NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

January 27, 2011

MATERIALS LABORATORY STUDY Report No. 11-001S

A. INVESTIGATION INFORMATION

Place	:	Miami, Florida
Date	:	October 26, 2010
Vehicle	:	Boeing 757-223, N626AA
NTSB No.	:	DCA11FA004
Investigator	:	Clinton Crookshanks, AS-40

B. COMPONENTS EXAMINED

Section of Fuselage Crown Skin.

C. REFERENCES

1) NTSB Materials Laboratory Factual Report 11-001, dated 1/27/2011.
2) D. Broek, The Practical Uses of Fracture Mechanics, Kluwer Academic Publishers, Dordrecht, 1989.

D. DETAILS OF THE STUDY

This study is an analysis of the fatigue striation data contained in reference 1. A discrete averaged-rate numerically-simple analysis of accumulated cycles versus crack length is performed using two assumptions for initial crack growth rates.

1. ACCUMULATED FATIGUE CYCLES

Based on the measured fatigue striation spacing data contained in reference 1, discrete estimates of the total number of fatigue cycles were made from initiation at or near the inner surface of the skin to complete penetration of the skin. For an aircraft fuselage remote from major attachment points, it is reasonable to assume that fatigue cycles are almost exclusively attributable to pressurization loads that normally occur once per flight. Therefore, crack growth rates derived from measurements of fatigue striations on the fracture surface can be directly related to the number of flight cycles the aircraft experienced.

As detailed in the factual report (reference 1), measurements of striation spacing were made at several points along the fatigue path. These data points were then used to estimate the growth rate of the fatigue crack and the total accumulated fatigue cycles through the thickness of the skin.

For this study, the average crack growths rates (avg da/dN), expressed in inches of crack growth per striation or cycle, was calculated between each adjacent measurement locations, *i* and i_{+1}. The average rate between these two locations was then applied over the intervening crack propagation interval, $a_{i+1} - a_i$, to determine the number of cycles present in that interval, $N_{i+1}-N_i$ (equation 1).

$$N_{i+1} - N_i = \frac{2(a_{i+1} - a_i)}{(da/dN)_{i+1} + (da/dN)_i}$$

Equation 1.

For the initial crack segment between crack initiation and the first physical measurement point, one set of calculations assumed an initial crack length, a_0, of zero and a crack growth rate, $(da/dN)_0$ of zero per reference 2.These will ber referred to as the 0,0 calculations. The second set of calculations assumes that the first reasonably measurable striations are at a crack length, a_0, of 0.001 inch and a reasonably measurable rate, da/dN_0, of $1X10^{-6}$ inches per cycle, referred to as the offset calculations. In these calculations any cycles accumulated between the surface and a crack length of 0.001 inch are ignored.

To determine the growth rate between the last measurement point and the outer surface of the skin, the rate was considered to be a direct linear extrapolation of the last two data points. The total accumulated number of cycles is then the sum of cycles from each discreet interval.

Using the same initial data, the shapes of the data curves for both sets of calculations are the same, as would be expected, but the 0,0 method results are offset to higher cycles for all crack lengths when compared to the offset calculations.

As described in the factual, through the thickness measurements of fatigue striation spacing were taken along 5 lines in the flap area, at body stations 411.8, 412.0, 412.5, 413.0 and 413.5, at 7 locations in the through crack region, BS 385.8, 386.0, 386.2, 386.5, 386.7, 386.9 and 387.0, and at 2 locations at the opened crack indication, BS 383.85 and 383.9.

In addition to calculating the total accumulated fatigue cycles at a crack length of 0.035 inch, the cycles at a crack length of 0.013 inch were determined graphically and the interval between 0.013 inch and 0.035 inch were calculated. Boeing reports that a crack of length 0.013 inch represents the lower confidence limit of crack detection for existing nondestructive inspection (NDI) methods applicable to the fuselage skin. The interval between 0.013 inch and the outer surface of the skin then represents the opportunity for detection of growing cracks.

For the flap area, the total accumulated cycles averaged 3,919 cycles with an average of 1,098 cycles between 0.013 inch and through thickness (0.035 inch). At the through crack, the total accumulated cycles averaged 3,542 cycles with an average interval of 736 cycles. Combining the data from both fatigue regions resulted in an

average total cycles of 3,709 cycles with an average interval of 917 cycles. Because of the relatively short crack length at the eddy current crack, only the cycles at 0.013 inch were calculated.

