Curve Fitting Material Data from the Fracture Mechanics Database AFMAT

Cordell Smith

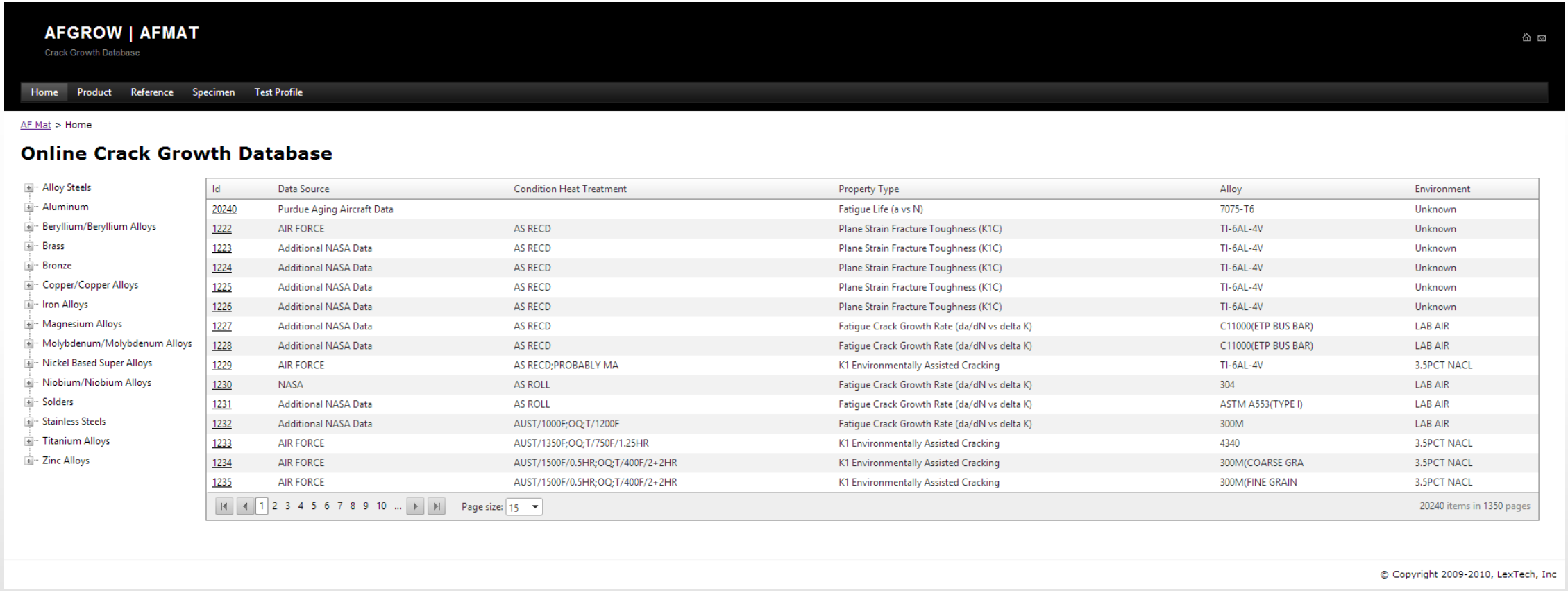
James A. Harter

LexTech, Inc.

8285 Rhine Way

Centerville, OH 45458

AFMAT Crack Growth Database



AFGROW | AFMAT

Crack Growth Database

Home | Product | Reference | Specimen | Test Profile

AF Mat > Home

Online Crack Growth Database

- Alloy Steels
- Aluminum
- Beryllium/Beryllium Alloys
- Brass
- Bronze
- Copper/Copper Alloys
- Iron Alloys
- Magnesium Alloys
- Molybdenum/Molybdenum Alloys
- Nickel Based Super Alloys
- Niobium/Niobium Alloys
- Solders
- Stainless Steels
- Titanium Alloys
- Zinc Alloys

Id	Data Source	Condition Heat Treatment	Property Type	Alloy	Environment
20240	Purdue Aging Aircraft Data		Fatigue Life (a vs N)	7075-T6	Unknown
1222	AIR FORCE	AS RECD	Plane Strain Fracture Toughness (K1C)	TI-6AL-4V	Unknown
1223	Additional NASA Data	AS RECD	Plane Strain Fracture Toughness (K1C)	TI-6AL-4V	Unknown
1224	Additional NASA Data	AS RECD	Plane Strain Fracture Toughness (K1C)	TI-6AL-4V	Unknown
1225	Additional NASA Data	AS RECD	Plane Strain Fracture Toughness (K1C)	TI-6AL-4V	Unknown
1226	Additional NASA Data	AS RECD	Plane Strain Fracture Toughness (K1C)	TI-6AL-4V	Unknown
1227	Additional NASA Data	AS RECD	Fatigue Crack Growth Rate (da/dN vs delta K)	C11000(ETP BUS BAR)	LAB AIR
1228	Additional NASA Data	AS RECD	Fatigue Crack Growth Rate (da/dN vs delta K)	C11000(ETP BUS BAR)	LAB AIR
1229	AIR FORCE	AS RECD;PROBABLY MA	K1 Environmentally Assisted Cracking	TI-6AL-4V	3.5PCT NACL
1230	NASA	AS ROLL	Fatigue Crack Growth Rate (da/dN vs delta K)	304	LAB AIR
1231	Additional NASA Data	AS ROLL	Fatigue Crack Growth Rate (da/dN vs delta K)	ASTM A553(TYPE I)	LAB AIR
1232	Additional NASA Data	AUST/1000F;OQ;T/1200F	Fatigue Crack Growth Rate (da/dN vs delta K)	300M	LAB AIR
1233	AIR FORCE	AUST/1350F;OQ;T/750F/1.25HR	K1 Environmentally Assisted Cracking	4340	3.5PCT NACL
1234	AIR FORCE	AUST/1500F/0.5HR;OQ;T/400F/2+2HR	K1 Environmentally Assisted Cracking	300M(COARSE GRA	3.5PCT NACL
1235	AIR FORCE	AUST/1500F/0.5HR;OQ;T/400F/2+2HR	K1 Environmentally Assisted Cracking	300M(FINE GRAIN	3.5PCT NACL

1 2 3 4 5 6 7 8 9 10 ... Page size: 15

20240 items in 1350 pages

- AFMAT is available to users with a permanent user license.
- The database contains data for over 600 materials, 1229 sources, and 11 property types.
- Only permanent licensed users may perform filtered searches and download data.

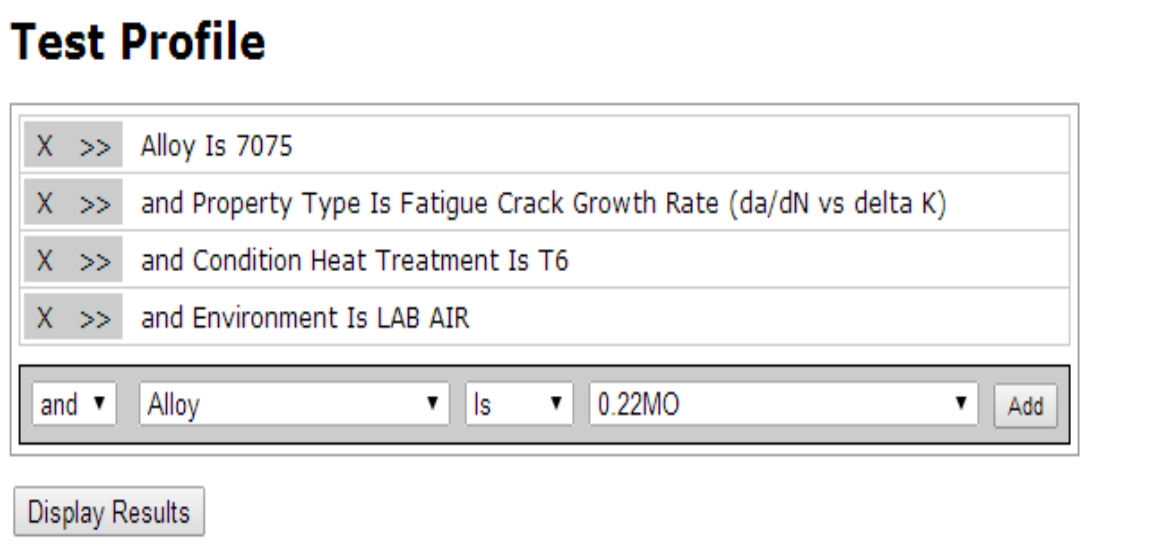
Project Background

- Project Sponsored by T-38
- Assigned to create curve fits for the twelve materials listed below:
  1. 2024-T3511
  2. 7175-T74
  3. 2024-T351
  4. 2024-T3
  5. 7075-T6
  6. 17-7PH (Not enough data in the database)
  7. 2024-T42
  8. AMS6526 (No data in database)
  9. 7075-T76
  10. 7075-T76511
  11. 4340
  12. 7075-T73(Not enough data in the database)

Summary of Data Collected

Material	Stress Ratios (R)	Temperatures (°F)	Environment	Orientation	Number of datasets
2024-T3511	0.05,0.1,0.8	UKN,70,74,75,76	Lab Air	L-T	9
2024-T351	0,0.01,0.05,0.1,0.4,0.8	UKN,70,72,74,78	Lab Air	L-T	36
2024-T3	0,0.05,0.2,0.4,0.5,0.75	UKN,70,72,76	Lab Air	L-T	15
7075-T76	0.08 & 0.30	70	LHA	L-T	7
7075-T6	0,0.02,0.1,0.5,0.75	UKN & 70	Lab Air	L-T	23
7175-T74	0.02,0.5,0.8	70,73,74,75	Lab Air	L-T	11
4340	0,0.02,0.1,0.5	70 & 75	Lab Air	L-T	19
7075-T7651	0.08 & 0.30	70	LHA	L-T	7
2024-T42	0.02,0.5,-1	70	Lab Air	L-T	5

Test Profile Search Criteria



- Alloy, Property type, Environment, Data Source, Condition Heat Treatment, and ID
- Property type used to perform curve fitting was Crack Growth rate (da/dN vs delta K)

