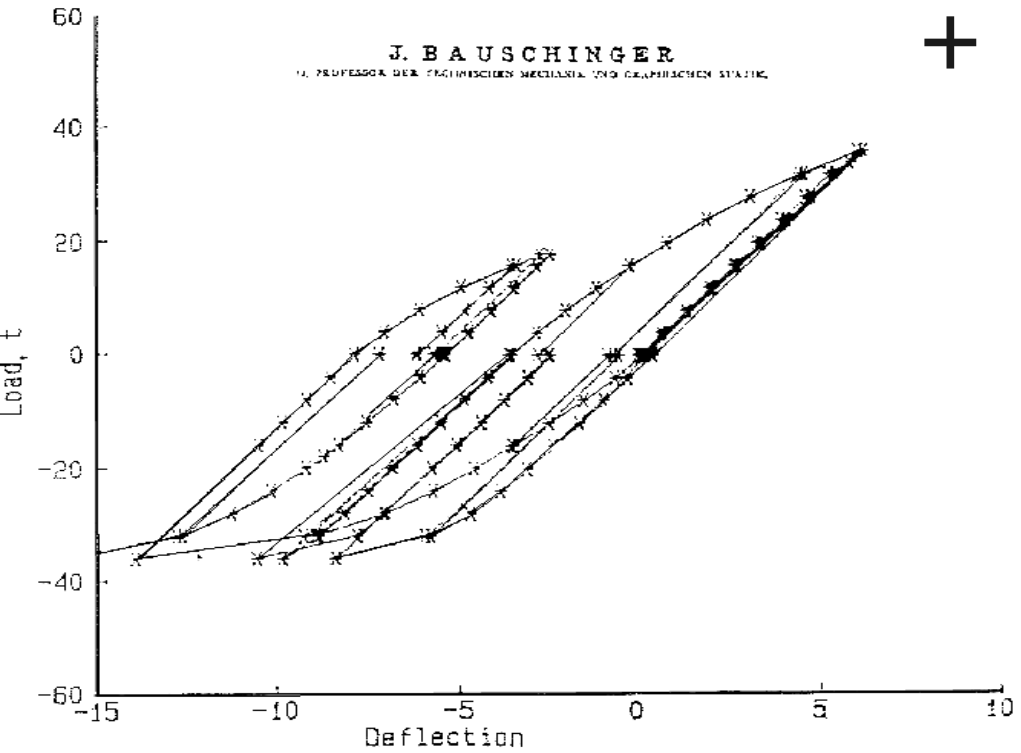
Crack Propagation Program with Material Memory Effect Simulation

Al Conle, U. Windsor, Canada
F.D.+E. Ames, Iowa, Apr. 25 2013



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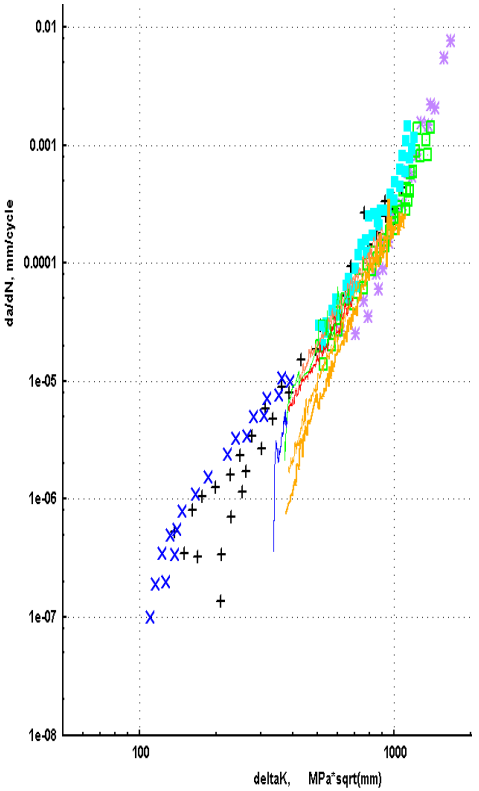
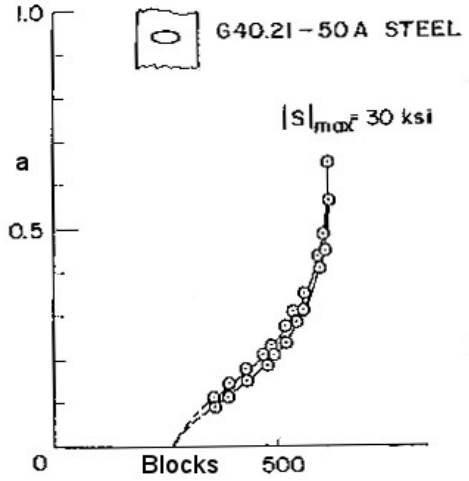
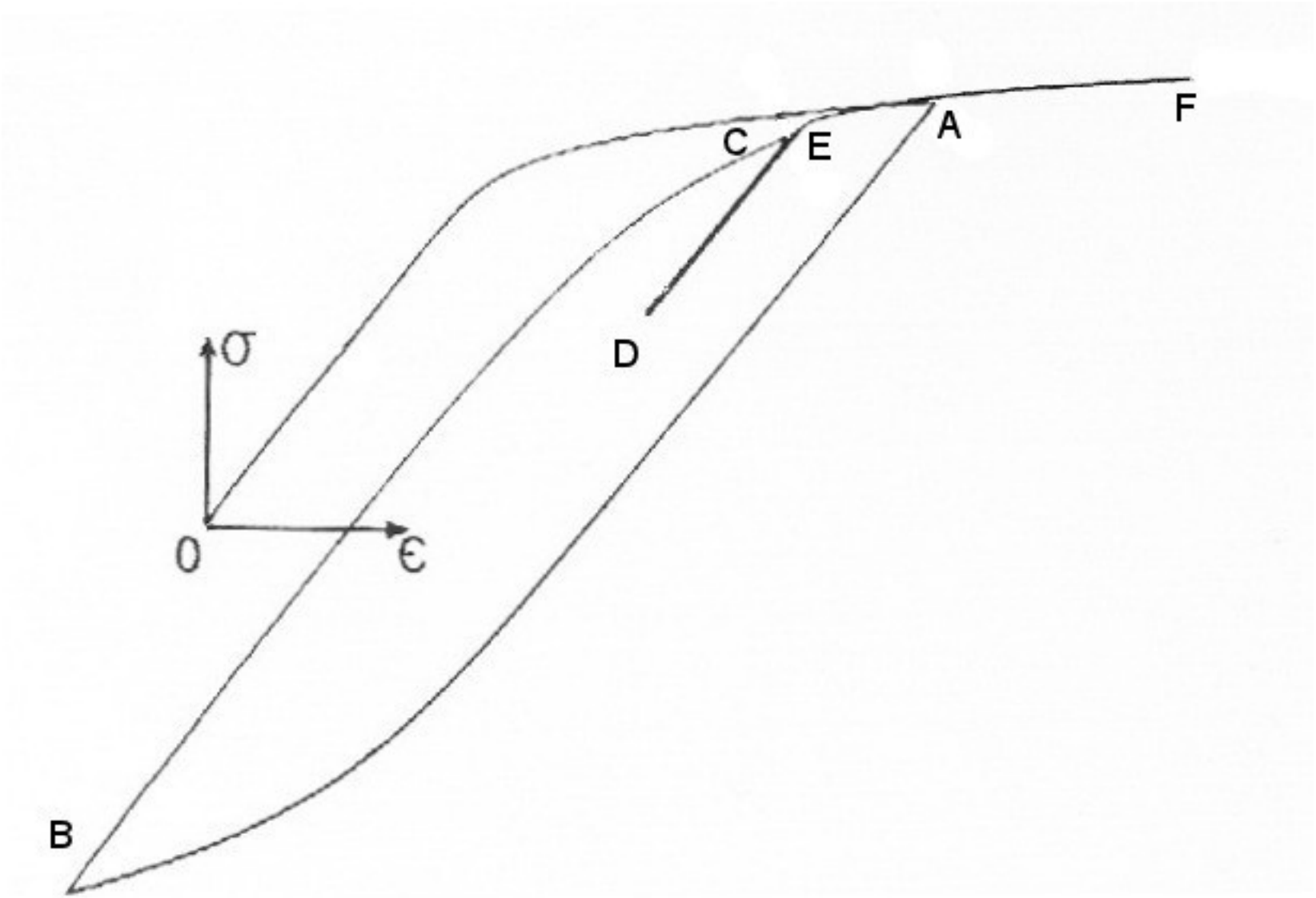
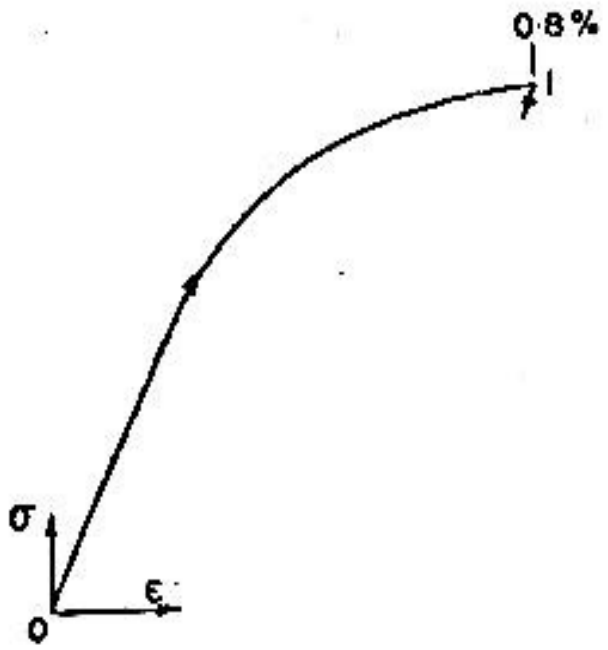