A summary of the data is presented below with detailed tables and graphs of the data at each measurement point following.

Joe Epperson
Senior Metallurgist

Count Location	Cycles at 0.013 inch	Cycles at 0.035 inch	Interval
Middle Bay Flap			
411.8	3400	3814	414
411.8 Offset	2550	2971	421
412.0	2250	2755	505
412.0 Offset	1800	2296	496
412.5	4000	5418	1418
412.5 Offset	3250	4685	1435
413.0	2850	3450	600
413.0 Offset	2350	2947	597
413.5	2950	3321	371
413.5 Offset	2100	2487	387
Forward Bay Thru Crack			
385.8	2200	2980	780
385.8 Offset	1700	2483	783
386.0	2500	3324	824
386.0 Offset	2000	2819	819
386.2	3150	5002	1852
386.2 Offset	2550	4439	1889
386.5	3350	5729	2379
386.5 Offset	2750	5174	2424
386.7	5000	5854	854
387.7 Offset	4100	5005	905
386.9	2950	3404	454
386.9 Offset	2275	2716	441
387.0	3000	3482	482
387.0 Offset	1975	2458	483
Crack Indication			
383.85	5550		
383.85 Offset	4600		
383.9	4100		
383.9 Offset	3550		

BS 411.8

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3351	0.00528	4.29E-06	2.15E-06	0.00528	2459.1	2459
3350	0.00638	3.20E-06	3.74E-06	0.00110	294.4	2753
3349	0.00783	6.55E-06	4.87E-06	0.00146	298.9	3052
3348	0.00870	1.07E-05	8.61E-06	0.00087	100.6	3153
3347	0.00906	5.14E-06	7.91E-06	0.00035	44.8	3198
3346	0.01110	2.73E-05	1.62E-05	0.00205	126.2	3324
3345	0.01295	3.80E-05	3.26E-05	0.00185	56.7	3381
3344	0.01370	3.43E-05	3.61E-05	0.00075	20.7	3402
3342	0.01709	5.89E-05	4.66E-05	0.00339	72.7	3475
3343	0.01831	6.49E-05	6.19E-05	0.00122	19.7	3495
3341	0.02181	4.03E-05	5.26E-05	0.00350	66.6	3562

BS 411.8 Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3351	0.00528	4.29E-06	2.65E-06	0.00428	1616.3	1616
3350	0.00638	3.20E-06	3.74E-06	0.00110	294.4	1910
3349	0.00783	6.55E-06	4.87E-06	0.00146	298.9	2209
3348	0.00870	1.07E-05	8.61E-06	0.00087	100.6	2310
3347	0.00906	5.14E-06	7.91E-06	0.00035	44.8	2355
3346	0.01110	2.73E-05	1.62E-05	0.00205	126.2	2481
3345	0.01295	3.80E-05	3.26E-05	0.00185	56.7	2538
3344	0.01370	3.43E-05	3.61E-05	0.00075	20.7	2559
3342	0.01709	5.89E-05	4.66E-05	0.00339	72.7	2632
3343	0.01831	6.49E-05	6.19E-05	0.00122	19.7	2652
3341	0.02181	4.03E-05	5.26E-05	0.00350	66.6	2719

BS 412.0

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3307	0.00406	6.21E-06	3.11E-06	0.00406	1306.0	1306
3305	0.00571	3.86E-06	5.03E-06	0.00165	328.4	1634
3303	0.00657	5.18E-06	4.52E-06	0.00087	191.6	1826
3302	0.00717	6.78E-06	5.98E-06	0.00059	98.7	1925
3301	0.00799	9.41E-06	8.10E-06	0.00083	102.1	2027
3300	0.01012	2.25E-05	1.60E-05	0.00213	133.3	2160
3299	0.01390	4.13E-05	3.19E-05	0.00378	118.6	2279
3298	0.01591	2.30E-05	3.21E-05	0.00201	62.5	2341
3297	0.01972	4.76E-05	3.53E-05	0.00382	108.1	2449
3296	0.02295	6.10E-05	5.43E-05	0.00323	59.4	2508
3295	0.02602	3.72E-05	4.91E-05	0.00307	62.5	2571