Search Results

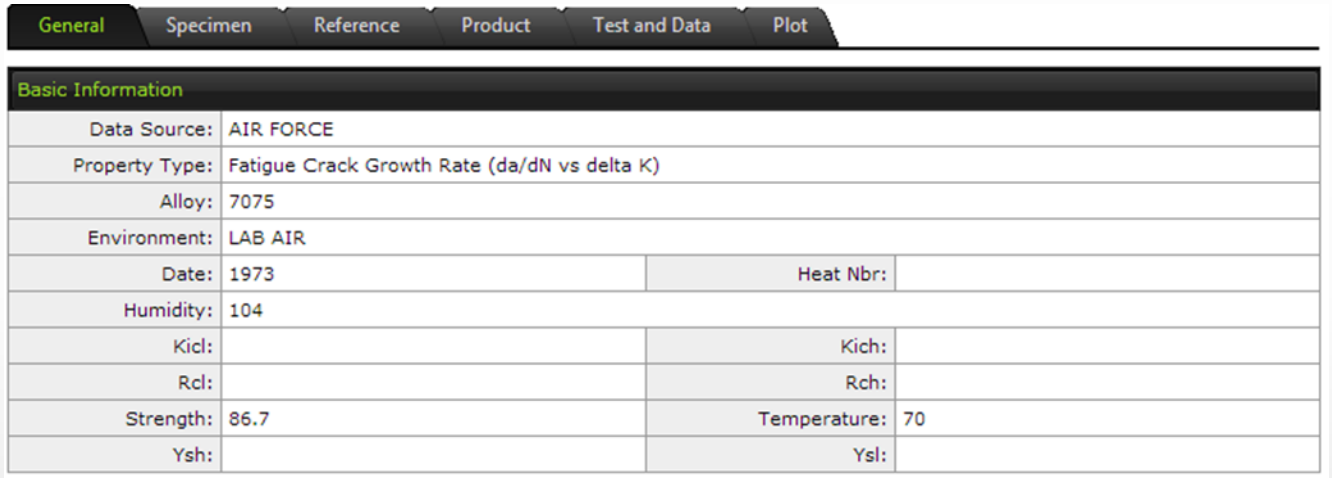
Aluminum

Id	Alloy	Data Source	Condition Heat Treatment	Property Type	Environment
8265	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8268	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8269	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8270	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8283	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8284	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8285	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8286	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8287	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
8288	7075	Additional NASA Data	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
7764	7075	AIR FORCE	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
7765	7075	AIR FORCE	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
7766	7075	AIR FORCE	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
7775	7075	AIR FORCE	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR
7786	7075	AIR FORCE	T6	Fatigue Crack Growth Rate (da/dN vs delta K)	LAB AIR

1 2 Page size: 15 18 items in 2 pages

- The results will list the ID number, Alloy, data source, condition heat treatment, property type and environment

Reviewing and Downloading Data



General | Specimen | Reference | Product | Test and Data | Plot

Basic Information

Data Source:	AIR FORCE		
Property Type:	Fatigue Crack Growth Rate (da/dN vs delta K)		
Alloy:	7075		
Environment:	LAB AIR		
Date:	1973	Heat Nbr:	
Humidity:	104		
Kicl:		Kich:	
Rcl:		Rch:	
Strength:	86.7	Temperature:	70
Ysh:		Ysl:	

- The general tab lists the dataset's source, property type, environment, test date, humidity, strength, and temperature

Reviewing and Downloading Data

General | Specimen | Reference | Product | Test and Data | Plot

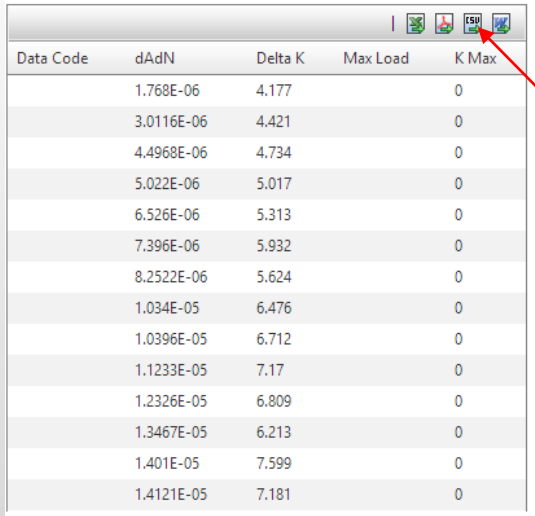
Specimen			
Type:	Middle Tension (MT)		
Orientation:	L-T		
Width:	4	Thickness:	0.156

- The specimen tab lists the test type, orientation, width, and thickness of the specimen

Reviewing and Downloading Data

General | Specimen | Reference | Product | Test and Data | Plot

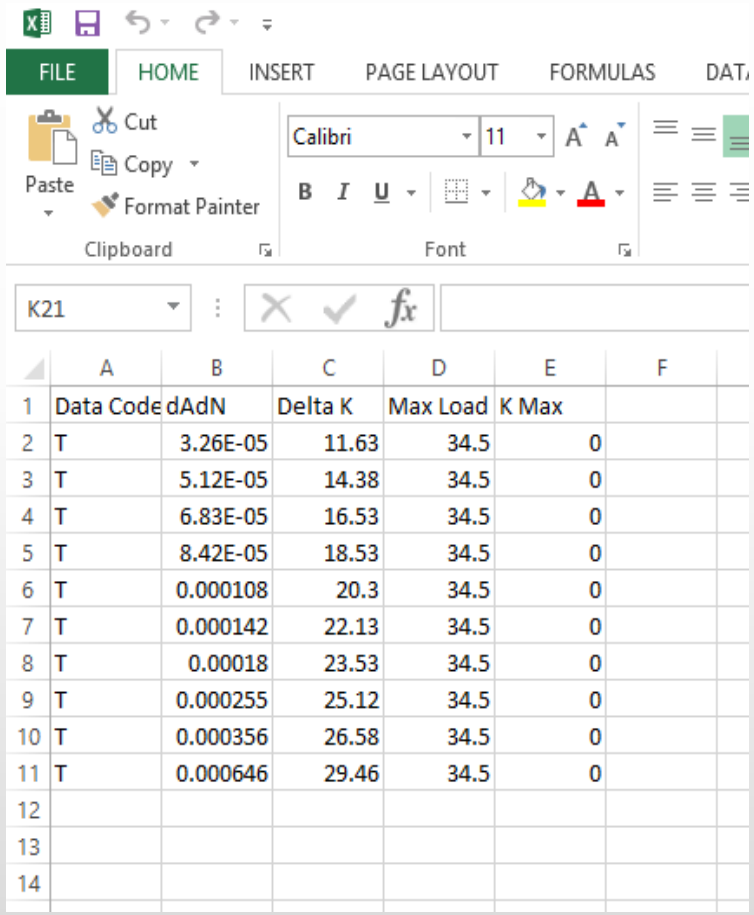
Test Information					
Stress Ratio:	0.5	Specimen Description:		Stress Intensity Format:	0
Composition:		Joint Preparation:		Wave Form:	
Preheat Temperature:		Frequency High:		Interpass Temperature:	
Frequency Low:	10	Postheat Temperature:		Percent Reduction in Area:	
Percent Elongation:		Voltage:		Amperage:	
Tensile Test Orientation:	0	Tensile Test Temperature:		Heat Input:	
Test Standard Year:		Test Standard:		Travel Speed:	
Filler Size/Diameter:		Filler Type/Name:	0	Data Source:	0
Reduction Method:	0	Error Criteria:		Pressure:	
Notch Length:	0	Product Width:		Total Side Groove Depth:	



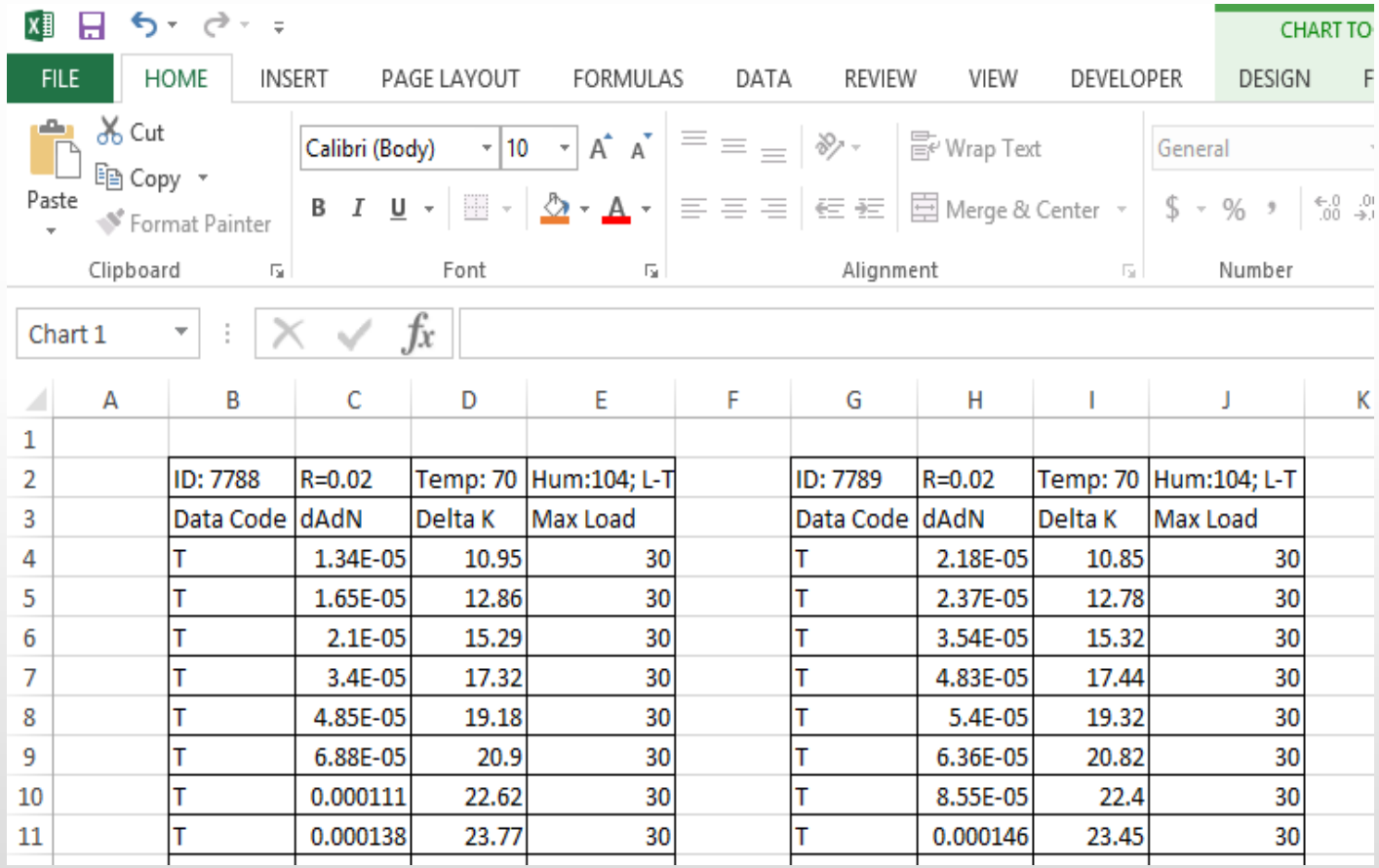
Data Code	dAdN	Delta K	Max Load	K Max
	1.768E-06	4.177		0
	3.0116E-06	4.421		0
	4.4968E-06	4.734		0
	5.022E-06	5.017		0
	6.526E-06	5.313		0
	7.396E-06	5.932		0
	8.2522E-06	5.624		0
	1.034E-05	6.476		0
	1.0396E-05	6.712		0
	1.1233E-05	7.17		0
	1.2326E-05	6.809		0
	1.3467E-05	6.213		0
	1.401E-05	7.599		0
	1.4121E-05	7.181		0