=

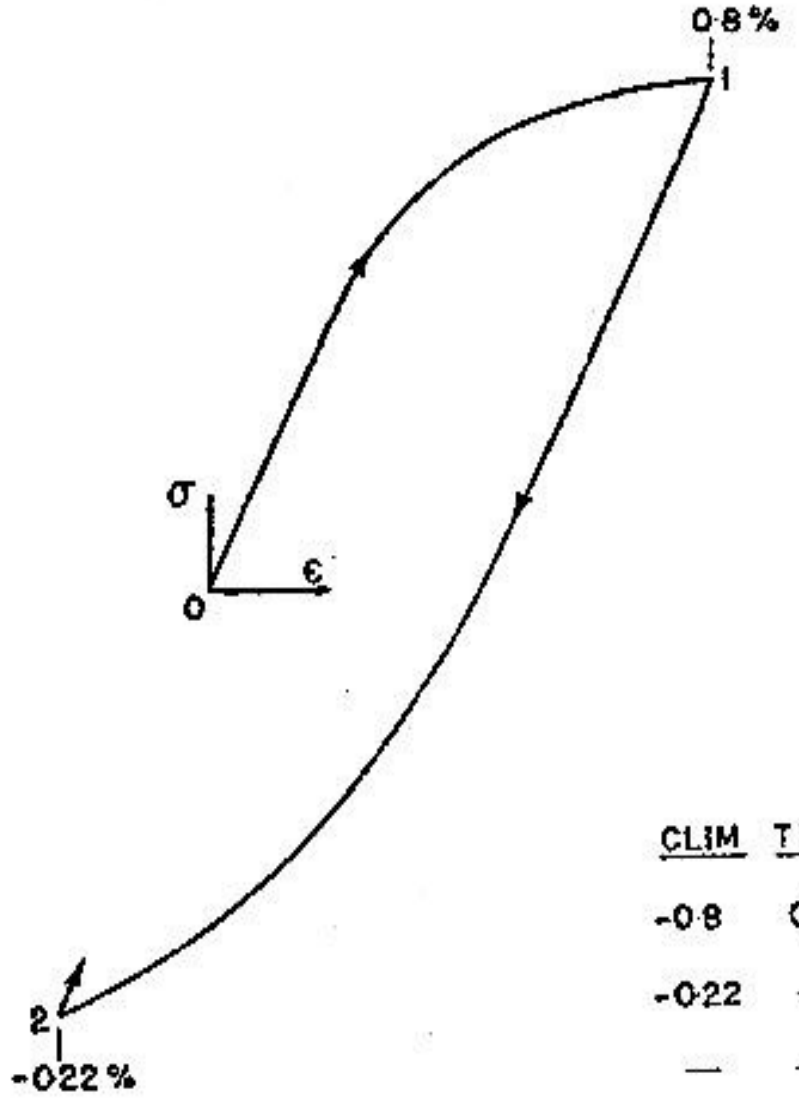



F
A
C
E
D
σ
0
ϵ
B



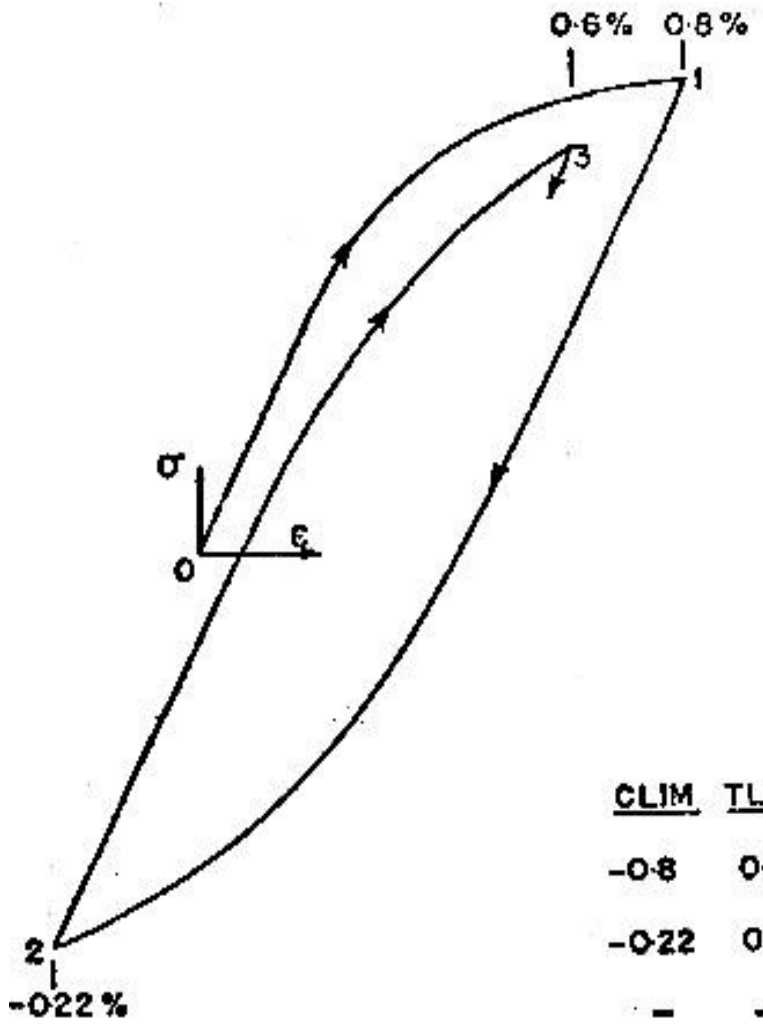
CLIM	TLIM
-0·8	0·8
—	—
—	—
—	—

(a)



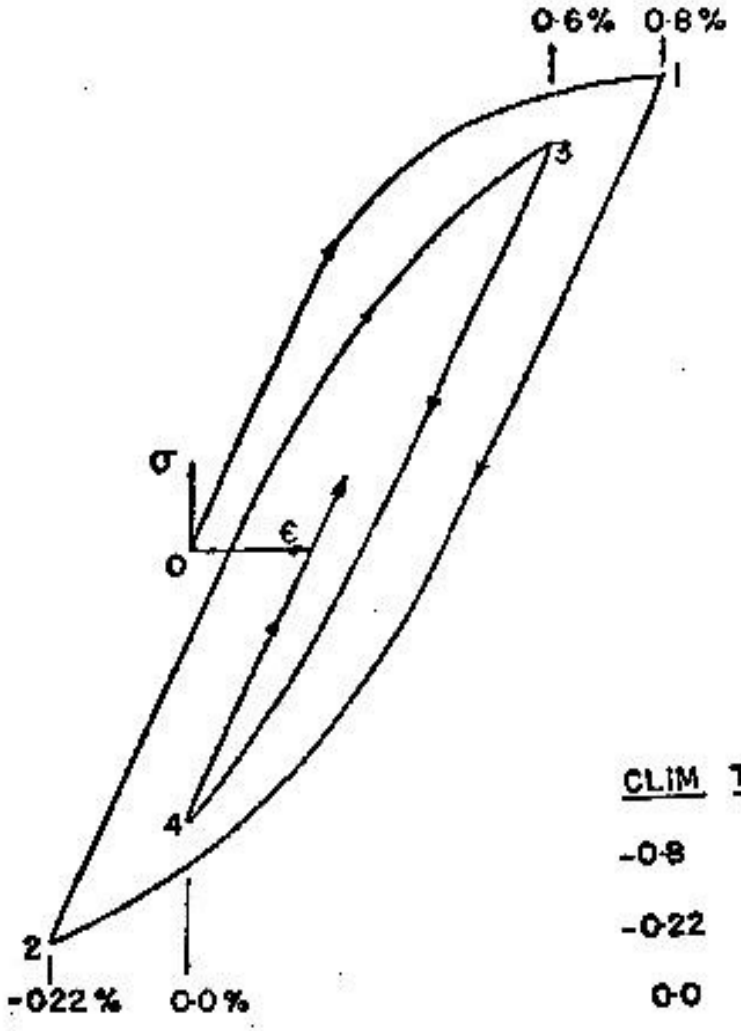
CLIM	TLIM
-0·8	0·8
-0·22	—
—	—
—	—

(b)



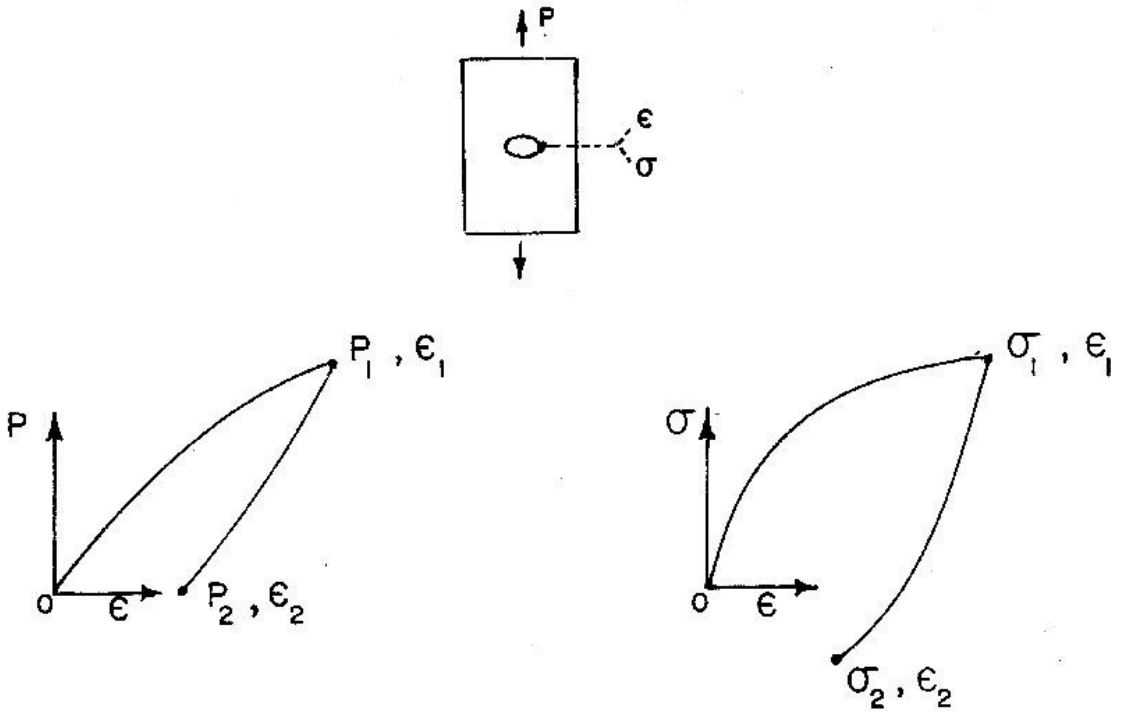
CLIM	TLIM
-0·8	0·8
-0·22	0·6
-	-
-	-

(c)



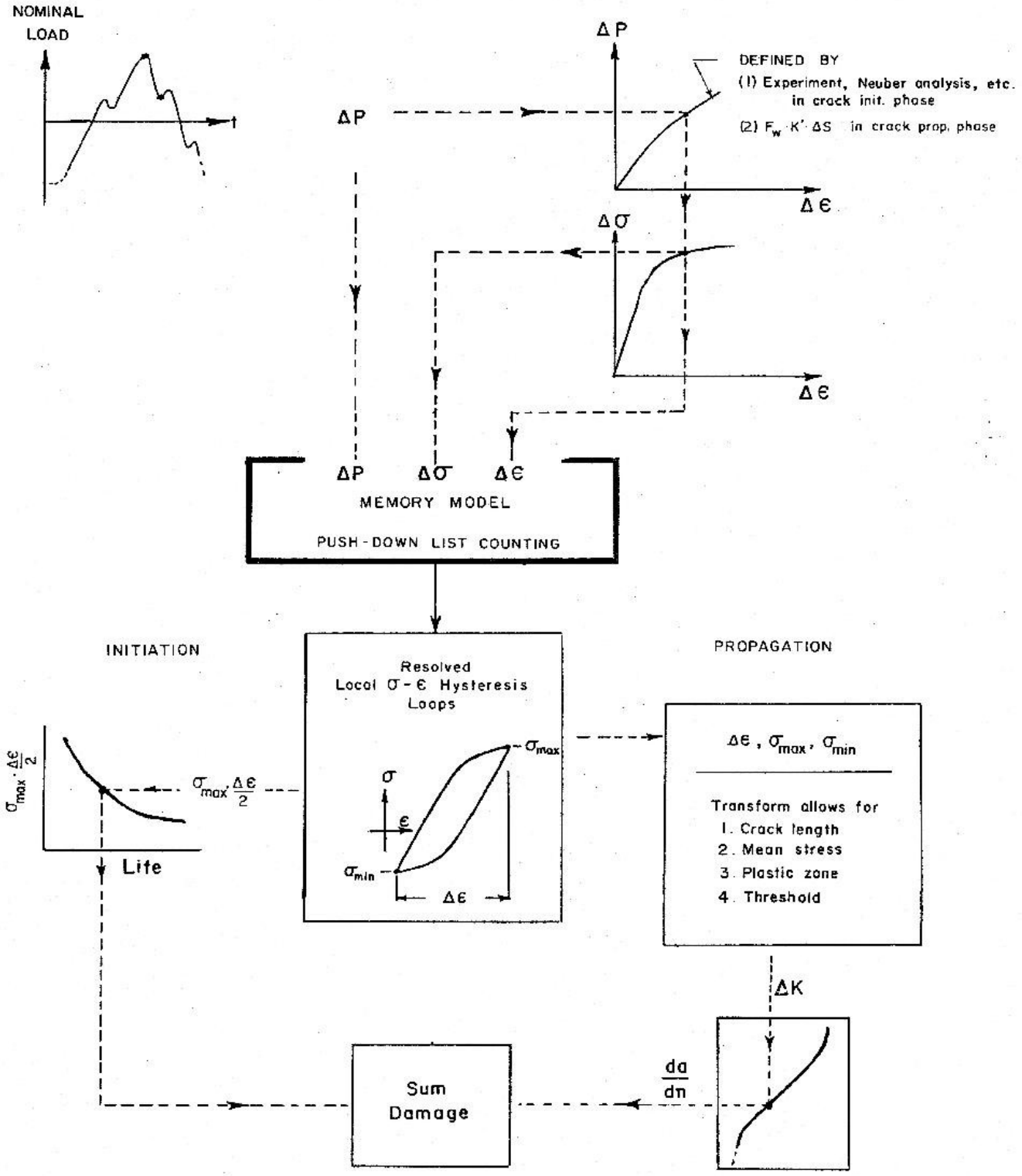
CLIM	TLIM
-0·8	0·8
-0·22	0·6
0·0	-
-	-

(d)