BS 412.0 Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3307	0.00406	6.21E-06	3.61E-06	0.00306	847.4	847
3305	0.00571	3.86E-06	5.03E-06	0.00165	328.4	1175
3303	0.00657	5.18E-06	4.52E-06	0.00087	191.6	1367
3302	0.00717	6.78E-06	5.98E-06	0.00059	98.7	1466
3301	0.00799	9.41E-06	8.10E-06	0.00083	102.1	1568
3300	0.01012	2.25E-05	1.60E-05	0.00213	133.3	1701
3299	0.01390	4.13E-05	3.19E-05	0.00378	118.6	1820
3298	0.01591	2.30E-05	3.21E-05	0.00201	62.5	1882
3297	0.01972	4.76E-05	3.53E-05	0.00382	108.1	1990
3296	0.02295	6.10E-05	5.43E-05	0.00323	59.4	2049
3295	0.02602	3.72E-05	4.91E-05	0.00307	62.5	2112

BS 412.5

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3322	0.00406	4.29E-06	2.15E-06	0.00406	1888.3	1888
3321	0.00429	6.99E-06	5.64E-06	0.00024	41.9	1930
3323	0.00520	4.70E-06	5.84E-06	0.00091	155.0	2085
3318	0.00807	4.03E-06	4.37E-06	0.00287	658.4	2743
3317	0.01008	3.89E-06	3.96E-06	0.00201	507.3	3250
3316	0.01236	3.35E-06	3.62E-06	0.00228	631.2	3881
3315	0.01421	8.18E-06	5.77E-06	0.00185	320.9	4202
3314	0.01772	1.75E-05	1.28E-05	0.00350	272.9	4475
3313	0.01870	1.44E-05	1.59E-05	0.00098	61.7	4537
3312	0.02441	1.12E-05	1.28E-05	0.00571	446.3	4983
3311	0.02748	2.47E-05	1.80E-05	0.00307	171.1	5154
3310	0.03016	3.25E-05	2.86E-05	0.00268	93.6	5248

BS 412.5 Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3322	0.00406	4.29E-06	2.65E-06	0.00306	1154.0	1154
3321	0.00429	6.99E-06	5.64E-06	0.00024	41.9	1196
3323	0.00520	4.70E-06	5.84E-06	0.00091	155.0	1351
3318	0.00807	4.03E-06	4.37E-06	0.00287	658.4	2009
3317	0.01008	3.89E-06	3.96E-06	0.00201	507.3	2516
3316	0.01236	3.35E-06	3.62E-06	0.00228	631.2	3147
3315	0.01421	8.18E-06	5.77E-06	0.00185	320.9	3468
3314	0.01772	1.75E-05	1.28E-05	0.00350	272.9	3741
3313	0.01870	1.44E-05	1.59E-05	0.00098	61.7	3803
3312	0.02441	1.12E-05	1.28E-05	0.00571	446.3	4249
3311	0.02748	2.47E-05	1.80E-05	0.00307	171.1	4420
3310	0.03016	3.25E-05	2.86E-05	0.00268	93.6	4514

BS 413.0

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3288	0.00441	5.93E-06	2.96E-06	0.00441	1488.4	1488
3285	0.00579	3.38E-06	4.65E-06	0.00138	296.2	1784
3284	0.00626	3.09E-06	3.23E-06	0.00047	146.1	1930
3283	0.00799	5.14E-06	4.11E-06	0.00173	421.0	2351
3282	0.00870	6.22E-06	5.68E-06	0.00071	124.8	2476
3281	0.01028	1.02E-05	8.21E-06	0.00157	191.8	2668
3280	0.01134	1.46E-05	1.24E-05	0.00106	85.9	2754
3278	0.01417	2.75E-05	2.10E-05	0.00283	134.9	2889
3277	0.01531	3.65E-05	3.20E-05	0.00114	35.7	2925
3275	0.01807	4.99E-05	4.32E-05	0.00276	63.8	2989
3274	0.01917	2.09E-05	3.54E-05	0.00110	31.1	3020
3273	0.02394	4.29E-05	3.19E-05	0.00476	149.3	3169
3272	0.02433	3.22E-05	3.76E-05	0.00039	10.5	3179