- The test and data tab is where the user can download the data
- Use the CSV format to download directly into Excel with normal cell borders

Organizing Downloaded Data



	A	B	C	D	E	F
1	Data Code	dAdN	Delta K	Max Load	K Max	
2	T	3.26E-05	11.63	34.5	0	
3	T	5.12E-05	14.38	34.5	0	
4	T	6.83E-05	16.53	34.5	0	
5	T	8.42E-05	18.53	34.5	0	
6	T	0.000108	20.3	34.5	0	
7	T	0.000142	22.13	34.5	0	
8	T	0.00018	23.53	34.5	0	
9	T	0.000255	25.12	34.5	0	
10	T	0.000356	26.58	34.5	0	
11	T	0.000646	29.46	34.5	0	
12						
13						
14						



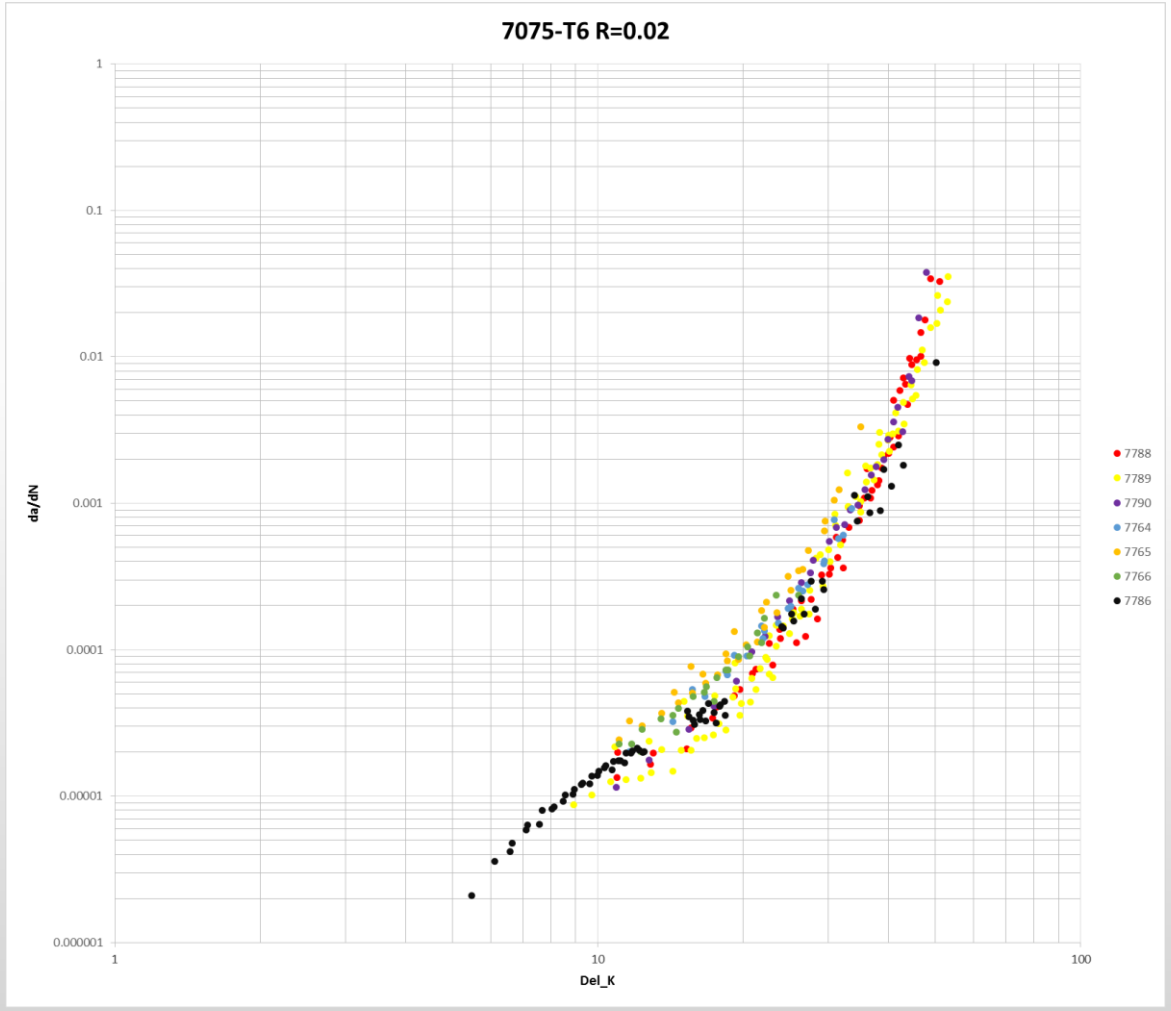
	A	B	C	D	E	F	G	H	I	J	K
1											
2		ID: 7788	R=0.02	Temp: 70	Hum:104; L-T		ID: 7789	R=0.02	Temp: 70	Hum:104; L-T	
3		Data Code	dAdN	Delta K	Max Load		Data Code	dAdN	Delta K	Max Load	
4		T	1.34E-05	10.95	30		T	2.18E-05	10.85	30	
5		T	1.65E-05	12.86	30		T	2.37E-05	12.78	30	
6		T	2.1E-05	15.29	30		T	3.54E-05	15.32	30	
7		T	3.4E-05	17.32	30		T	4.83E-05	17.44	30	
8		T	4.85E-05	19.18	30		T	5.4E-05	19.32	30	
9		T	6.88E-05	20.9	30		T	6.36E-05	20.82	30	
10		T	0.000111	22.62	30		T	8.55E-05	22.4	30	
11		T	0.000138	23.77	30		T	0.000146	23.45	30	

Example of data collected (7075-T6)

Material	R	ID	Temperature	Environment	Orientation	Used in fit
7075-T6	0.02	7788	70	Lab Air	L-T	Yes
7075-T6	0.02	7789	70	Lab Air	L-T	Yes
7075-T6	0.02	7790	70	Lab Air	L-T	Yes
7075-T6	0.02	7764	70	Lab Air	L-T	Yes
7075-T6	0.02	7765	70	Lab Air	L-T	Yes
7075-T6	0.02	7775	70	Lab Air	T-L	No
7075-T6	0.02	7766	70	Lab Air	L-T	Yes
7075-T6	0.02	7786	70	Lab Air	L-T	Yes
7075-T6	0.0	7784	70	LHA	L-T	No
7075-T6	0.1	8286	-	Lab Air	L-T	Yes
7075-T6	0.1	8287	-	Lab Air	L-T	Yes
7075-T6	0.1	8288	-	Lab Air	L-T	Yes
7075-T6	0.5	8265	-	Lab Air	L-T	Yes
7075-T6	0.5	8268	-	Lab Air	T-L	No
7075-T6	0.5	8269	-	Lab Air	L-T	Yes
7075-T6	0.5	8270	-	Lab Air	L-T	Yes
7075-T6	0.5	7765	70	Lab Air	L-T	Yes
7075-T6	0.5	7764	70	Lab Air	L-T	Yes
7075-T6	0.5	7764	70	Lab Air	L-T	Yes
7075-T6	0.5	7786	70	Lab Air	L-T	Yes
7075-T6	0.5	7766	70	Lab Air	L-T	Yes
7075-T6	0.75	8283	-	Lab Air	UNK	Yes
7075-T6	0.75	8284	-	Lab Air	UNK	Yes

- 7075-T6 had five total R's in the database: 0, 0.02, 0.1, 0.5 and 0.75
- Make sure all data used in the fit is tested under the same conditions i.e. environment, orientation, and temperature

Graphing Data



ID: 7788	R=0.02	Temp: 70	Hum:104; L-T
Data Code	**dAdN**	**Delta K**	Max Load
T	1.34E-05	10.95	30
T	1.65E-05	12.86	30
T	2.1E-05	15.29	30
T	3.4E-05	17.32	30
T	4.85E-05	19.18	30
T	6.88E-05	20.9	30
T	0.000111	22.62	30
T	0.000138	23.77	30
T	0.000189	25.39	30
T	0.000216	26.37	30
T	0.000221	27.62	30
T	0.000323	29.03	30
T	0.000363	30.34	30
T	0.000427	31.35	30
T	0.000559	32.09	30
T	0.000682	33.1	30
T	0.000765	34.84	30
T	0.001084	35.62	30
T	0.001085	36.71	30
T	0.001333	37.9	30
T	0.001734	38.68	30
T	0.002198	40.04	30
T	0.002409	40.98	30
T	0.002887	41.95	30
T	0.004716	43.78	30
T	0.007215	42.89	30
T	0.00888	44.65	30
T	0.009532	45.67	30
T	0.010106	46.66	30
T	1.96E-05	13.01	30
T	2E-05	11.01	30
T	2.91E-05	15.58	30