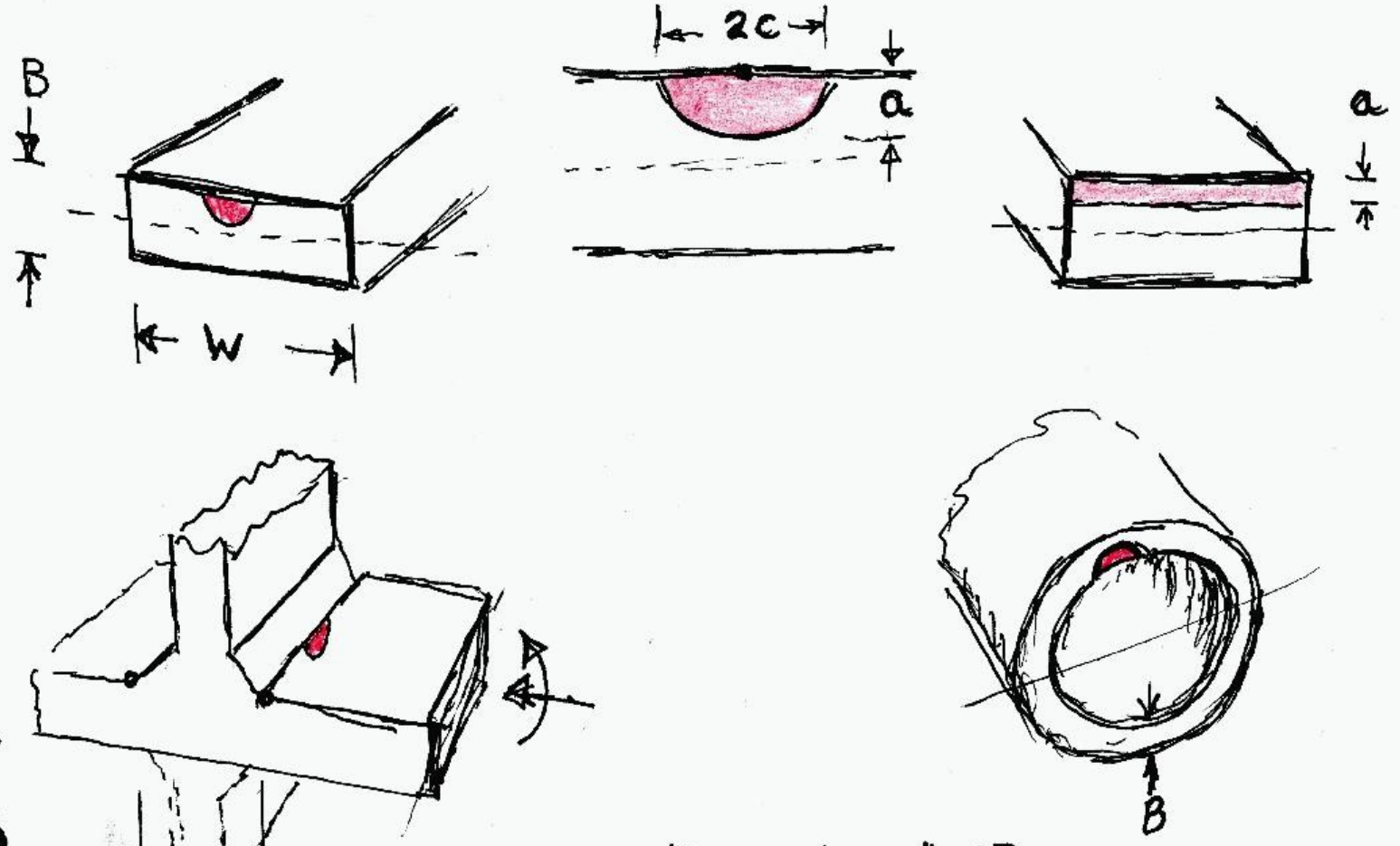


STACKS

COMPRESSION				TENSION			
DAMAGE	STRESS	STRAIN	LOAD	LOAD	STRAIN	STRESS	DAMAGE
D_{01}	$-\sigma_1$	$-\epsilon_1$	$-P_1$	P_1	ϵ_1	σ_1	D_{01}
D_{12}	σ_2	ϵ_2	P_2	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–

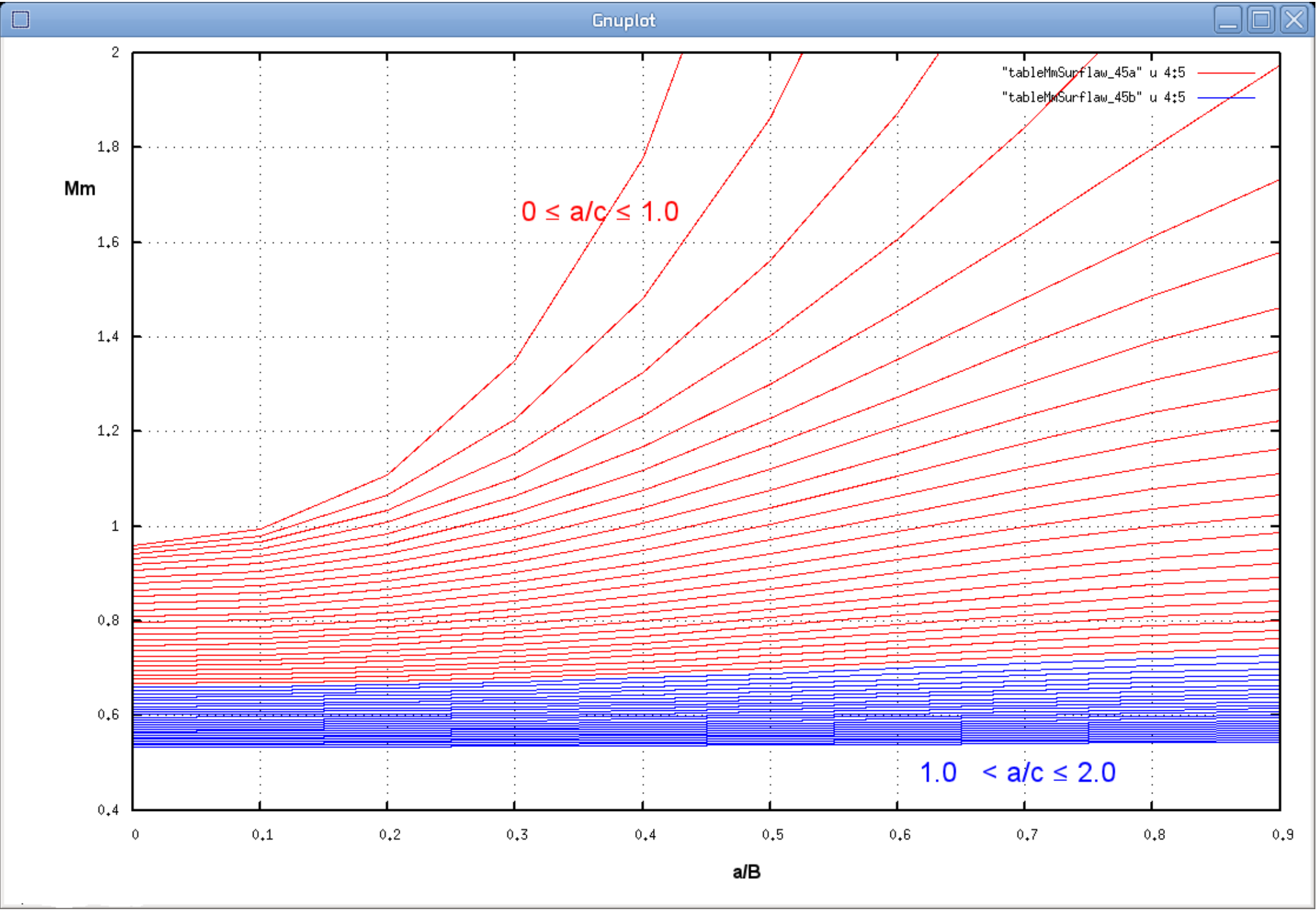

NOMINAL
LOAD
t
ΔP
Δε
DEFINED BY
(1) Experiment, Neuber analysis, etc.
in crack init. phase
(2) $F_w \cdot K' \cdot \Delta S$ in crack prop. phase
Δσ
Δε
ΔP Δσ Δε
MEMORY MODEL
PUSH-DOWN LIST COUNTING
INITIATION
Resolved
Local σ - ε Hysteresis
Loops
PROPAGATION
$\sigma_{max} \cdot \frac{\Delta\varepsilon}{2}$
$\sigma_{max} \cdot \frac{\Delta\varepsilon}{2}$
Life
σ_{max}
σ
ε
σ_{min}
Δε
Δε , σ_{max}, σ_{min}
Transform allows for
1. Crack length
2. Mean stress
3. Plastic zone
4. Threshold
ΔK
Sum
Damage
$\frac{da}{dn}$

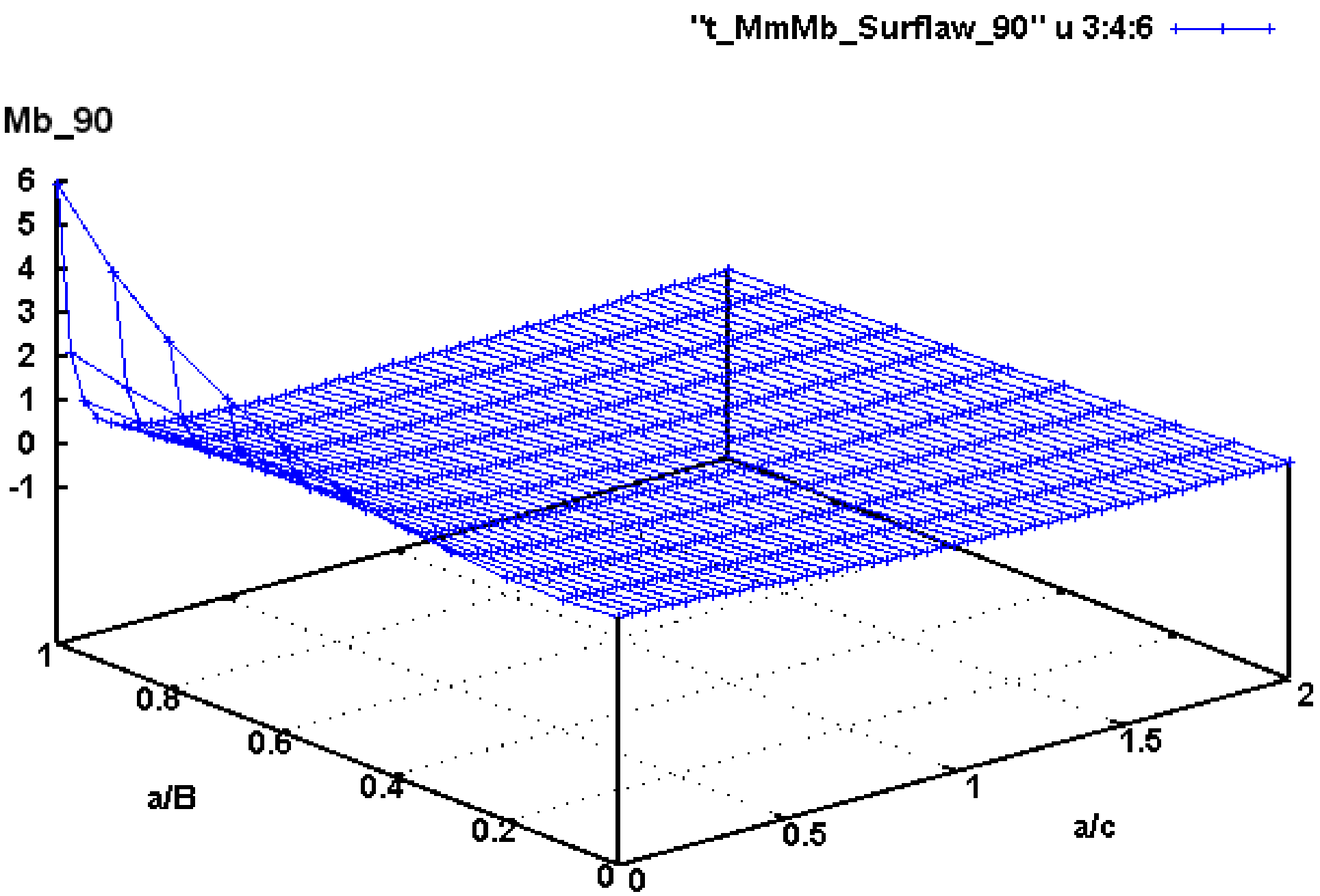
Stress Intensity K follows Br. Std. BS-7910