BS 413.0 Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3288	0.00441	5.93E-06	3.46E-06	0.00341	984.7	985
3285	0.00579	3.38E-06	4.65E-06	0.00138	296.2	1281
3284	0.00626	3.09E-06	3.23E-06	0.00047	146.1	1427
3283	0.00799	5.14E-06	4.11E-06	0.00173	421.0	1848
3282	0.00870	6.22E-06	5.68E-06	0.00071	124.8	1973
3281	0.01028	1.02E-05	8.21E-06	0.00157	191.8	2165
3280	0.01134	1.46E-05	1.24E-05	0.00106	85.9	2251
3278	0.01417	2.75E-05	2.10E-05	0.00283	134.9	2386
3277	0.01531	3.65E-05	3.20E-05	0.00114	35.7	2422
3275	0.01807	4.99E-05	4.32E-05	0.00276	63.8	2486
3274	0.01917	2.09E-05	3.54E-05	0.00110	31.1	2517
3273	0.02394	4.29E-05	3.19E-05	0.00476	149.3	2666
3272	0.02433	3.22E-05	3.76E-05	0.00039	10.5	2676

BS 413.5

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3338	0.00315	3.53E-06	1.77E-06	0.00315	1782.3	1782
3335	0.00547	3.89E-06	3.71E-06	0.00232	625.9	2408
3334	0.00709	9.58E-06	6.73E-06	0.00161	239.7	2648
3333	0.00906	1.84E-05	1.40E-05	0.00197	140.5	2788
3332	0.01252	2.98E-05	2.41E-05	0.00346	143.8	2932
3330	0.01433	3.97E-05	3.47E-05	0.00181	52.1	2984
3331	0.01657	4.13E-05	4.05E-05	0.00224	55.4	3039
3329	0.01957	4.74E-05	4.43E-05	0.00299	67.5	3106
3328	0.02000	4.72E-05	4.73E-05	0.00043	9.2	3115
3327	0.02583	9.76E-05	7.24E-05	0.00583	80.4	3195

BS 413.5 Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3338	0.00315	3.53E-06	2.27E-06	0.00215	948.1	948
3335	0.00547	3.89E-06	3.71E-06	0.00232	625.9	1574
3334	0.00709	9.58E-06	6.73E-06	0.00161	239.7	1814
3333	0.00906	1.84E-05	1.40E-05	0.00197	140.5	1954
3332	0.01252	2.98E-05	2.41E-05	0.00346	143.8	2098
3330	0.01433	3.97E-05	3.47E-05	0.00181	52.1	2150
3331	0.01657	4.13E-05	4.05E-05	0.00224	55.4	2205
3329	0.01957	4.74E-05	4.43E-05	0.00299	67.5	2272
3328	0.02000	4.72E-05	4.73E-05	0.00043	9.2	2281
3327	0.02583	9.76E-05	7.24E-05	0.00583	80.4	2361

BS 383.9

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3369	0.00094	3.66E-06	1.83E-06	0.00094	516.2	516
3366	0.00437	3.95E-06	3.81E-06	0.00343	900.1	1416
3365	0.00480	4.85E-06	4.40E-06	0.00043	98.5	1514
3364	0.00736	2.21E-06	3.53E-06	0.00256	725.7	2240
3363	0.00913	2.28E-06	2.24E-06	0.00177	789.4	3029
3362	0.00992	2.59E-06	2.43E-06	0.00079	323.5	3352
3361	0.01138	5.06E-06	3.82E-06	0.00146	380.9	3733
3359	0.01291	3.75E-06	4.41E-06	0.00154	348.5	4082
3358	0.01417	5.08E-06	4.42E-06	0.00126	285.3	4367
3357	0.01516	5.47E-06	5.27E-06	0.00098	186.6	4554
3356	0.01657	6.34E-06	5.91E-06	0.00142	240.0	4794

BS 383.9
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3369	0.00094	3.66E-06	2.33E-06	-0.00006	-23.7	-24
3366	0.00437	3.95E-06	3.81E-06	0.00343	900.1	876
3365	0.00480	4.85E-06	4.40E-06	0.00043	98.5	974
3364	0.00736	2.21E-06	3.53E-06	0.00256	725.7	1700
3363	0.00913	2.28E-06	2.24E-06	0.00177	789.4	2489
3362	0.00992	2.59E-06	2.43E-06	0.00079	323.5	2812
3361	0.01138	5.06E-06	3.82E-06	0.00146	380.9	3193
3359	0.01291	3.75E-06	4.41E-06	0.00154	348.5	3542
3358	0.01417	5.08E-06	4.42E-06	0.00126	285.3	3827
3357	0.01516	5.47E-06	5.27E-06	0.00098	186.6	4014
3356	0.01657	6.34E-06	5.91E-06	0.00142	240.0	4254