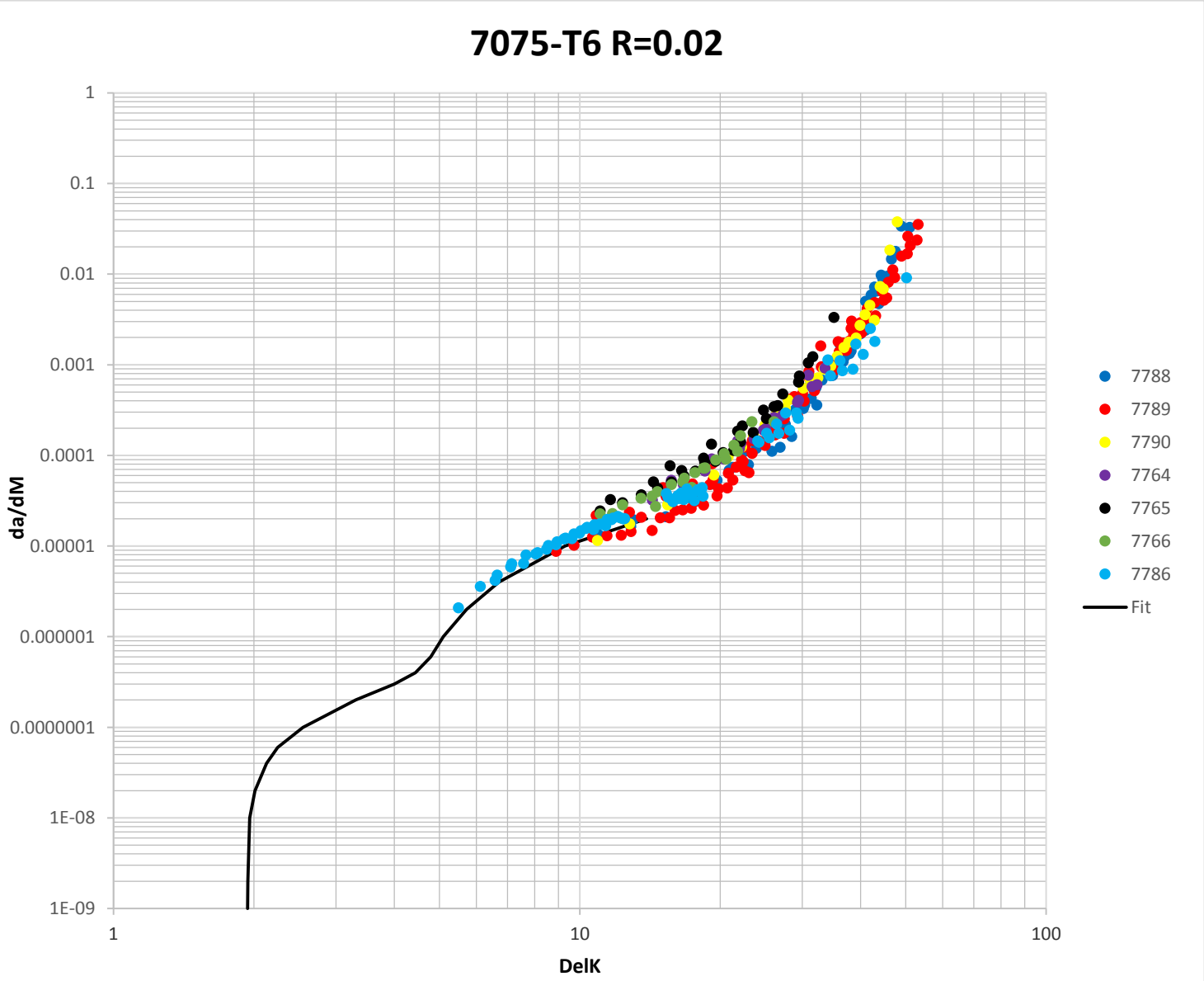
- Once data is collected, graph delta k versus the growth rate on a log log plot

Standard Growth Rates

Del_K	da/dN
	1.00E-09
	2.00E-09
	1.00E-08
	2.00E-08
	4.00E-08
	6.00E-08
	1.00E-07
	2.00E-07
	3.00E-07
	4.00E-07
	6.00E-07
	1.00E-06
	2.00E-06
	4.00E-06
	1.00E-05
	2.00E-05
	4.00E-05
	1.00E-04
	2.00E-04
	4.00E-04
	6.00E-04
	8.00E-04
	1.00E-03
	4.00E-03
	1.00E-02

- The 25 standard rates range from 1E-9 to .01
- Rates can be added but not removed
- Keeping the same growth rate values allows for m-values for similar materials to be compared

Fitting Data



R=0.02	
Del_K	da/dN
1.940	1.00E-09
1.941	2.00E-09
1.960	1.00E-08
2.010	2.00E-08
2.130	4.00E-08
2.250	6.00E-08
2.550	1.00E-07
3.310	2.00E-07
4.000	3.00E-07
4.440	4.00E-07
4.790	6.00E-07
5.100	1.00E-06
5.720	2.00E-06
6.700	4.00E-06
9.300	1.00E-05
13.900	2.00E-05
	4.00E-05
	1.00E-04
	0.0002
	0.0004
	0.0006
	0.0008
	0.001
	0.002
	0.004
	0.01
	0.02
	0.04
	0.06
	0.1

- Using the standard 25 rates create Delta k values so that they fit the data and graph them on the plot versus the growth rates to make the curve fit.
- Use the data available, similar materials, and good engineering judgment to set threshold values.
- It is helpful to start fitting data at the smallest R value available then use the Delta k values created to start the fit for the next R.

Rules to Follow When Fitting Data

- AFGROW calculates growth rates based on the rule of similitude and assumes that:
  - Crack growth rate data monotonically increases with Delta K (or Kmax when R<0)
  - Crack growth rate curves for different stress ratios (R's) do not cross each other
- Crack growth rate curves for positive stress ratios shift to the left of the curve for R=0 when data for R>=0 are plotted as da/dN vs. delta K
- Crack growth rate curves for negative R-values shift to the left of the curve for R=0 when plotted as da/dN vs. Kmax
- For a given absolute value of R, the crack growth rate curve for a positive R-value is to the left of the curve for the corresponding negative R-value when the negative R data are plotted as da/dN vs. Kmax
- Crack growth rate curves for negative R-values will stop shifting to the left when R<Rlo when plotted as da/dN vs. Kmax

Calculating M-values using the Harter T-Method

$$m = 1 + \left[\log_{10}\left(\frac{\Delta K_1}{\Delta K_2} \right) / \log_{10}\left(\frac{(1 - R_2)}{(1 - R_1)} \right) \right] \qquad \text{if } R_1 \text{ and } R_2 \geq 0$$

$$m = 1 + \left[\log_{10}\left(\frac{K_{\max 1}}{\Delta K_2} \right) / \log_{10}\left((1 - R_1)(1 - R_2) \right) \right] \qquad \text{if } R_1 < 0 \text{ and } R_2 \geq 0$$

$$m = 1 - \left[\log_{10}\left(\frac{K_{\max 1}}{K_{\max 2}} \right) / \log_{10}\left(\frac{(1 - R_2)}{(1 - R_1)} \right) \right] \qquad \text{if } R_1 \text{ and } R_2 < 0$$

Plotting M-values

- Use the appropriate formula to calculate the m-values for two neighboring R's and plot it vs. the growth rate.
- The m-values calculated for each pair of R-curves should produce a continuous, smooth curve when plotted against crack growth rate. This helps to ensure that the R-curves for extrapolated data are continuous and monotonically increasing.

Example of M Plotting

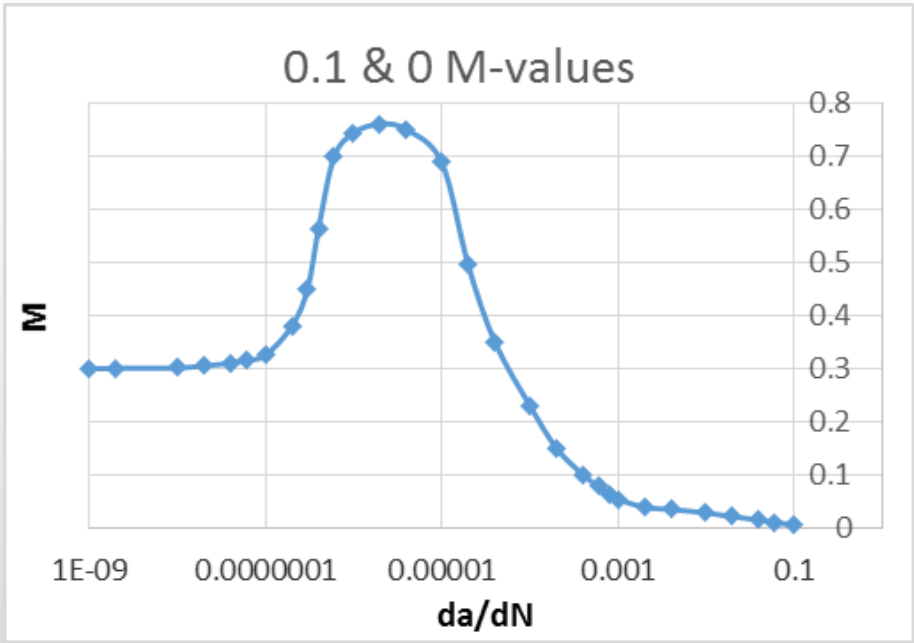
$$\Delta K_1 = \Delta K_2 * [(1-R_2)^{m-1}/(1-R_1)^{m-1}]$$

R1=0	
Del_K1	da/dN
1.940	1E-09
1.941	2E-09
1.960	1E-08
2.010	2E-08
2.130	4E-08
2.250	6E-08
2.550	1E-07
3.310	2E-07
4.000	3E-07
4.440	4E-07
4.790	6E-07
5.100	0.000001
5.720	0.000002
6.700	0.000004
9.300	0.00001
13.900	0.00002
18.250	0.00004
23.800	0.0001
28.000	0.0002
31.940	0.0004
34.000	0.0006
35.575	0.0008
36.760	0.001
39.950	0.002
43.400	0.004
48.000	0.01
51.200	0.02
53.500	0.04
54.400	0.06
55.250	0.1

R2 = 0.1	
Del_k2	da/dN
1.802	1E-09
1.803	2E-09
1.821	1E-08
1.868	2E-08
1.981	4E-08
2.093	6E-08
2.375	1E-07
3.101	2E-07
3.775	3E-07
4.240	4E-07
4.640	6E-07
4.964	0.000001
5.578	0.000002
6.526	0.000004
9.000	0.00001
13.180	0.00002
17.042	0.00004
21.945	0.0001
25.601	0.0002
29.050	0.0004
30.850	0.0006
32.225	0.0008
33.270	0.001
36.100	0.002
39.200	0.004
43.325	0.01
46.180	0.02
48.220	0.04
49.010	0.06
49.750	0.1