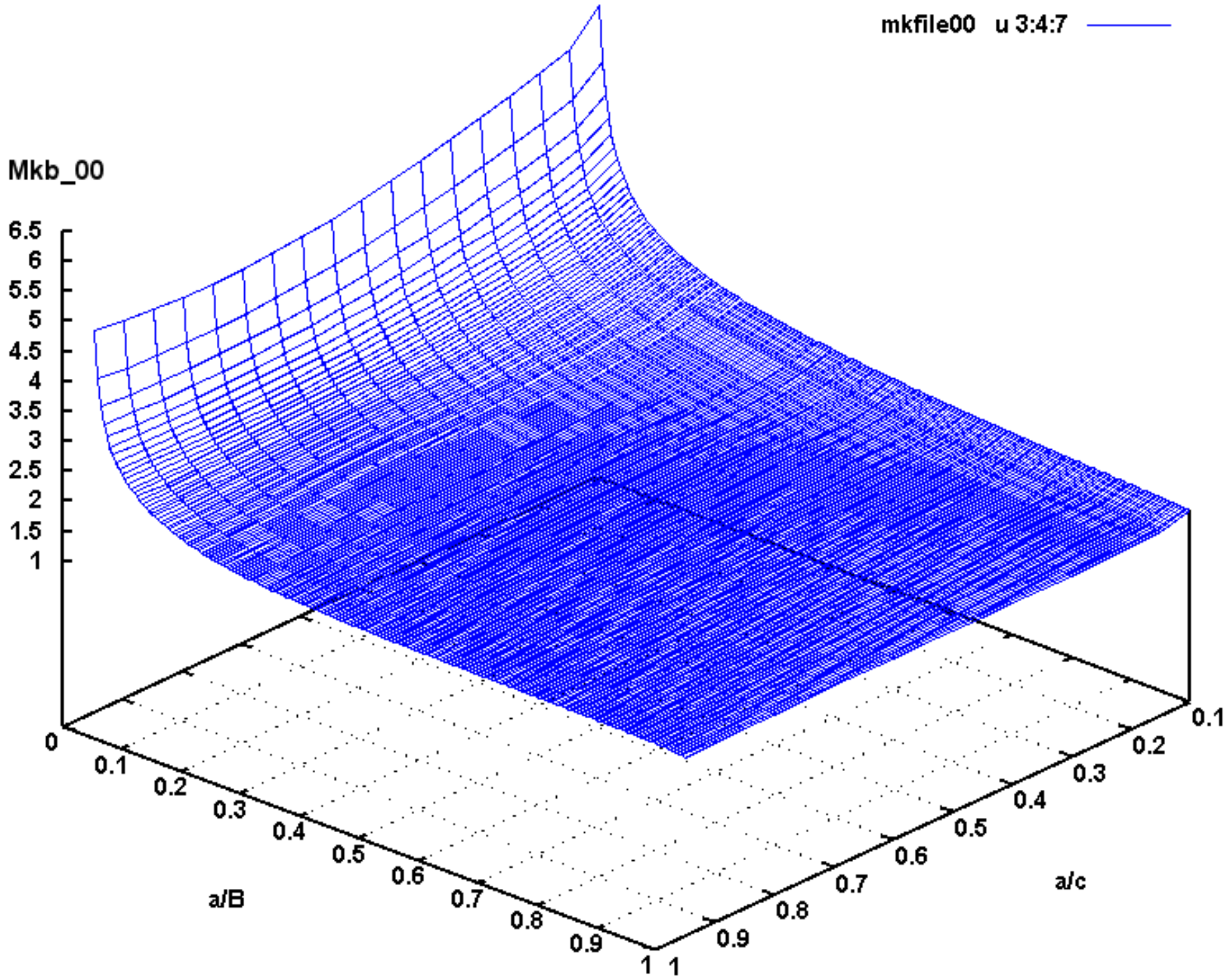


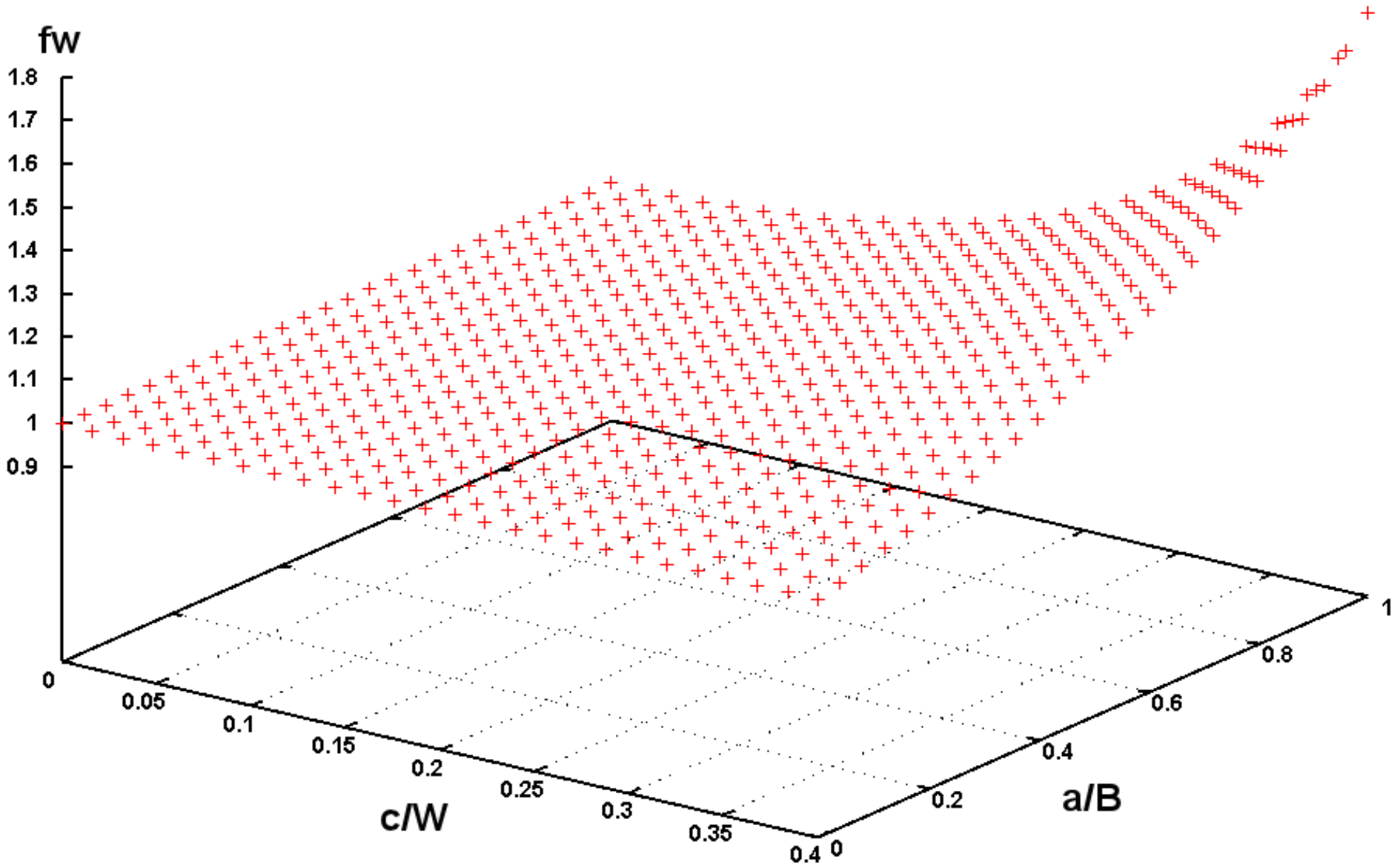
$a/B,\ a/c,\ L/B$

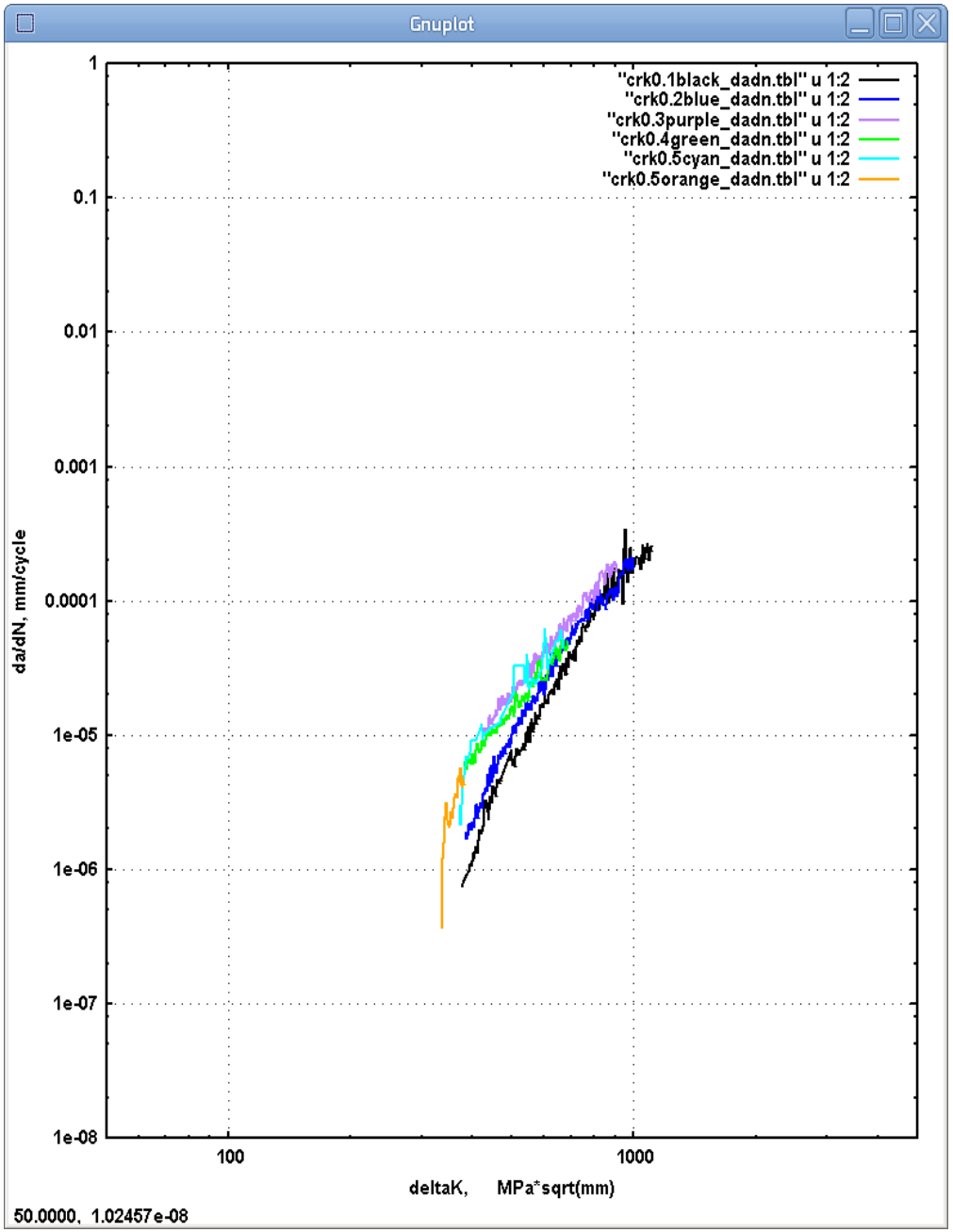
$$Y\sigma_1 = M f_w \left[k_{tm} \cdot M_{km} \cdot M_m \cdot P_m + k_{tb} \cdot M_{kb} \cdot M_b \cdot \{ P_b + (k_m - 1) P_m \} \right]$$