BS 385.8

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3218	0.00319	5.40E-06	2.70E-06	0.00319	1181.3	1181
3219	0.00539	1.08E-05	8.10E-06	0.00220	272.2	1453
3220	0.00740	8.25E-06	9.52E-06	0.00201	210.9	1664
3194	0.01110	1.06E-05	9.44E-06	0.00370	392.2	2056
3193	0.01252	1.34E-05	1.20E-05	0.00142	118.2	2174
3221	0.01370	1.64E-05	1.49E-05	0.00118	79.3	2253
3222	0.01547	2.11E-05	1.88E-05	0.00177	94.5	2347
3192	0.01902	4.27E-05	3.19E-05	0.00354	111.0	2458
3223	0.02181	2.93E-05	3.60E-05	0.00280	77.6	2536
3191	0.02472	3.01E-05	2.97E-05	0.00291	98.1	2634

BS 385.8
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3218	0.00319	5.40E-06	3.20E-06	0.00219	684.1	684
3219	0.00539	1.08E-05	8.10E-06	0.00220	272.2	956
3220	0.00740	8.25E-06	9.52E-06	0.00201	210.9	1167
3194	0.01110	1.06E-05	9.44E-06	0.00370	392.2	1559
3193	0.01252	1.34E-05	1.20E-05	0.00142	118.2	1677
3221	0.01370	1.64E-05	1.49E-05	0.00118	79.3	1756
3222	0.01547	2.11E-05	1.88E-05	0.00177	94.5	1850
3192	0.01902	4.27E-05	3.19E-05	0.00354	111.0	1961
3223	0.02181	2.93E-05	3.60E-05	0.00280	77.6	2039
3191	0.02472	3.01E-05	2.97E-05	0.00291	98.1	2137

BS 386.0

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3140	0.00335	5.41E-06	2.71E-06	0.00335	1237.1	1237
3138	0.00567	7.75E-06	6.58E-06	0.00232	353.0	1590
3137	0.00614	4.59E-06	6.17E-06	0.00047	76.6	1667
3145	0.00669	5.24E-06	4.92E-06	0.00055	112.1	1779
3134	0.00756	4.08E-06	4.66E-06	0.00087	185.9	1965
3144	0.00949	1.00E-05	7.05E-06	0.00193	273.7	2239
3132	0.01130	1.22E-05	1.11E-05	0.00181	163.2	2402
3131	0.01622	2.03E-05	1.62E-05	0.00492	303.3	2705
3143	0.01787	1.40E-05	1.71E-05	0.00165	96.4	2801
3130	0.02106	3.21E-05	2.30E-05	0.00319	138.4	2939
3142	0.02240	4.72E-05	3.97E-05	0.00134	33.8	2973
3129	0.02622	4.14E-05	4.43E-05	0.00382	86.2	3059
3141	0.02630	4.81E-05	4.47E-05	0.00008	1.8	3061
3127	0.02815	3.03E-05	3.92E-05	0.00185	47.2	3108
3126	0.02913	3.41E-05	3.22E-05	0.00098	30.6	3139

BS 386.0
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3140	0.00335	5.41E-06	3.21E-06	0.00235	732.1	732
3138	0.00567	7.75E-06	6.58E-06	0.00232	353.0	1085
3137	0.00614	4.59E-06	6.17E-06	0.00047	76.6	1162
3145	0.00669	5.24E-06	4.92E-06	0.00055	112.1	1274
3134	0.00756	4.08E-06	4.66E-06	0.00087	185.9	1460
3144	0.00949	1.00E-05	7.05E-06	0.00193	273.7	1734
3132	0.01130	1.22E-05	1.11E-05	0.00181	163.2	1897
3131	0.01622	2.03E-05	1.62E-05	0.00492	303.3	2200
3143	0.01787	1.40E-05	1.71E-05	0.00165	96.4	2296
3130	0.02106	3.21E-05	2.30E-05	0.00319	138.4	2434
3142	0.02240	4.72E-05	3.97E-05	0.00134	33.8	2468
3129	0.02622	4.14E-05	4.43E-05	0.00382	86.2	2554
3141	0.02630	4.81E-05	4.47E-05	0.00008	1.8	2556
3127	0.02815	3.03E-05	3.92E-05	0.00185	47.2	2603
3126	0.02913	3.41E-05	3.22E-05	0.00098	30.6	2634