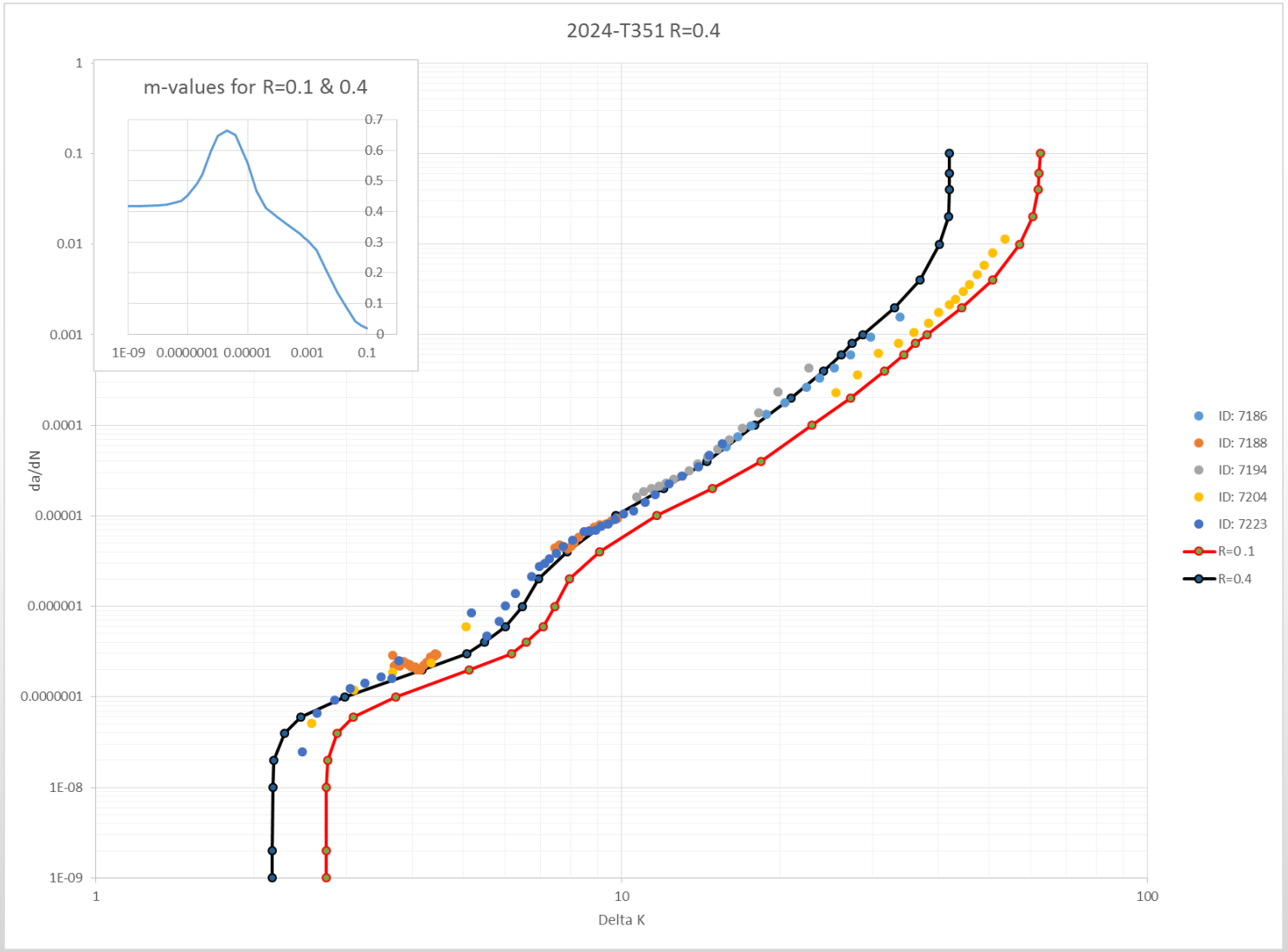
M's for R=0 to 0.1	
DK0	m
1.94	0.299635
1.941	0.3001
1.96	0.301
2.01	0.305
2.13	0.31
2.25	0.3152
2.55	0.325
3.31	0.38
4	0.45
4.44	0.563545
4.79	0.698666
5.1	0.744361
5.72	0.761
6.7	0.75041
9.3	0.688785
13.9	0.495178
18.25	0.35
23.8	0.23
28	0.15
31.94	0.099846
34	0.077228
35.575	0.061313
36.76	0.053211
39.95	0.038199
43.4	0.033958
48	0.027423
51.2	0.020575
53.5	0.013788
54.4	0.009688
55.25	0.004771

$$= 1 + \left(\frac{\log_{10}\left(\frac{1.94}{1.802}\right)}{\log_{10}\left(\frac{0.9}{1}\right)}\right)$$



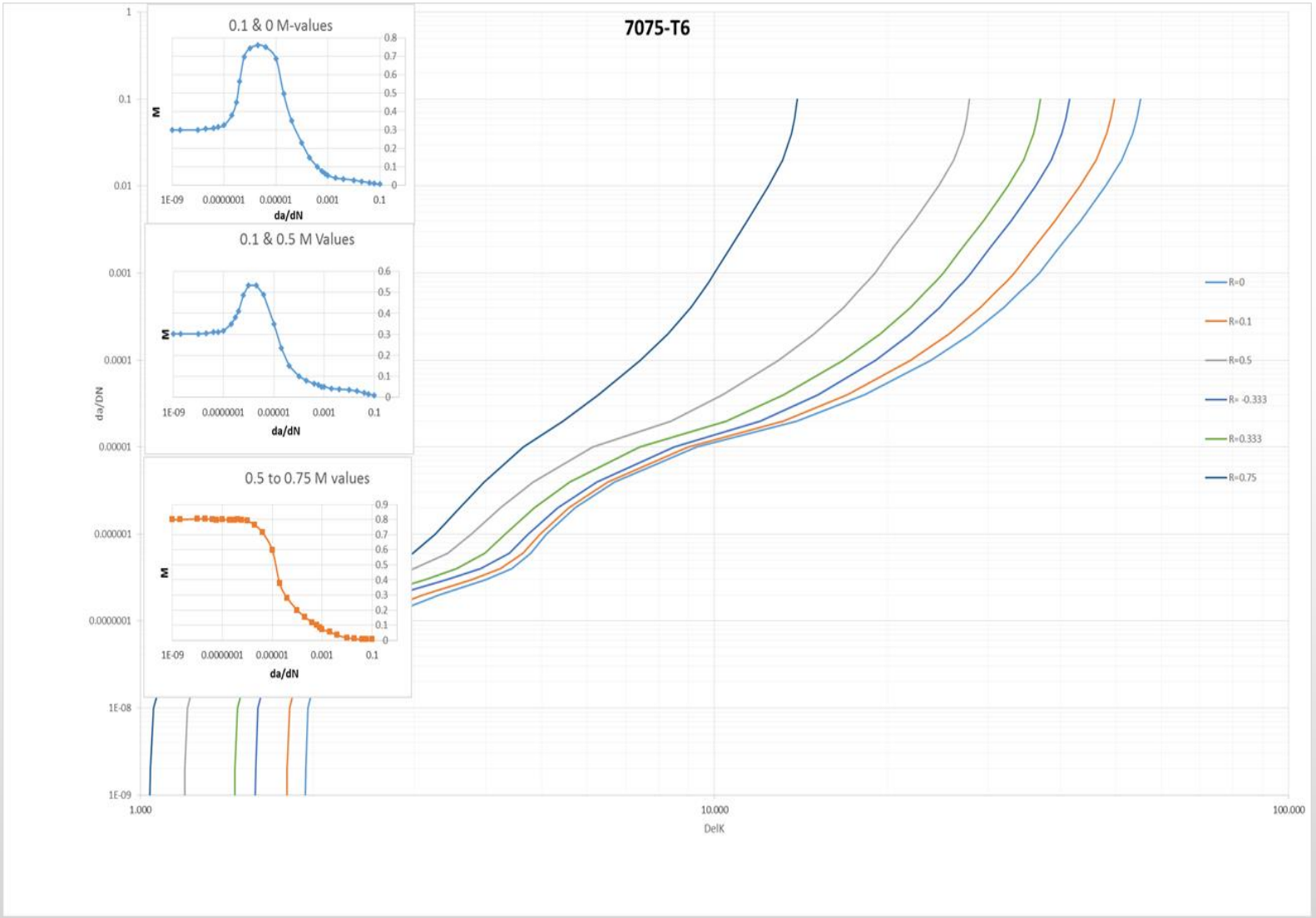
Curve Fitting Data

$$\Delta K_2 = \Delta K_1 * [(1 - R_1)^{m-1}/(1 - R_2)^{m-1}]$$



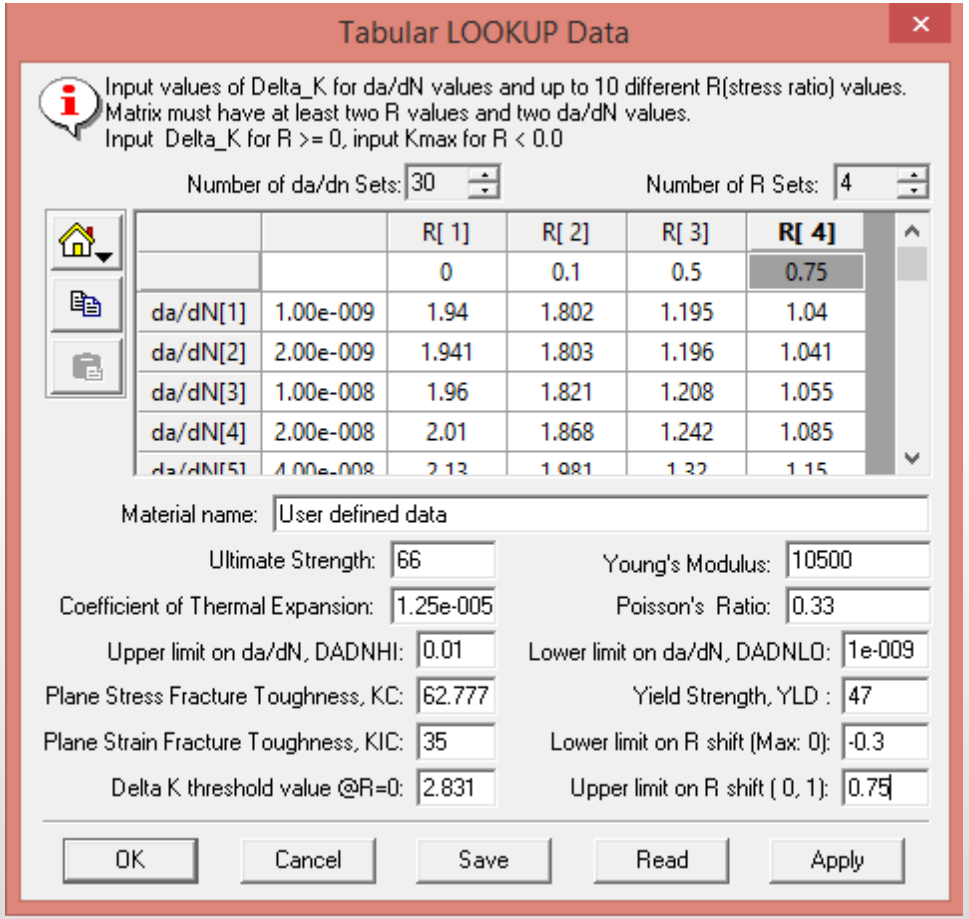
R=0.1			R=0.4			DK0	m
2.739	1E-09		2.164	1E-09		2.739	0.418854
2.74	2E-09		2.165	2E-09		2.74	0.419093
2.744	1E-08		2.169	1E-08		2.744	0.420048
2.758	2E-08		2.182	2E-08		2.758	0.422234
2.88	4E-08		2.285	4E-08		2.88	0.429238
3.085	6E-08		2.453977	6E-08		3.085	0.435607
3.715	1E-07		2.975	1E-07		3.715	0.452149
5.13	2E-07		4.175	2E-07		5.13	0.491963
6.165	3E-07		5.075	3E-07		6.165	0.520152
6.578	4E-07		5.48	4E-07		6.578	0.54959
7.08	6E-07		6.01	6E-07		7.08	0.595898
7.465	0.000001		6.47	0.000001		7.465	0.647197
7.96	0.000002		6.95	0.000002		7.96	0.665354
9.084	0.000004		7.88	0.000004		9.084	0.649324
11.67	0.00001		9.75	0.00001		11.67	0.556672
14.89	0.00002		12	0.00002		14.89	0.467813
18.4	0.00004		14.5	0.00004		18.4	0.412522
23	0.0001		17.9	0.0001		23	0.381714
27.2	0.0002		20.98	0.0002		27.2	0.359631
31.607	0.0004		24.18	0.0004		31.607	0.339394
34.405	0.0006		26.18	0.0006		34.405	0.326191
36.2	0.0008		27.42117	0.0008		36.2	0.315
38.0671	0.001		28.7421	0.001		38.0671	0.307
44.35	0.002		33.05426	0.002		44.35	0.275
50.7	0.004		36.9	0.004		50.7	0.21642
57.1	0.01		40.2	0.01		57.1	0.134483
60.4	0.02		41.7729	0.02		60.4	0.090572
61.9	0.04		41.98	0.04		61.9	0.042268
62.25	0.06		41.99	0.06		62.25	0.02895
62.5	0.1		42	0.1		62.5	0.019652