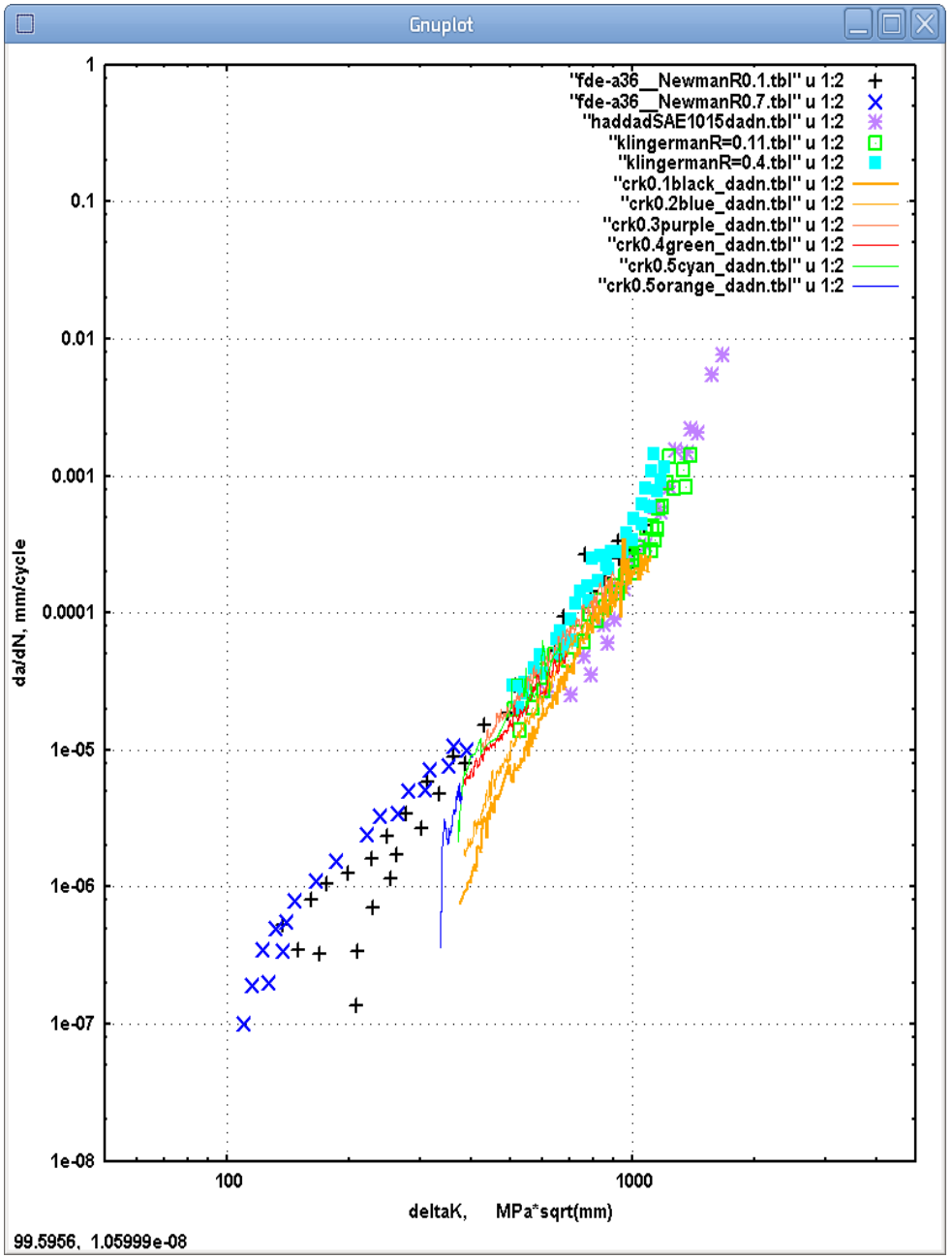

Gnuplot
"tableMmSurflaw_45a" u 4:5
"tableMmSurflaw_45b" u 4:5
0 ≤ a/c ≤ 1.0
1.0 < a/c ≤ 2.0
Mm
a/B
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

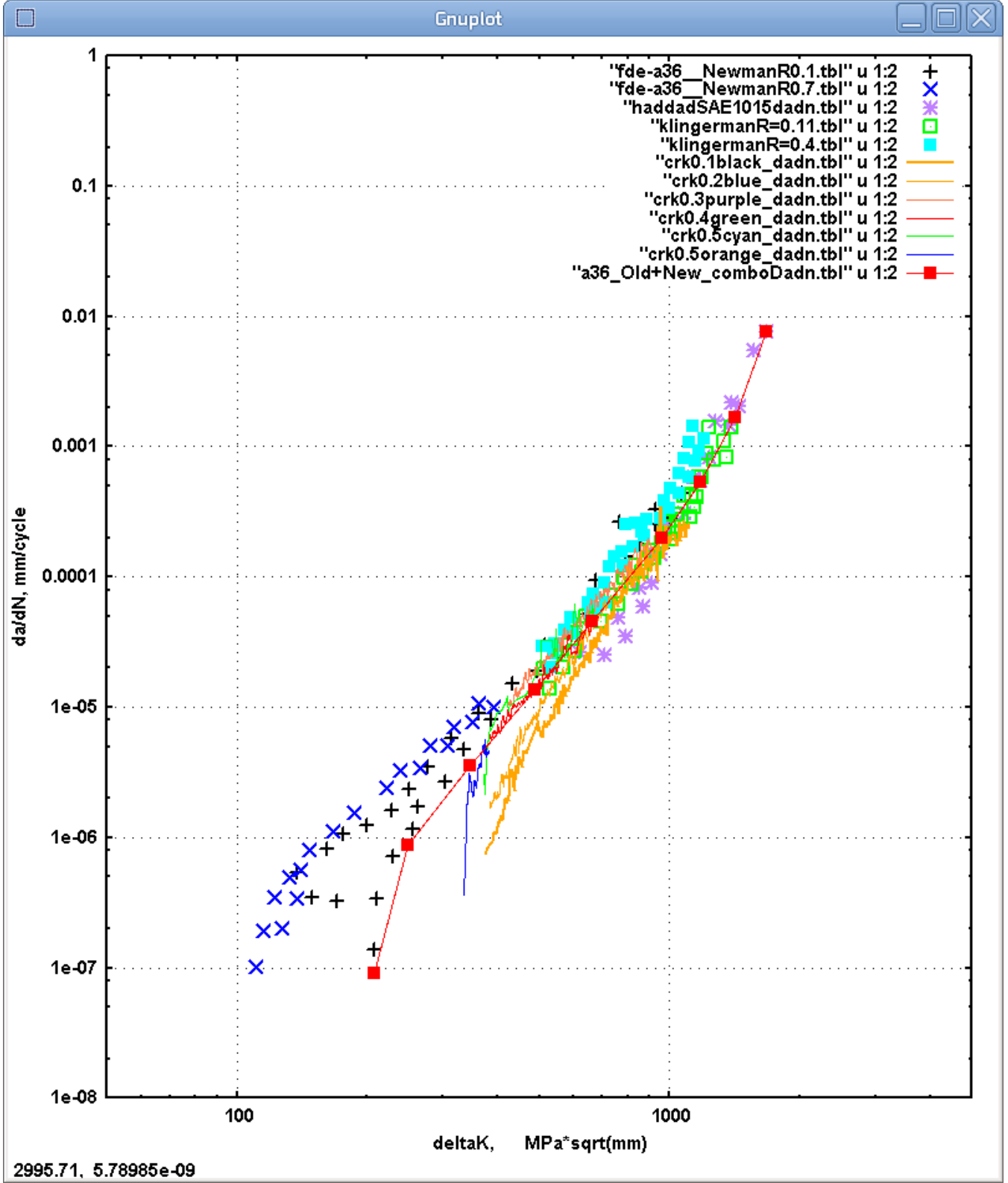

"t_MmMb_Surflaw_90" u 3:4:6
Mb_90
6
5
4
3
2
1
0
-1
1
0.8
0.6
0.4
0.2
0
a/B
0
0.5
1
1.5
2
a/c


mkfile00 u 3:4:7
Mkb_00
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
a/B
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
a/c


"fwData4Plot" u 3:4:5
fw
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
c/W
0
0.2
0.4
0.6
0.8
1
a/B


Gnuplot
"crk0.1black_dadn.tbl" u 1:2
"crk0.2blue_dadn.tbl" u 1:2
"crk0.3purple_dadn.tbl" u 1:2
"crk0.4green_dadn.tbl" u 1:2
"crk0.5cyan_dadn.tbl" u 1:2
"crk0.5orange_dadn.tbl" u 1:2
da/dN, mm/cycle
deltaK, MPa*sqrt(mm)
50.0000, 1.02457e-08

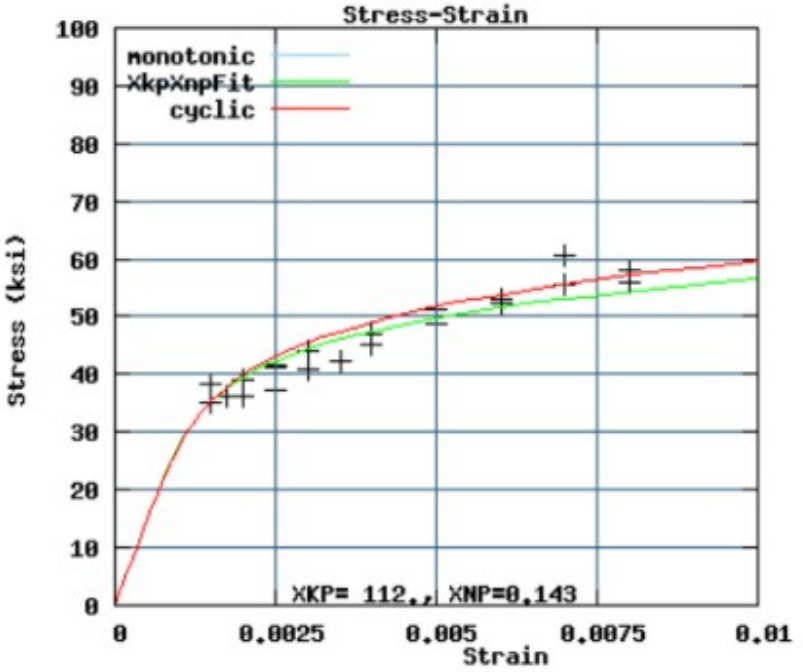

Gnuplot
"fde-a36__NewmanR0.1.tbl" u 1:2
"fde-a36__NewmanR0.7.tbl" u 1:2
"haddadSAE1015dadn.tbl" u 1:2
"klingermanR=0.11.tbl" u 1:2
"klingermanR=0.4.tbl" u 1:2
"crk0.1black_dadn.tbl" u 1:2
"crk0.2blue_dadn.tbl" u 1:2
"crk0.3purple_dadn.tbl" u 1:2
"crk0.4green_dadn.tbl" u 1:2
"crk0.5cyan_dadn.tbl" u 1:2
"crk0.5orange_dadn.tbl" u 1:2
da/dN, mm/cycle
deltaK, MPa*sqrt(mm)
99.5956, 1.05999e-08

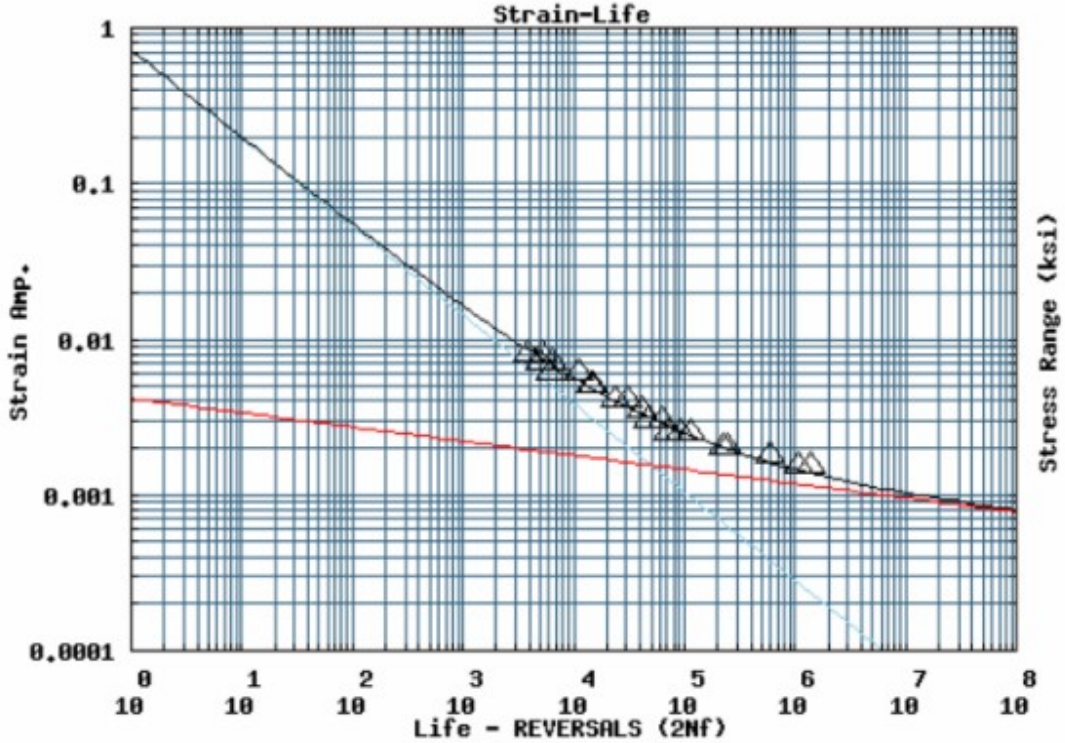

Gnuplot
"fde-a36__NewmanR0.1.tbl" u 1:2
"fde-a36__NewmanR0.7.tbl" u 1:2
"haddadSAE1015dadn.tbl" u 1:2
"klingermanR=0.11.tbl" u 1:2
"klingermanR=0.4.tbl" u 1:2
"crk0.1black_dadn.tbl" u 1:2
"crk0.2blue_dadn.tbl" u 1:2
"crk0.3purple_dadn.tbl" u 1:2
"crk0.4green_dadn.tbl" u 1:2
"crk0.5cyan_dadn.tbl" u 1:2
"crk0.5orange_dadn.tbl" u 1:2
"a36_Old+New_comboDadn.tbl" u 1:2
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
1e-07
1e-08
da/dN, mm/cycle
100
1000
deltaK, MPa*sqrt(mm)
2995.71, 5.78985e-09