BS 386.2

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3202	0.00283	4.70E-06	2.35E-06	0.00283	1205.6	1206
3201	0.00906	4.94E-06	4.82E-06	0.00622	1290.6	2497
3199	0.01224	6.30E-06	5.62E-06	0.00319	567.6	3065
3198	0.01783	1.09E-05	8.62E-06	0.00559	648.7	3714
3206	0.02224	1.11E-05	1.10E-05	0.00441	400.7	4115
3197	0.02602	1.37E-05	1.24E-05	0.00378	305.7	4421
3203	0.02917	1.73E-05	1.55E-05	0.00315	203.6	4625

BS 386.2
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3202	0.00283	4.70E-06	2.85E-06	0.00183	643.4	643
3201	0.00906	4.94E-06	4.82E-06	0.00622	1290.6	1934
3199	0.01224	6.30E-06	5.62E-06	0.00319	567.6	2502
3198	0.01783	1.09E-05	8.62E-06	0.00559	648.7	3151
3206	0.02224	1.11E-05	1.10E-05	0.00441	400.7	3552
3197	0.02602	1.37E-05	1.24E-05	0.00378	305.7	3858
3203	0.02917	1.73E-05	1.55E-05	0.00315	203.6	4062

BS 386.5

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00				0
3160	0.00224	4.43E-06	2.21E-06	0.00224	1013.3	1013
3158	0.00232	5.55E-06	4.99E-06	0.00008	15.8	1029
3156	0.00606	3.77E-06	4.66E-06	0.00374	802.6	1832
3155	0.00827	5.42E-06	4.59E-06	0.00220	479.9	2312
3154	0.01075	4.12E-06	4.77E-06	0.00248	520.4	2832
3153	0.01362	4.87E-06	4.50E-06	0.00287	639.4	3471
3152	0.01551	6.78E-06	5.83E-06	0.00189	324.3	3795
3151	0.01961	4.54E-06	5.66E-06	0.00409	723.5	4519
3150	0.02614	1.56E-05	1.01E-05	0.00654	648.1	5167
3149	0.02898	1.52E-05	1.54E-05	0.00283	183.9	5351
3147	0.03039	1.68E-05	1.60E-05	0.00142	88.6	5440

BS 386.5
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06				0
3160	0.00224	4.43E-06	2.71E-06	0.00124	458.3	458
3158	0.00232	5.55E-06	4.99E-06	0.00008	15.8	474
3156	0.00606	3.77E-06	4.66E-06	0.00374	802.6	1277
3155	0.00827	5.42E-06	4.59E-06	0.00220	479.9	1757
3154	0.01075	4.12E-06	4.77E-06	0.00248	520.4	2277
3153	0.01362	4.87E-06	4.50E-06	0.00287	639.4	2916
3152	0.01551	6.78E-06	5.83E-06	0.00189	324.3	3240
3151	0.01961	4.54E-06	5.66E-06	0.00409	723.5	3964
3150	0.02614	1.56E-05	1.01E-05	0.00654	648.1	4612
3149	0.02898	1.52E-05	1.54E-05	0.00283	183.9	4796
3147	0.03039	1.68E-05	1.60E-05	0.00142	88.6	4885

BS 386.7

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3214	0.00260	3.16E-06	1.58E-06	0.00260	1647.1	1647
3213	0.00610	2.08E-06	2.62E-06	0.00350	1337.7	2985
3212	0.01008	2.81E-06	2.45E-06	0.00398	1623.9	4609
3211	0.01472	1.35E-05	8.14E-06	0.00465	571.0	5180
3210	0.01870	2.34E-05	1.84E-05	0.00398	215.7	5396
3209	0.02236	3.31E-05	2.82E-05	0.00366	129.6	5526
3208	0.02697	3.79E-05	3.55E-05	0.00461	129.8	5656