Fitting Data



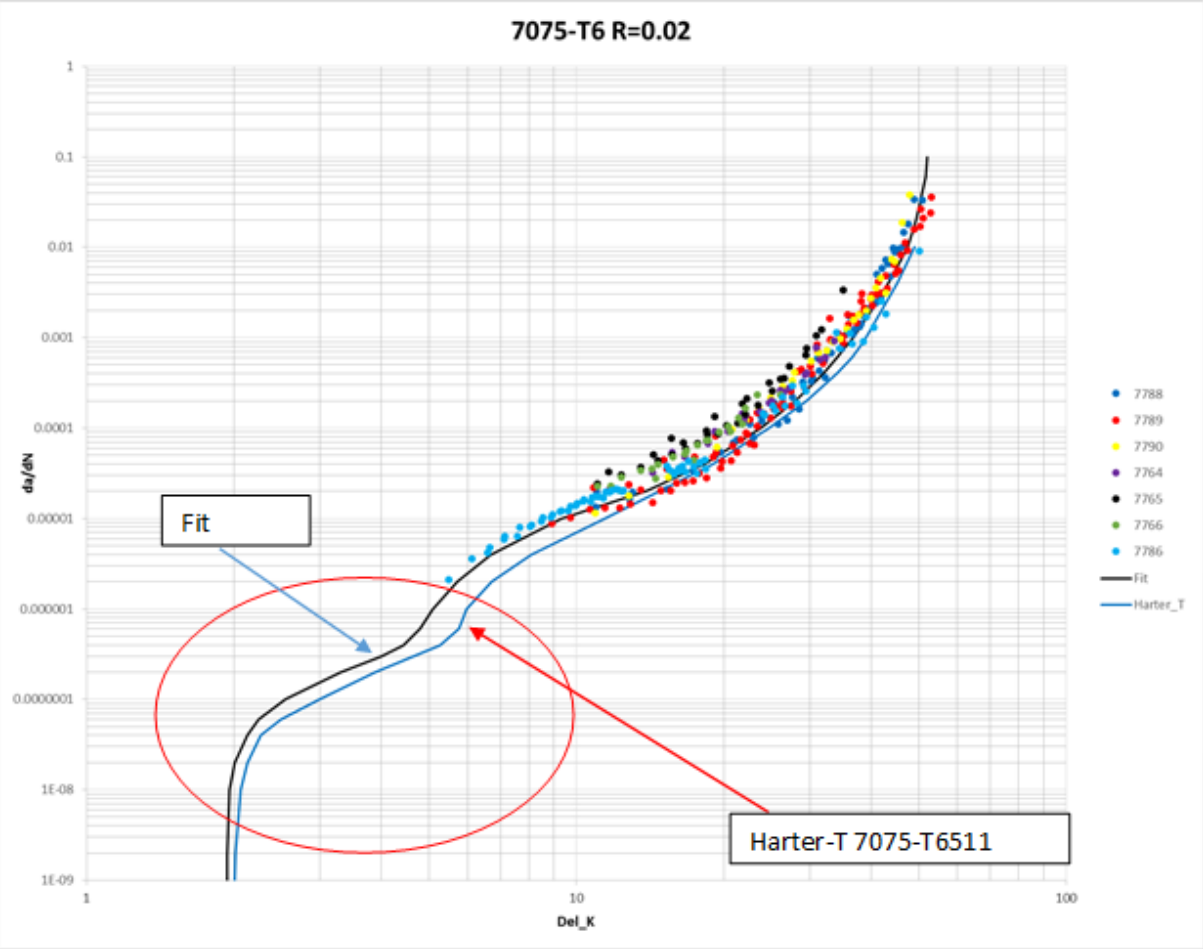
- Set R_{lo} and R_{HI} values
- Plot all R-curves and extrapolated curves on one plot.
- If the fits do not appear to be smooth use Engineering judgment to adjust delta k values until the curves are completely smooth.

Tabular Lookup



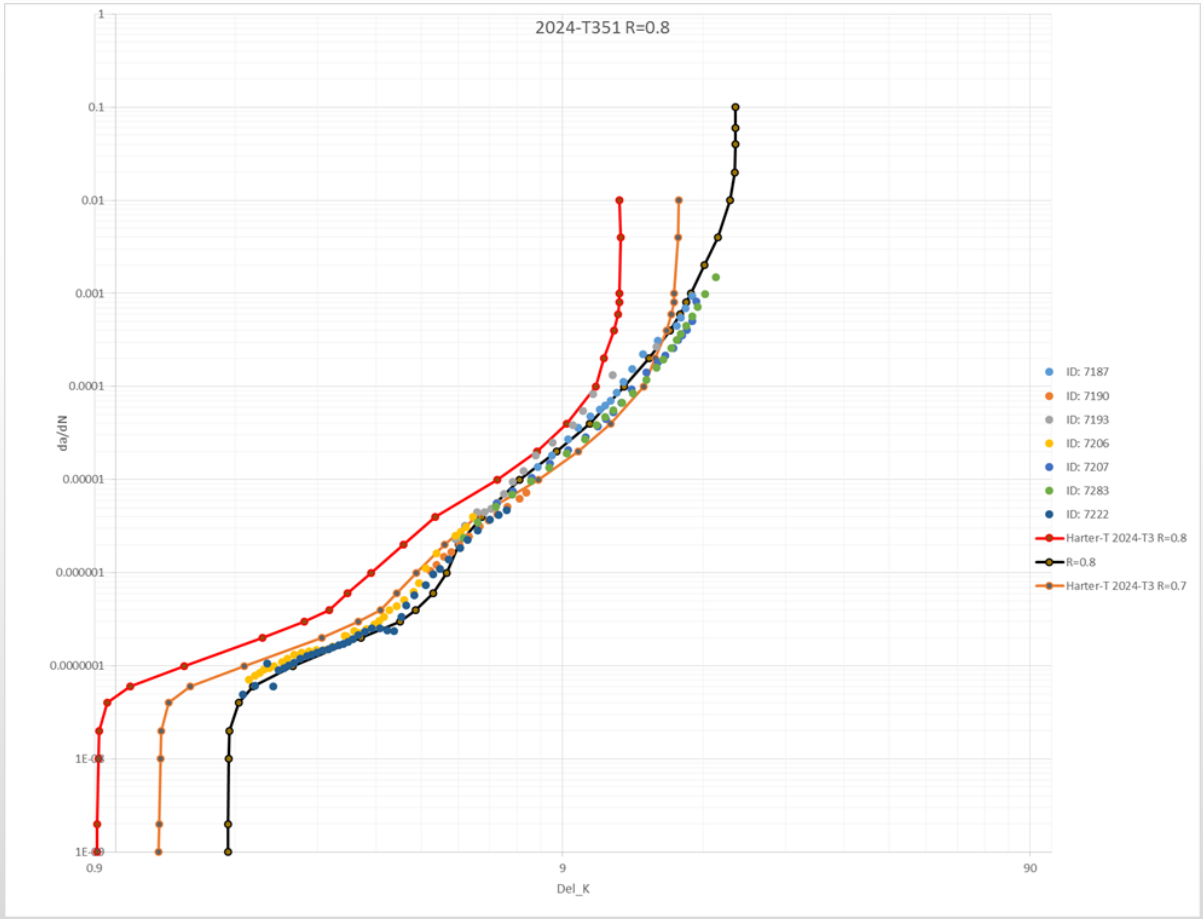
- To insert the data collected in AFGROW, copy the crack growth rates and R-curves (from least to greatest) from Excel to Tabular lookup.
- Data must be monotonically increasing, if not you will get an error message saying that your delta K values are not in ascending order.
- Delta K threshold value at R=0 must be greater than or equal to the threshold at R=0
- Lower and Upper limit on R shift define the limits for data extrapolation, so these values should be tested to verify that the rules of similitude apply.
- AFGROW will not extrapolate beyond the limits defined by: Rlo, Rhi, DADNLO, & DADNHI. However, Delta K threshold may be used to effectively increase DADNLO, but can never be lower.