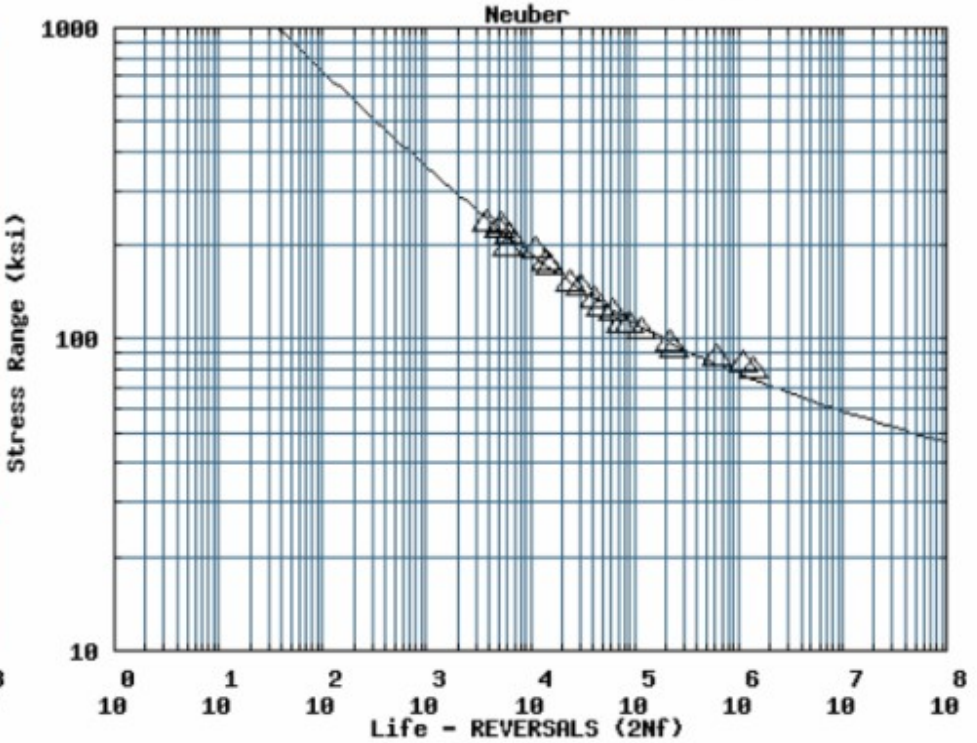
ASTM-A36 Normalized BHN= 138 Fn= 0

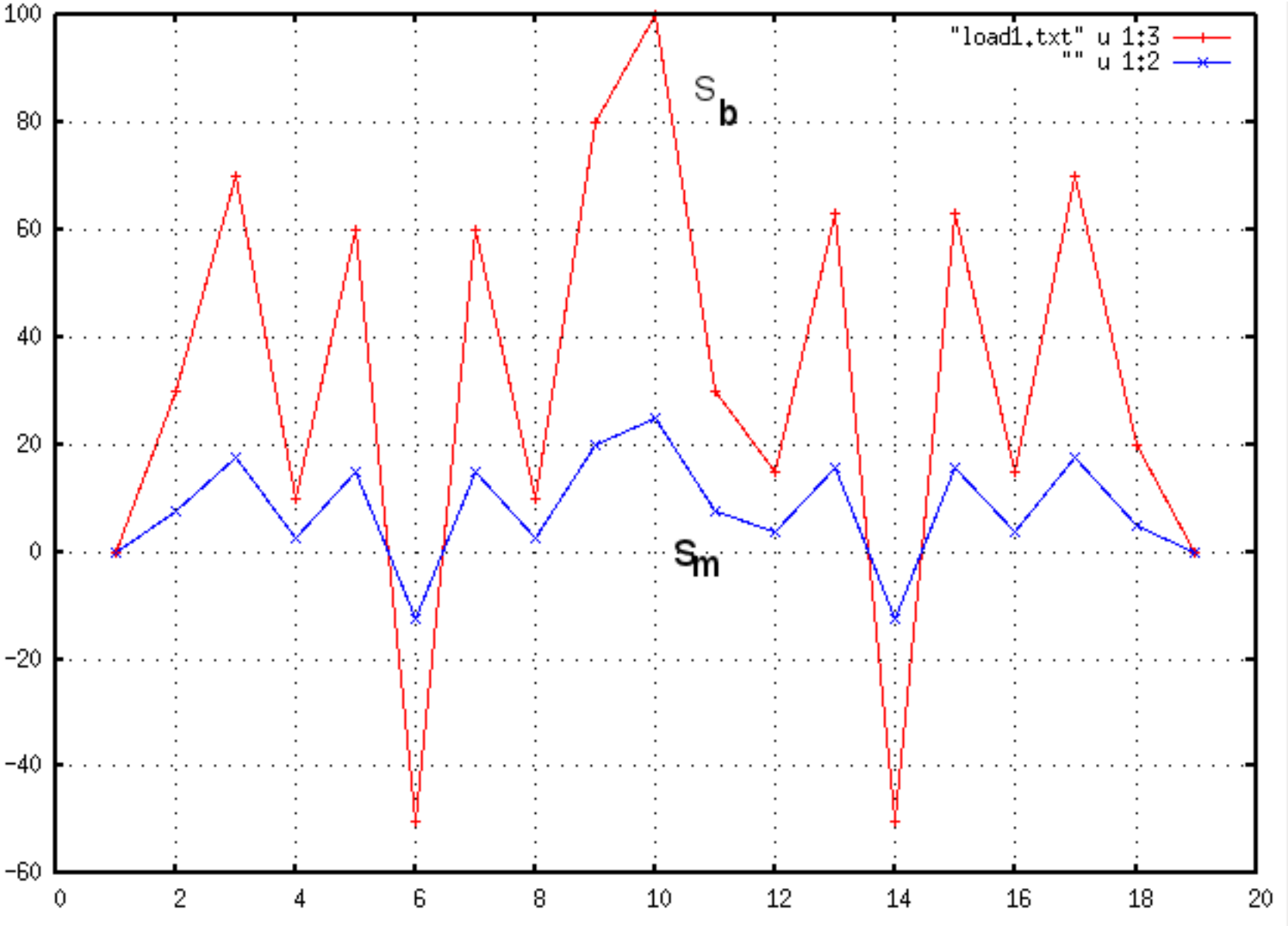
```
# A36 Steel Normalized and A36 Hot Rolled combined file
# Cut from 1.5inch  square bar, (38X38mm):
# Ref.: P.Dindinger report to Fat.Des.+Eval. Comm. Apr.2012
# From 4'x4' hot rolled bar:
# Ref.: P.Dindinger report to Fat.Des.+Eval. Comm. 2013
```

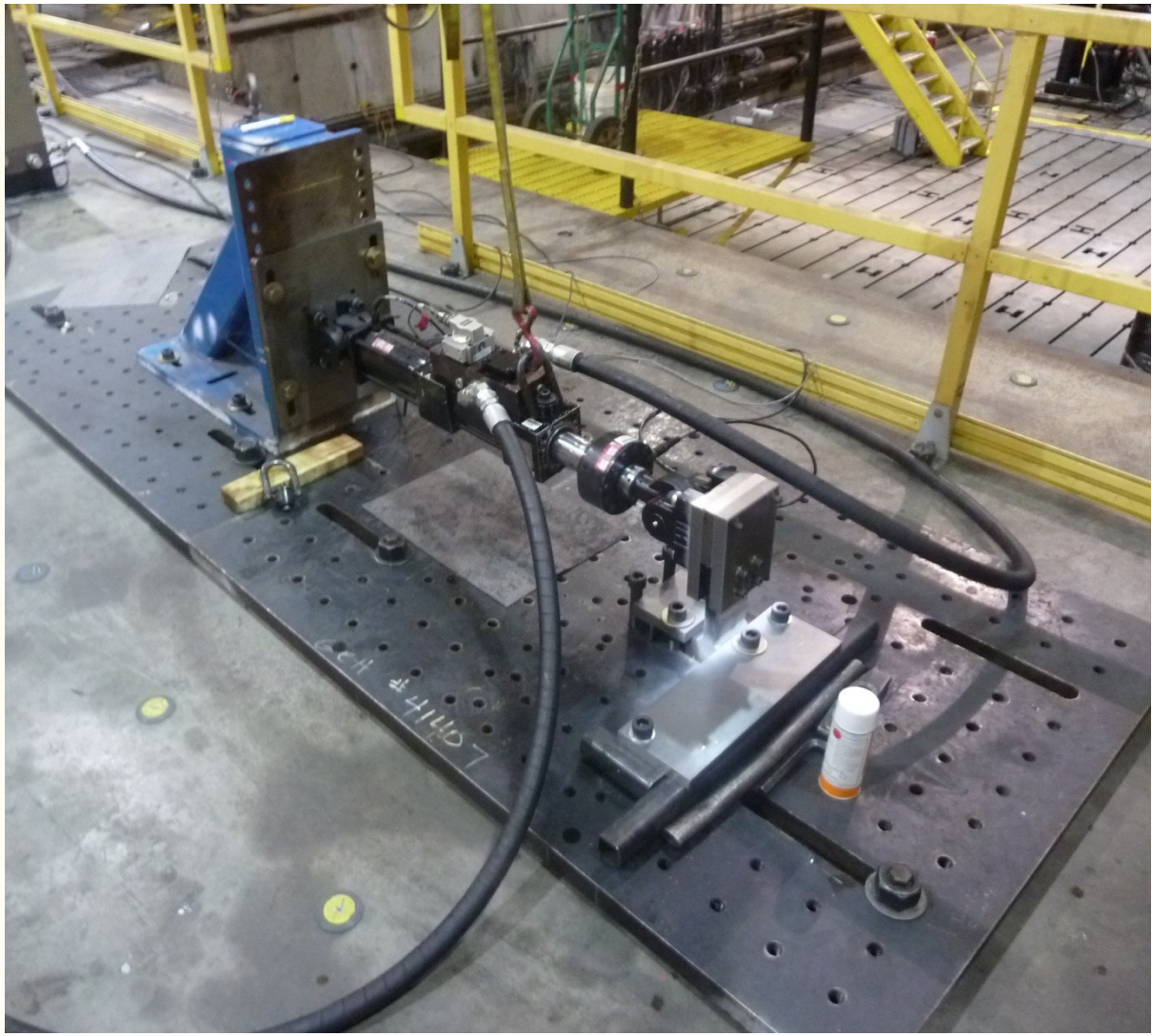
Monotonic Props.			Cyclic Props.	
ELAS. MOD.=	29556. KSI,	204. GPA	K' =	129.6 KSI, 894.MPA
YIELD,0.2%=	0. KSI,	0. MPA	N' =	0.1604
ULT. STRG.=	69. KSI,	476. MPA	F. STRG COEF=	123.0 KSI, 848.MPA
K =	NaN KSI,	NaN MPA	F.STRG EXP, b=	-0.0910
N =	0.0000		FAT DUCT COEF=	0.7200
RED. IN AREA =	0.0		F.DUCT EXP, c=	-0.5675
T. FRAC. STG.=	0.0 KSI,	0. MPA	Exp Cyc Yld =	48. Ksi, 330.MPA
T. FRAC. STR.=	0.000		Fit Cyc Yld =	46. Ksi, 319.MPA
No. data points=	21			



