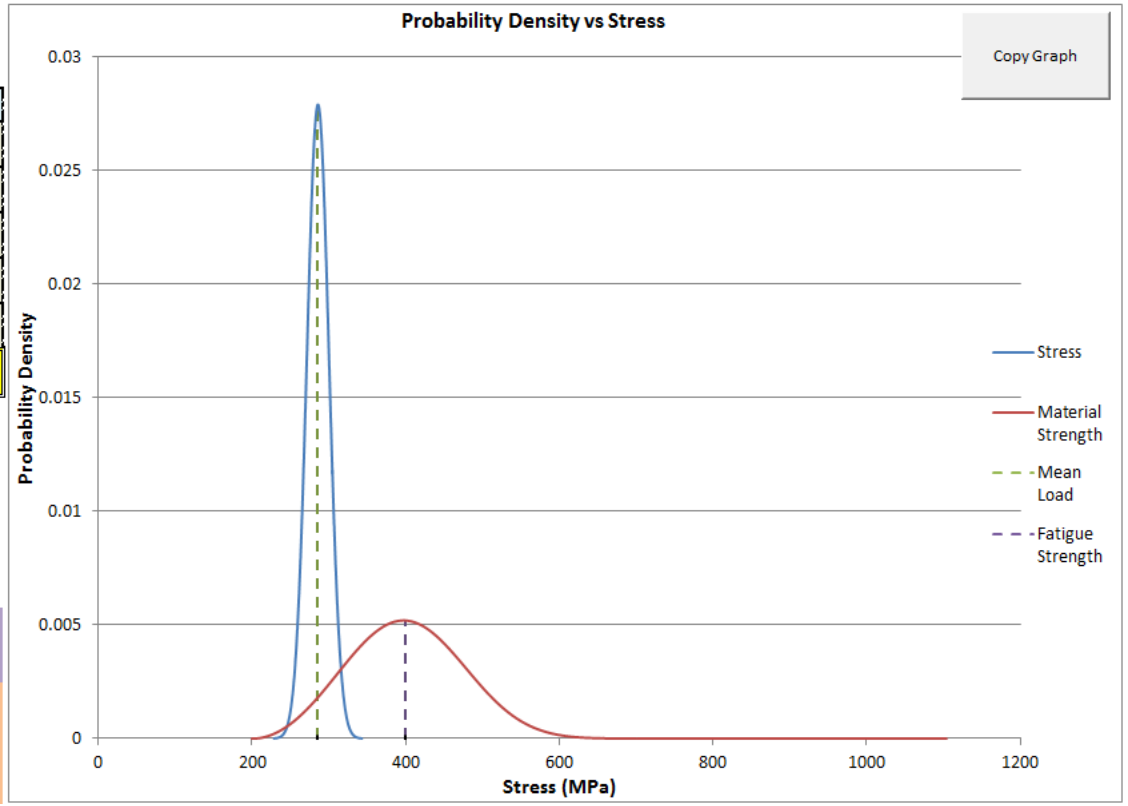
Use Material

Read Fatigue Parameters from Material File

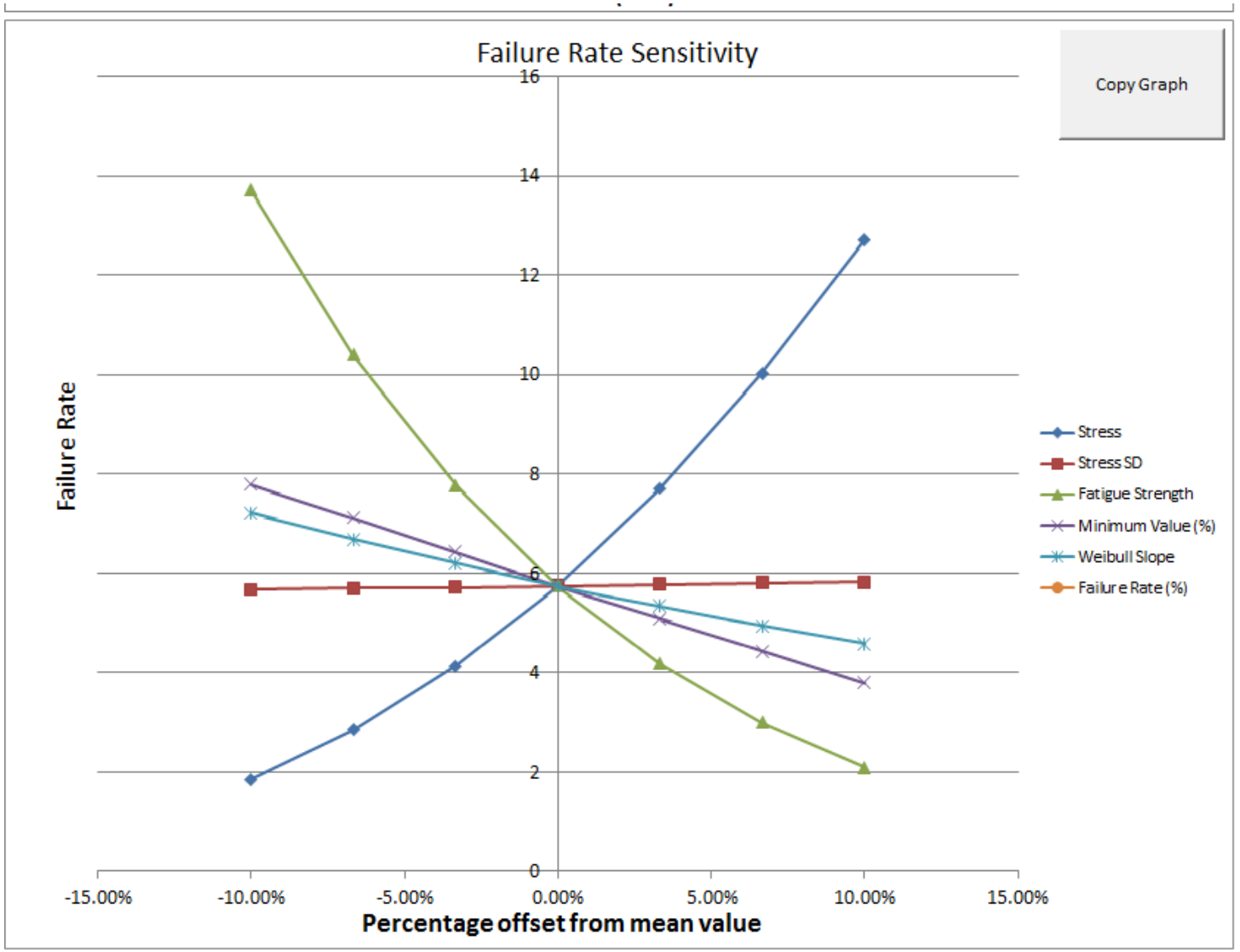
Number of cycles 1.00E+04

Material File Directory Z:\std_data\matl

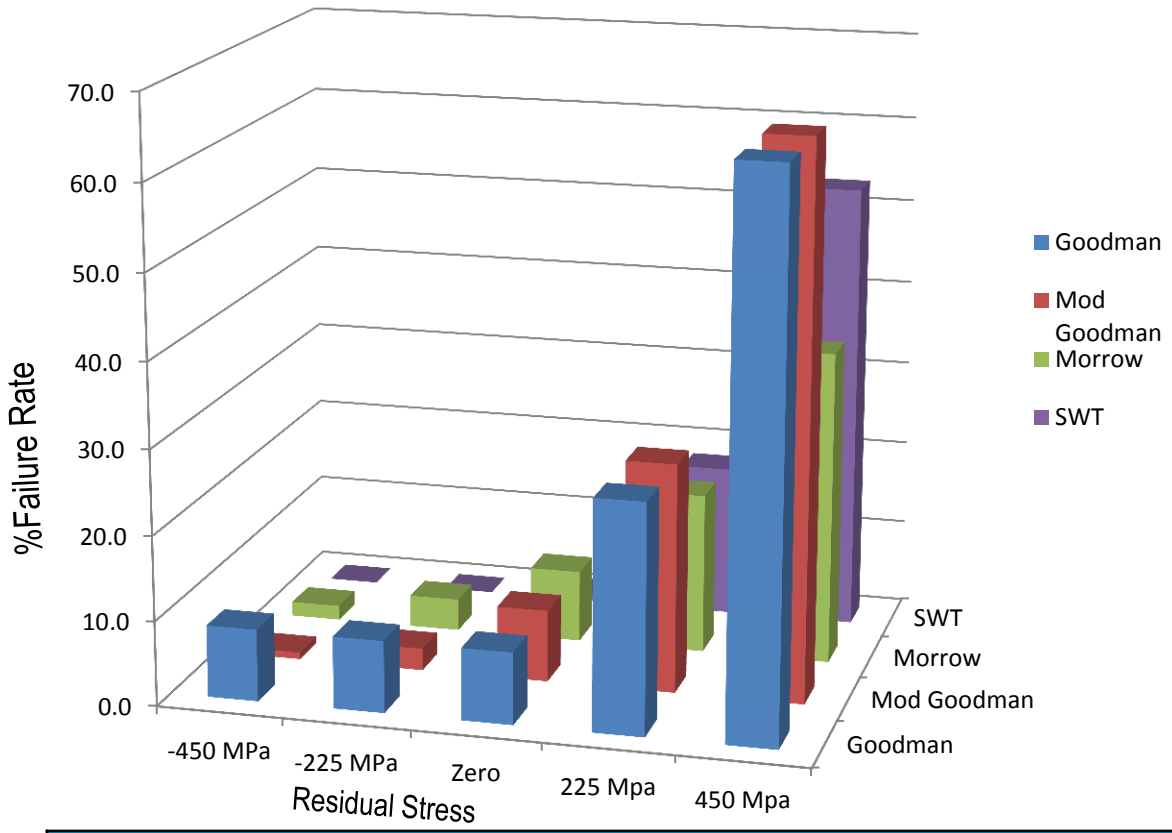
Extension



Failure Rate Sensitivity Study



%Failure Rate - Residual Stress vs. Mean Correction



Comparing % Failure Rate @ 1E6 Cycles for Residual Stress vs Mean Stress Correction for a Constant Amplitude Stress of 286MPa					
Residual Stress	-450 MPa	-225 MPa	Zero	225 Mpa	450 Mpa
Goodman	8.5	8.5	8.5	27.0	65.0
Mod Goodman	0.8	2.6	8.5	27.0	65.0
Morrow	1.7	3.8	8.5	19.0	37.0
SWT	0.0	0.0	0.9	18.0	53.0

Summary

- Residual stress can change fatigue life and the % Failure Rate dramatically!
- Mean Stress Correction Method vary fatigue life significantly when the mean stress is in compression. It's good idea to due some fatigue testing to find out what real effect is on life due to mean stress.
- These residual stresses come from manufacturing processes and are not always accounted for. Assuming zero residual stress can be a poor assumption. Xray, Hole Drilling, Slitting and Contour are processes to extract the residual stresses.
- There are many ways to impart compressive residual stress – shot peening, shot blasting, rolling, coining, heat treat, grinding, machining, etc.