Using Similar Material to Help Fit Data



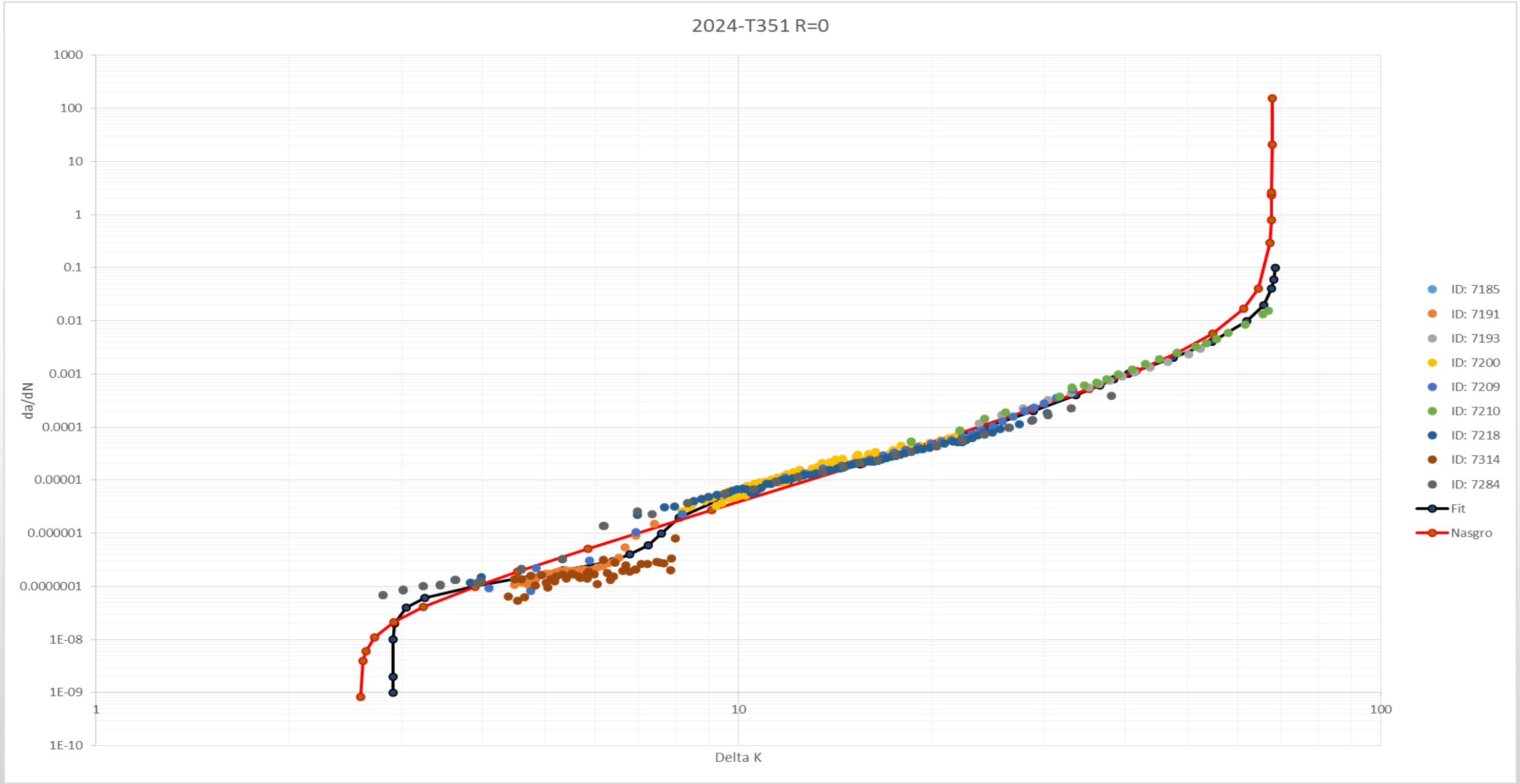
- The 7075-T6 data for R=0.02 did not have points at the lower rates
- Compared the Harter-T 7075-T6511 fit from AFGROW to estimate the material's behavior at the lower rates

Using Similar Data to Obtain the Correct Rhi Values

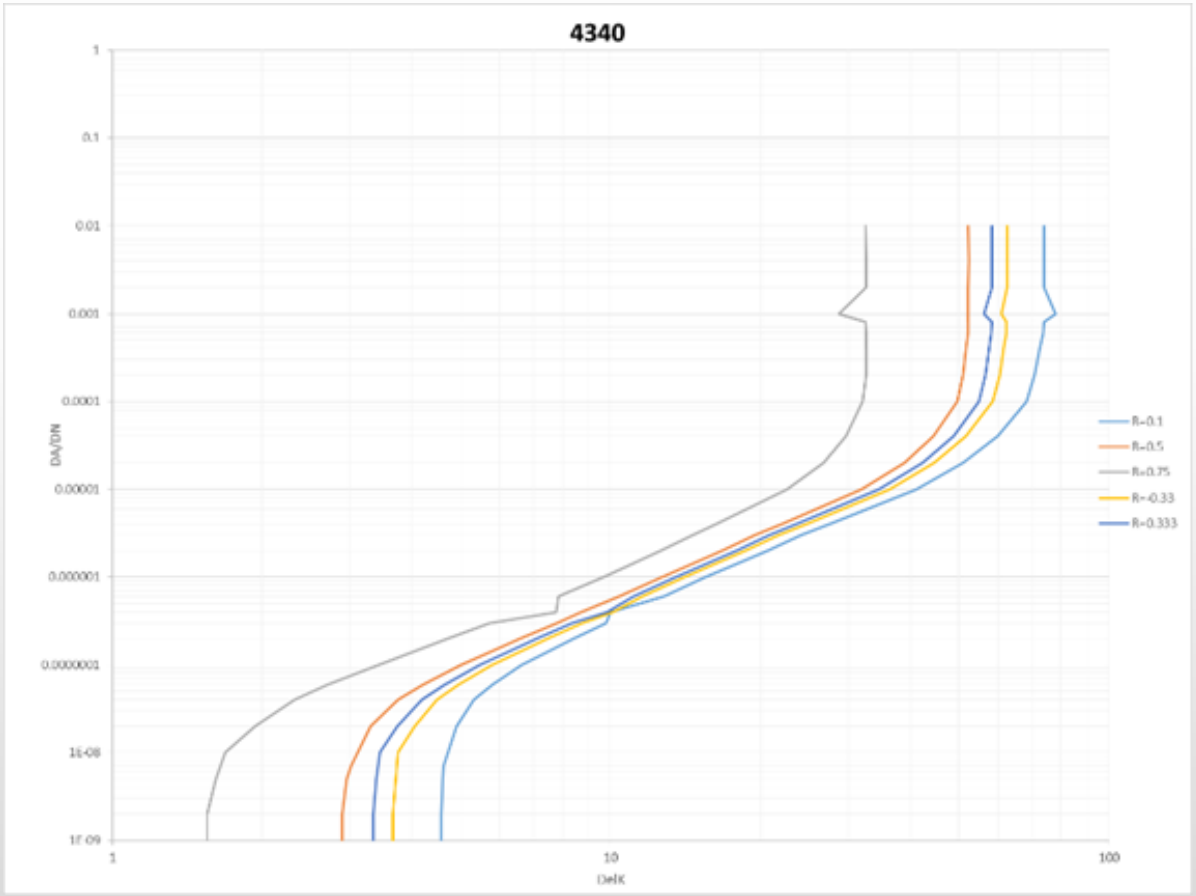


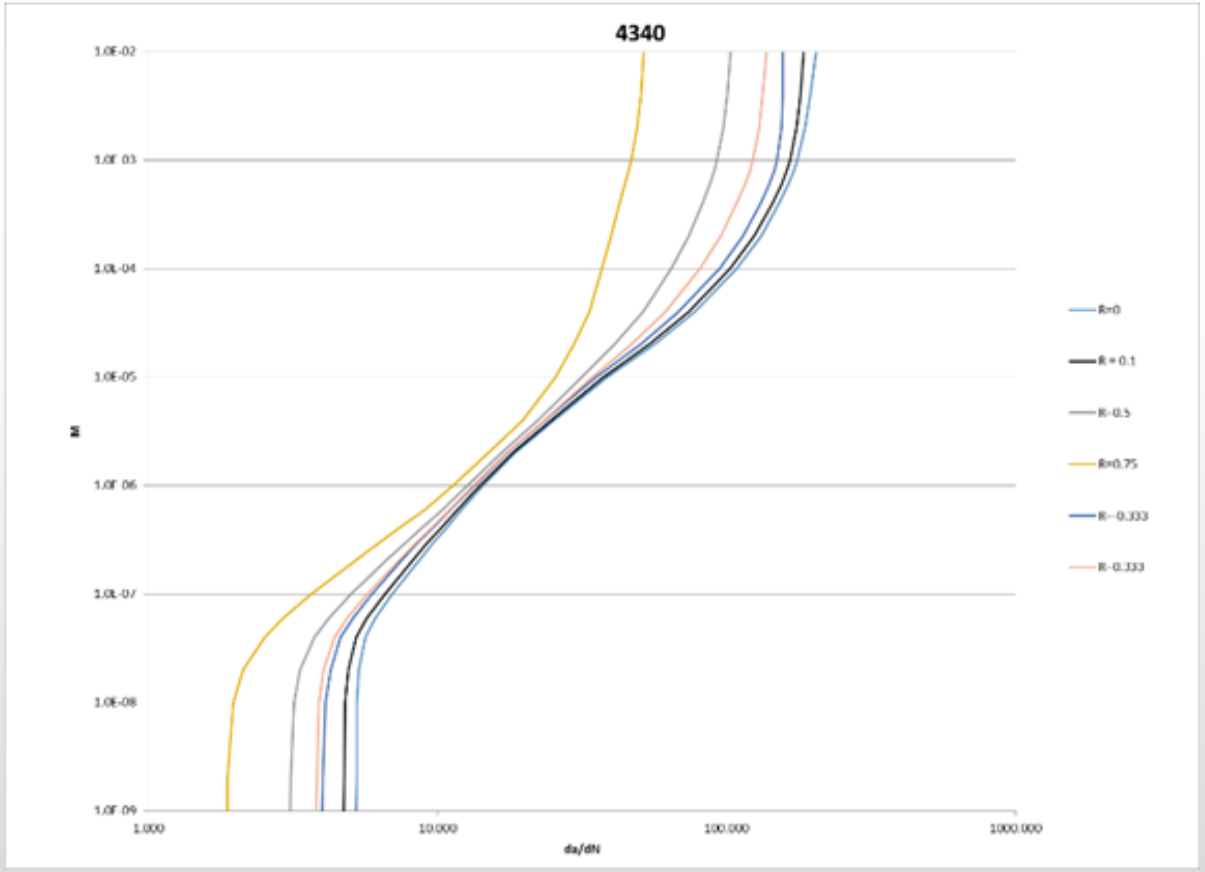
- 2024-T351 had data for R=0.8. Data for most materials stops shifting around 0.7 to 0.75
- Used 2024-T3 from Harter-T materials to check if the data has stopped shifting by comparing the data with the material at lower R values