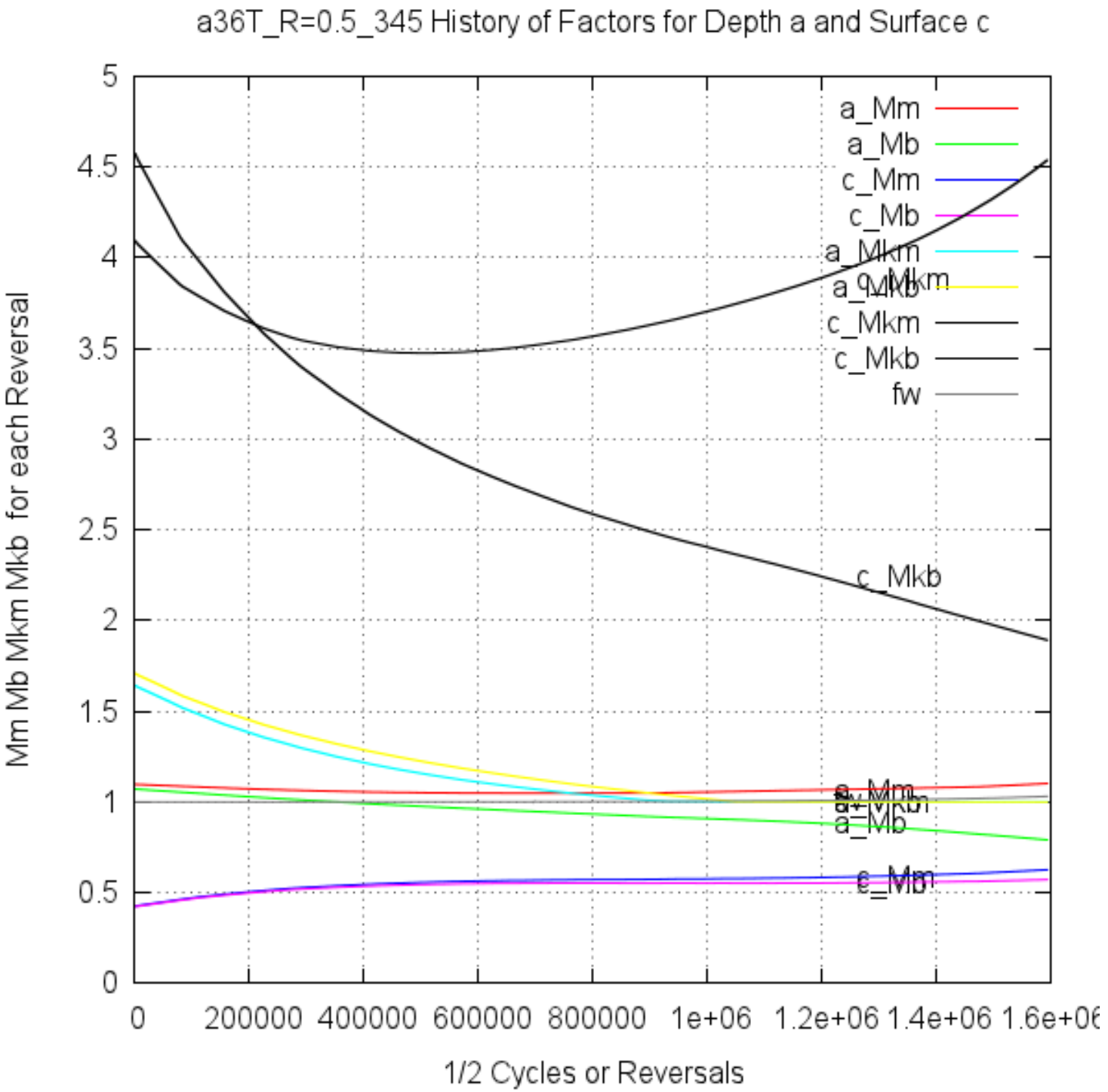


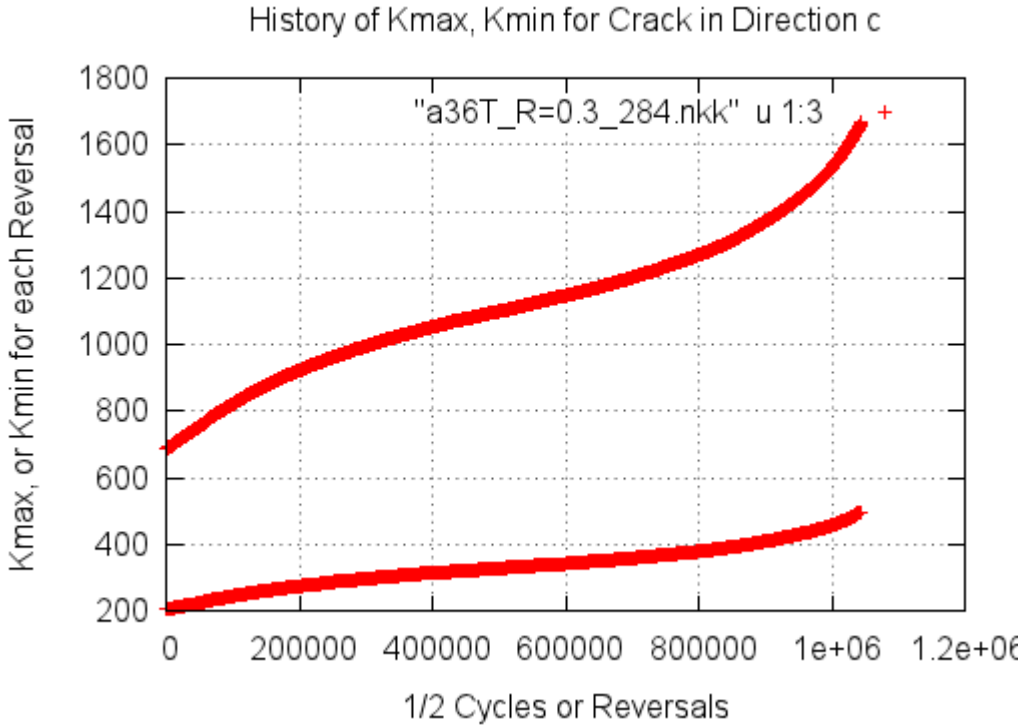


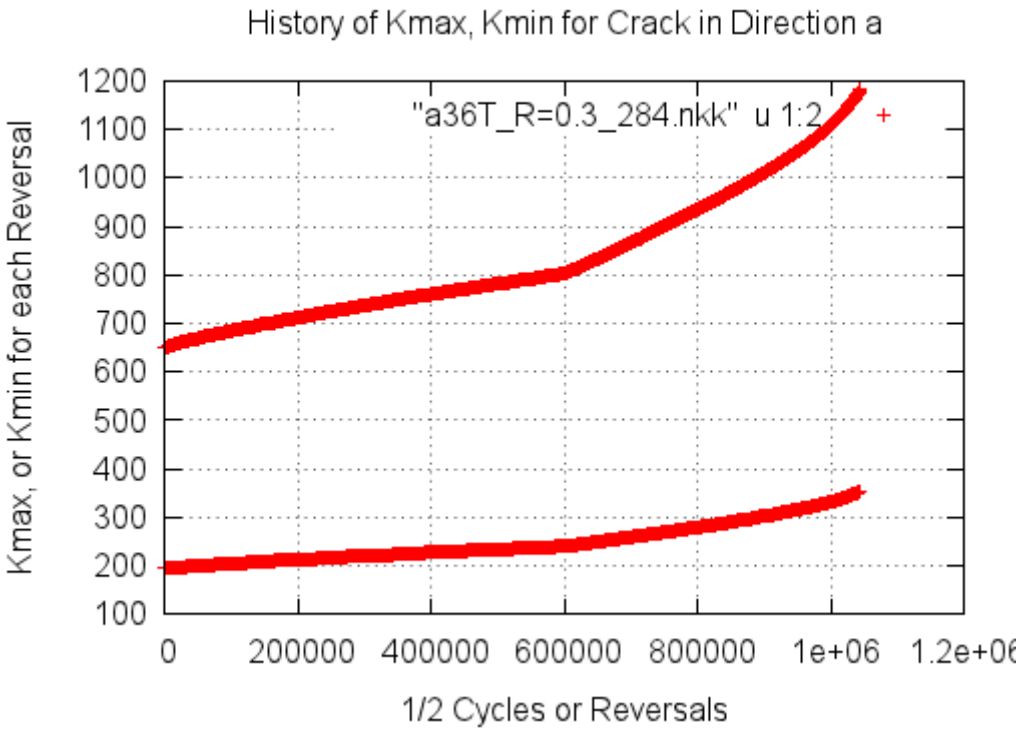

"load1.txt" u 1:3
"" u 1:2
S_b
S_m
100
80
60
40
20
0
-20
-40
-60
0
2
4
6
8
10
12
14
16
18
20

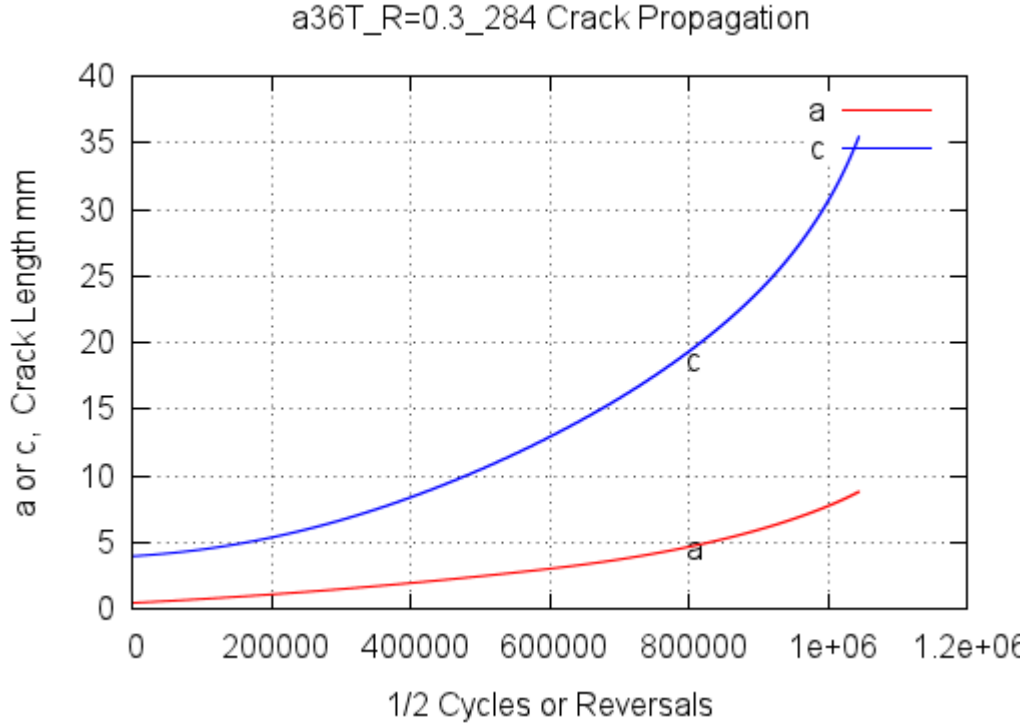


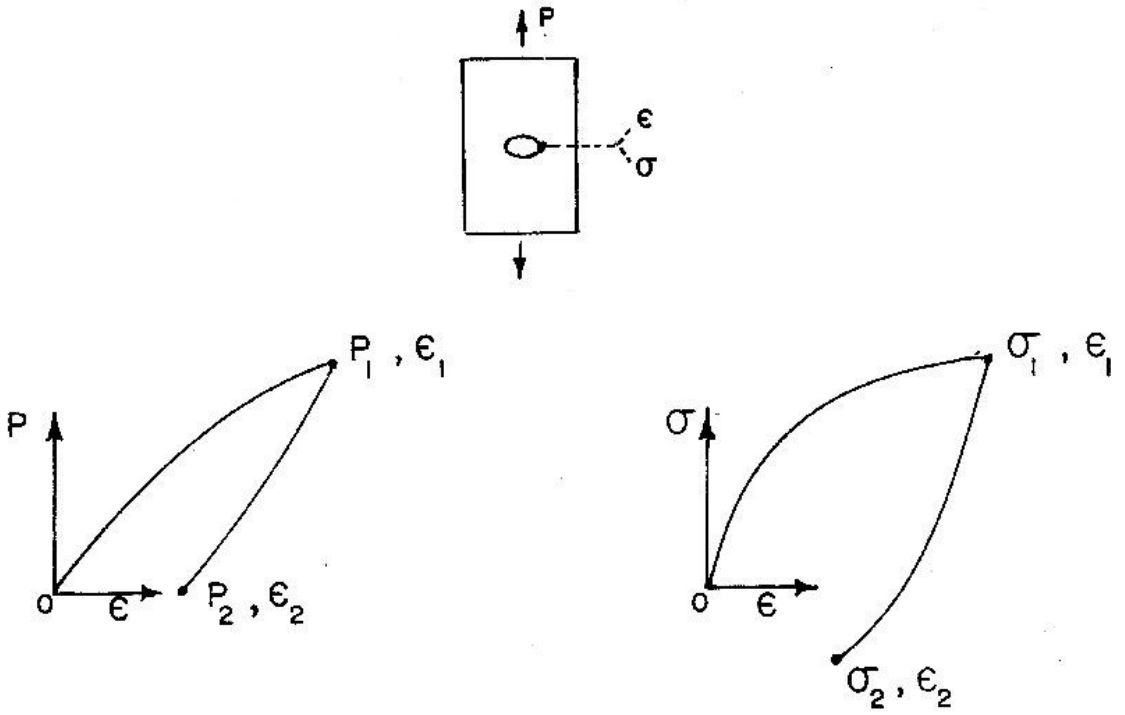
```
#TYPE= plate_surface_flaw     #with or without weld using ACTIVATEs:
#ACTIVATE_MmMb=    1   #  Deactivate  = 0
#ACTIVATE_MkmMkb=  1
#ACTIVATE_fw=      1
#                              #Other      #TYPE=  options:
#                              # plate_long_surface_flaw
#                              # plate_tru_flaw
#                              # plate_embedded_flaw
#                              # plate_edge_flaw
#                              #
#                              # pipe_inside_flaw

#                     (All dimensions in mm)
#B=    25.4         # plate (or pipe wall) thickness
#W=   101.6         # plate width
#ri=    0.          # Internal diameter if pipe problem. Ignored if not pipe
#azero= 0.5         # initial crack depth
#czero= 4.0         # initial 1/2 crack width at surface
#L= 66.8            # Weld Feature width.  Ignored  if ACTIVATE_MkmMkb= 0 (above)

#HISTORYFILE=  cycleR=0.5_10    # historyFileName

#                           # Note that the MEANADD (below) is added AFTER the MAGFACTOR is applied.
#MAGFACTOR_m= 1.0           # Multiply factor on membrane load. Result should be MPa
#MAGFACTOR_b= 1.0           # Multiply factor on bending load term. Result should be MPa
#MEANADD_m=   0.0           # Mean shift in MPa added to membrane stress.
#MEANADD_b=   0.0           # Mean shift in MPa added to bending stress.

#MAXREPS=  1000000    # Max no. history repeats in simulation.

#
#
#MATERIAL=  merged_a36_fitted.html

#DADN= table                                # Can be "table" or "Paris"
#DADN_PARIS= 0.0 0.0 0.0 0.0 none          # Kth  a  m  Kc units   (ignored if #DADN= table )
#DADN_TABLE= a36_Old+New_comboDadn.tbl     # digitized da/dN curve for material,
```