Curve Fit V.S. NASGRO



Mistakes Made and Corrections

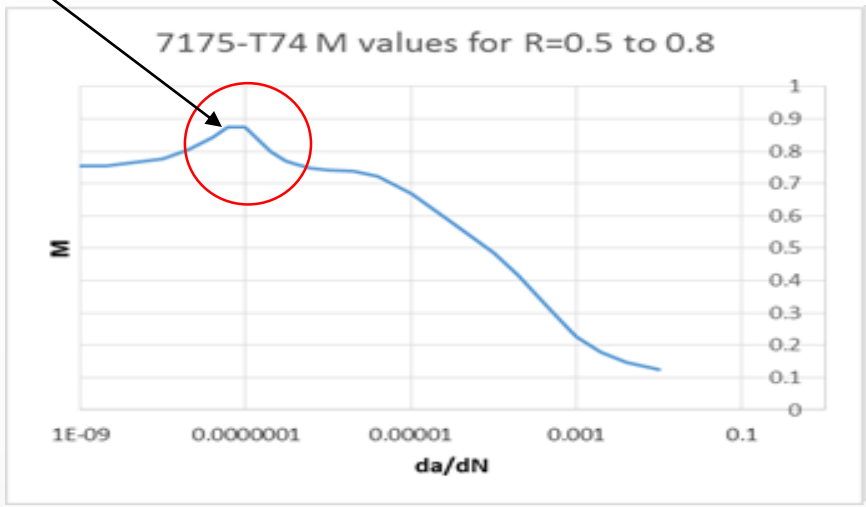


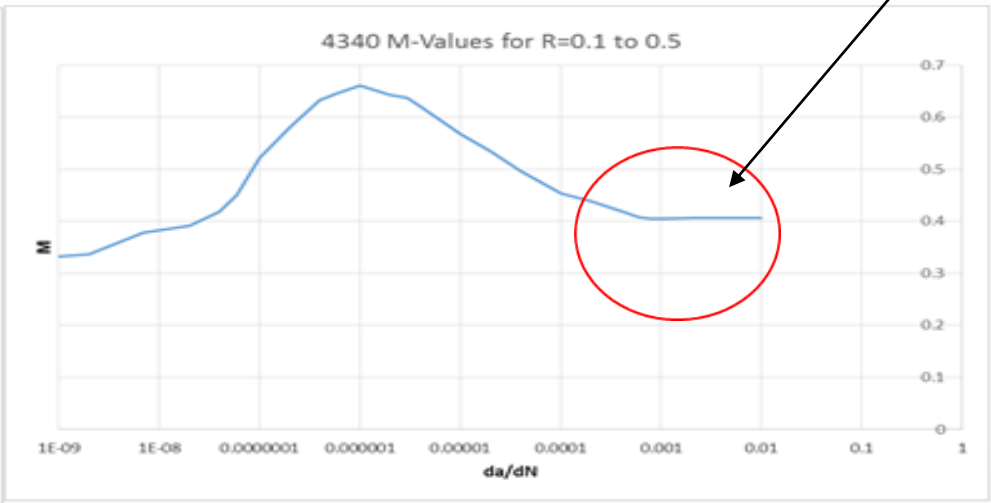


Mistakes Made and Corrections

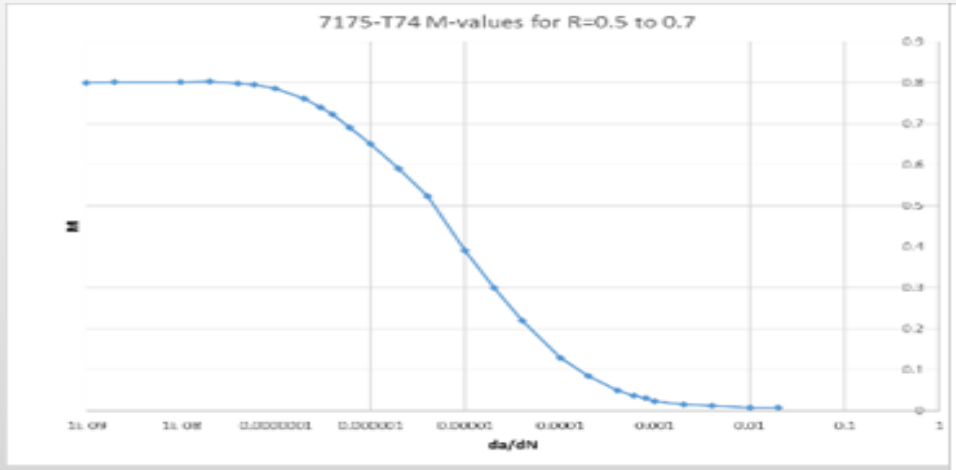
Large Peak

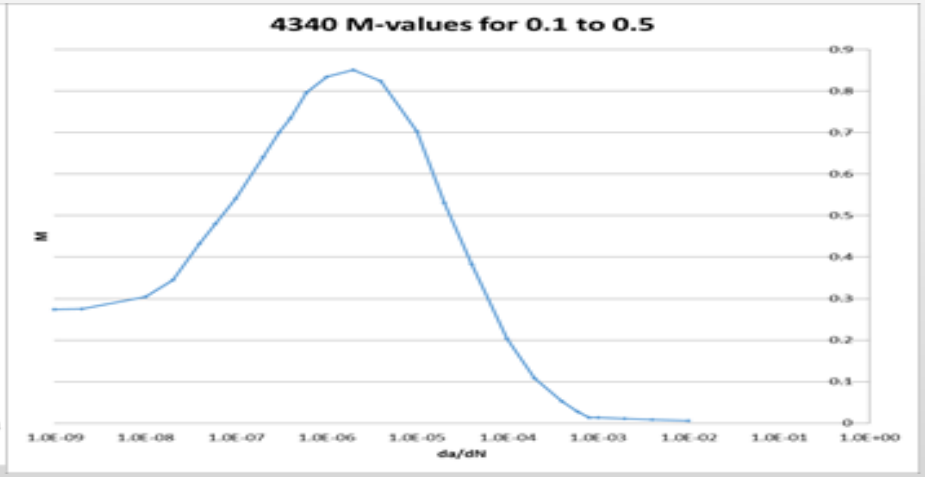
m-values at upper rates are too high.





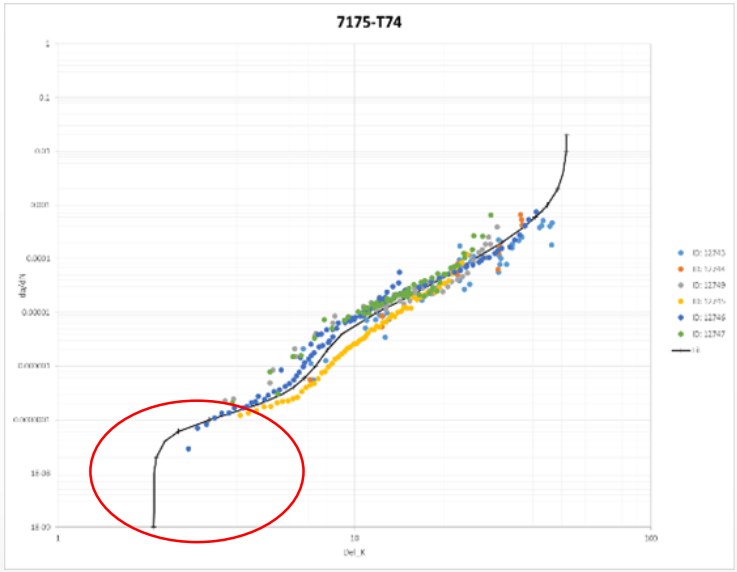
Incorrect m plots

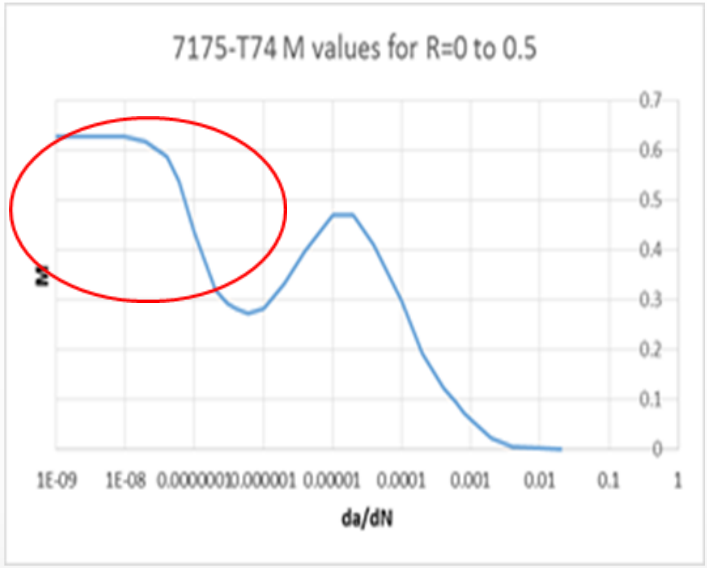


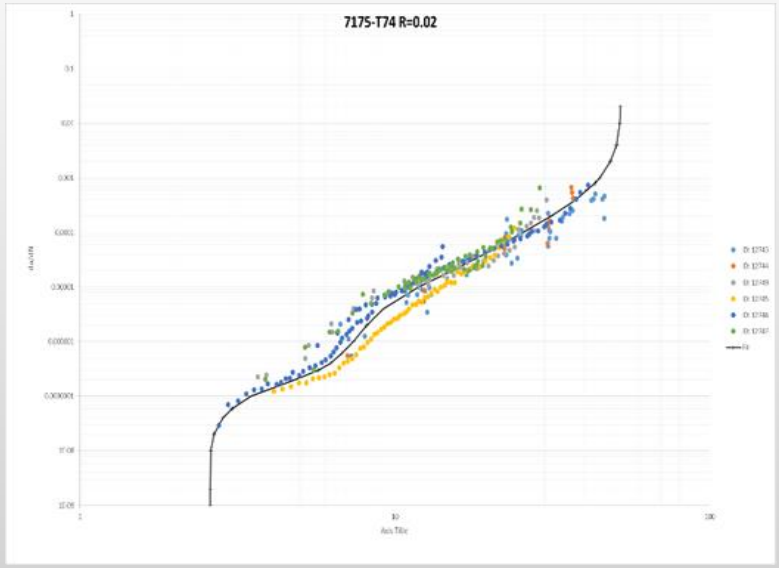


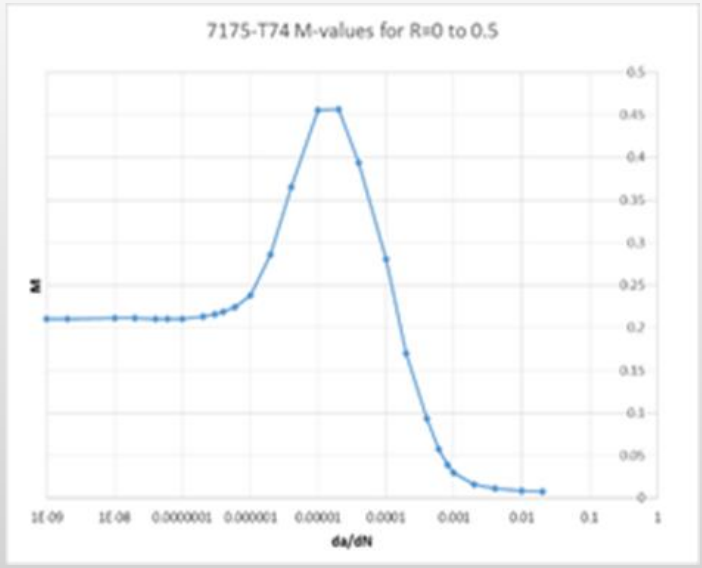
Corrected m plots

Mistakes Made and Corrections









- The threshold for the data at R=0.02 was too low compared to what the data suggests. This was also indicated in the m plot for R=0.02 to 0.5. As you can see in the upper m plot, the m's are too high at the low rates.
- Once this was corrected, the m-values returned to normal.

Tabular Curve Fits are Now Available for the Following Materials

- 2024-T3511
- 2024-T351
- 2024-T3
- 2024-T42
- 4340
- 7075-T74
- 7075-T7651
- 7075-T76
- 7075-T6
- 7175-T74

LexTech

AFGROW.NET

Special Thanks To:

- T-38 ASIP
- A-10 ASIP