a36T_R=0.5_345 History of Factors for Depth a and Surface c
Mm Mb Mkm Mkb for each Reversal
1/2 Cycles or Reversals
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
200000
400000
600000
800000
1e+06
1.2e+06
1.4e+06
1.6e+06
a_Mm
a_Mb
c_Mm
c_Mb
a_Mkm
a_Mkb
c_Mkm
c_Mkb
fw
c_Mkb
a_Mm
a_Mb
c_Mm


History of Kmax, Kmin for Crack in Direction c
"a36T_R=0.3_284.nkk" u 1:3
Kmax, or Kmin for each Reversal
1/2 Cycles or Reversals
1800
1600
1400
1200
1000
800
600
400
200
0
200000
400000
600000
800000
1e+06
1.2e+06


History of Kmax, Kmin for Crack in Direction a
"a36T_R=0.3_284.nkk" u 1:2
Kmax, or Kmin for each Reversal
1/2 Cycles or Reversals
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
200000
400000
600000
800000
1e+06
1.2e+06


a36T_R=0.3_284 Crack Propagation
a or c, Crack Length mm
1/2 Cycles or Reversals
a
c
40
35
30
25
20
15
10
5
0
200000
400000
600000
800000
1e+06
1.2e+06



STACKS

COMPRESSION				TENSION			
DAMAGE	STRESS	STRAIN	LOAD	LOAD	STRAIN	STRESS	DAMAGE
D_{01}	$-\sigma_1$	$-\epsilon_1$	$-P_1$	P_1	ϵ_1	σ_1	D_{01}
D_{12}	σ_2	ϵ_2	P_2	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–

F.D.& E. *saefcalc1* from UoWaterloo Calc. Site

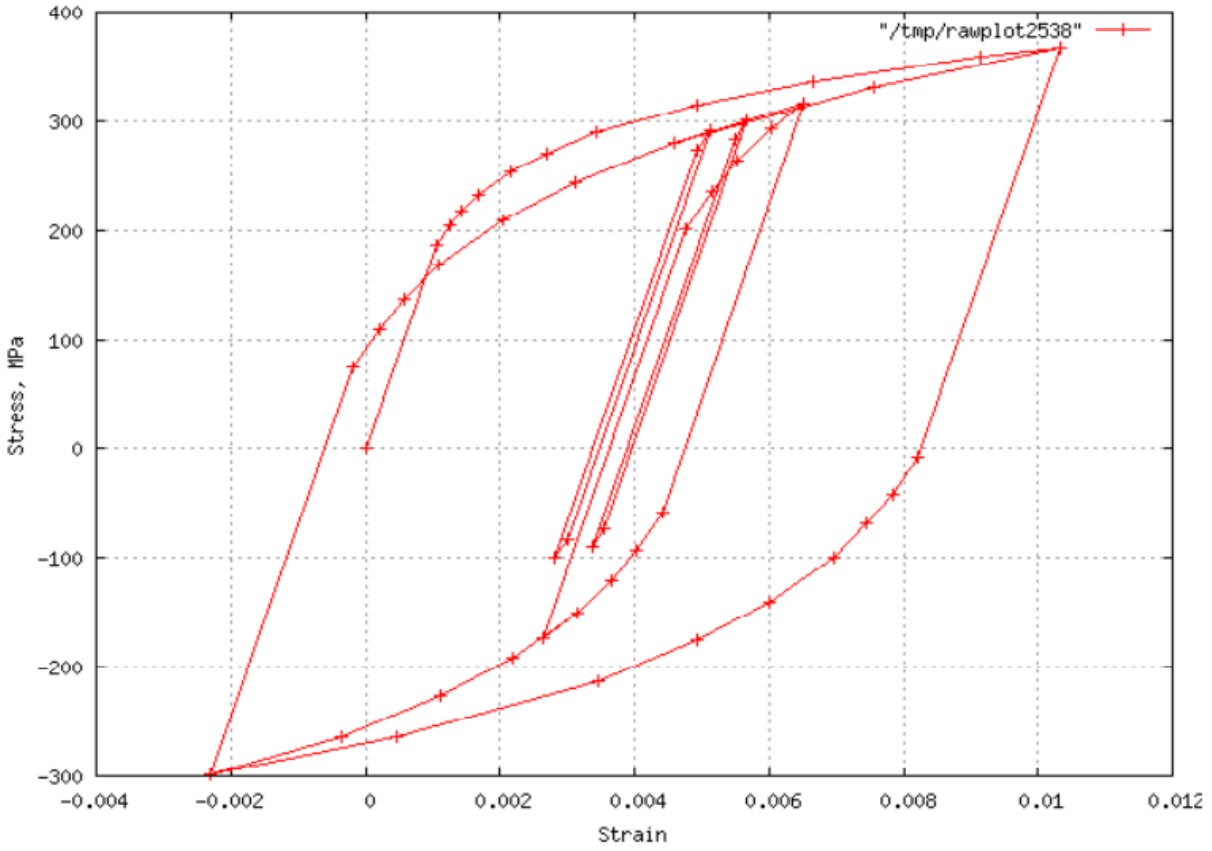
Mon Dec 24 00:41:17 EST 2012

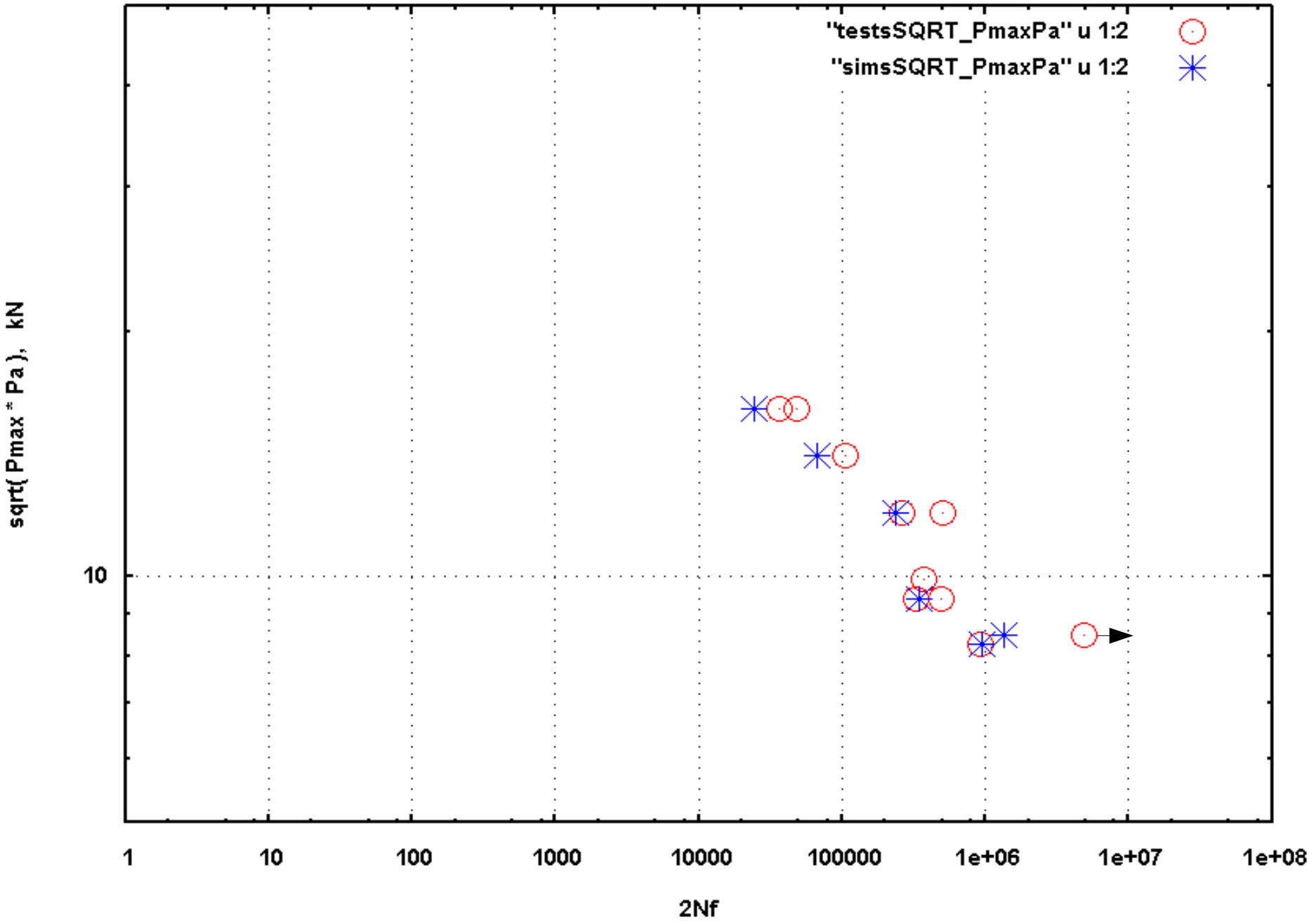
#NAME= ASTM-A36 #NAME= Structural #NAME= Steel #Sy= 38.4 0.2pc offset, 265 mpa #Su= 69. ksi from l
#read_a_line: # #MagFactor 1.0 879 -429 1 621 -429 1 621 0 1 514 85.7 2 557 129 2

#xcalc2	Loop	Smax	Smin	N	Sigmax	Sigmin	Delta	Epsmax	Epsmin	DeltaEps	%Eps	%SWaT	%Sts	%Morr	%Goodm
#xcalc2	1	879.0	-429.0	1.0	367.	-298.	665.	0.01034	-.00229	0.01263	67.7	67.4	67.7	71.4	71.0
#xcalc2	2	621.0	-429.0	1.0	316.	-298.	614.	0.00653	-.00229	0.00882	28.8	25.2	28.8	21.4	16.6
#xcalc2	3	621.0	0.0	1.0	316.	-173.	488.	0.00653	0.00265	0.00388	2.5	4.1	2.5	4.5	6.7
#xcalc2	4	514.0	85.7	2.0	291.	-100.	391.	0.00512	0.00282	0.00231	0.5	1.6	0.5	1.2	2.4
#xcalc2	5	557.0	129.0	2.0	301.	-90.	391.	0.00568	0.00337	0.00230	0.5	1.7	0.5	1.4	3.2

#xcalc3	StrainLife_Reps	SWaT_Life_Reps	StressLife_Reps	Morrow_Reps	Goodman_Reps (Reps= Repetions)
#xcalc3	3818.0	3163.1	3818.0	2522.4	1810.8

Local Stress and Strain Response:

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"simsSQRT_PmaxPa" u 1:2
sqrt(Pmax * Pa), kN
10
1
10
100
1000
10000
100000
1e+06
1e+07
1e+08
2Nf