BS 386.7
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3214	0.00260	3.16E-06	2.08E-06	0.00160	769.4	769
3213	0.00610	2.08E-06	2.62E-06	0.00350	1337.7	2107
3212	0.01008	2.81E-06	2.45E-06	0.00398	1623.9	3731
3211	0.01472	1.35E-05	8.14E-06	0.00465	571.0	4302
3210	0.01870	2.34E-05	1.84E-05	0.00398	215.7	4518
3209	0.02236	3.31E-05	2.82E-05	0.00366	129.6	4648
3208	0.02697	3.79E-05	3.55E-05	0.00461	129.8	4778

BS 386.9

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00				0
3177	0.00177	3.41E-06	1.71E-06	0.00177	1038.5	1038
3176	0.00224	3.41E-06	3.41E-06	0.00047	138.5	1176
3174	0.00323	5.15E-06	4.28E-06	0.00098	230.0	1406
3173	0.00382	5.25E-06	5.20E-06	0.00059	113.6	1520
3171	0.00516	3.28E-06	4.27E-06	0.00134	313.8	1834
3172	0.00713	4.27E-06	3.77E-06	0.00197	521.7	2356
3170	0.00858	5.59E-06	4.93E-06	0.00146	295.5	2651
3169	0.01087	1.44E-05	9.99E-06	0.00228	228.6	2880
3168	0.01366	3.54E-05	2.49E-05	0.00280	112.2	2992
3179	0.01685	3.94E-05	3.74E-05	0.00319	85.3	3077
3167	0.01799	3.75E-05	3.84E-05	0.00114	29.7	3107
3166	0.02079	3.82E-05	3.79E-05	0.00280	73.8	3181
3180	0.02303	5.11E-05	4.47E-05	0.00224	50.2	3231
3165	0.02449	8.61E-05	6.86E-05	0.00146	21.2	3252

BS 386.9
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06				0
3177	0.00177	3.41E-06	2.21E-06	0.00077	349.8	350
3176	0.00224	3.41E-06	3.41E-06	0.00047	138.5	488
3174	0.00323	5.15E-06	4.28E-06	0.00098	230.0	718
3173	0.00382	5.25E-06	5.20E-06	0.00059	113.6	832
3171	0.00516	3.28E-06	4.27E-06	0.00134	313.8	1146
3172	0.00713	4.27E-06	3.77E-06	0.00197	521.7	1668
3170	0.00858	5.59E-06	4.93E-06	0.00146	295.5	1963
3169	0.01087	1.44E-05	9.99E-06	0.00228	228.6	2192
3168	0.01366	3.54E-05	2.49E-05	0.00280	112.2	2304
3179	0.01685	3.94E-05	3.74E-05	0.00319	85.3	2389
3167	0.01799	3.75E-05	3.84E-05	0.00114	29.7	2419
3166	0.02079	3.82E-05	3.79E-05	0.00280	73.8	2493
3180	0.02303	5.11E-05	4.47E-05	0.00224	50.2	2543
3165	0.02449	8.61E-05	6.86E-05	0.00146	21.2	2564

BS 387.0

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3225	0.00303	2.95E-06	1.48E-06	0.00303	2053.3	2053
3187	0.00661	9.99E-06	6.47E-06	0.00358	553.7	2607
3215	0.00898	1.42E-05	1.21E-05	0.00236	195.0	2802
3185	0.01138	1.94E-05	1.68E-05	0.00240	142.8	2945
3216	0.01335	4.13E-05	3.04E-05	0.00197	64.8	3010
3183	0.01677	3.11E-05	3.62E-05	0.00343	94.7	3105
3182	0.02063	6.52E-05	4.82E-05	0.00386	80.1	3185

BS 387.0
Offset

Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3225	0.00303	2.95E-06	1.98E-06	0.00203	1027.9	1028
3187	0.00661	9.99E-06	6.47E-06	0.00358	553.7	1582
3215	0.00898	1.42E-05	1.21E-05	0.00236	195.0	1777
3185	0.01138	1.94E-05	1.68E-05	0.00240	142.8	1920
3216	0.01335	4.13E-05	3.04E-05	0.00197	64.8	1985
3183	0.01677	3.11E-05	3.62E-05	0.00343	94.7	2080
3182	0.02063	6.52E-05	4.82E-05	0.00386	80.1	2160

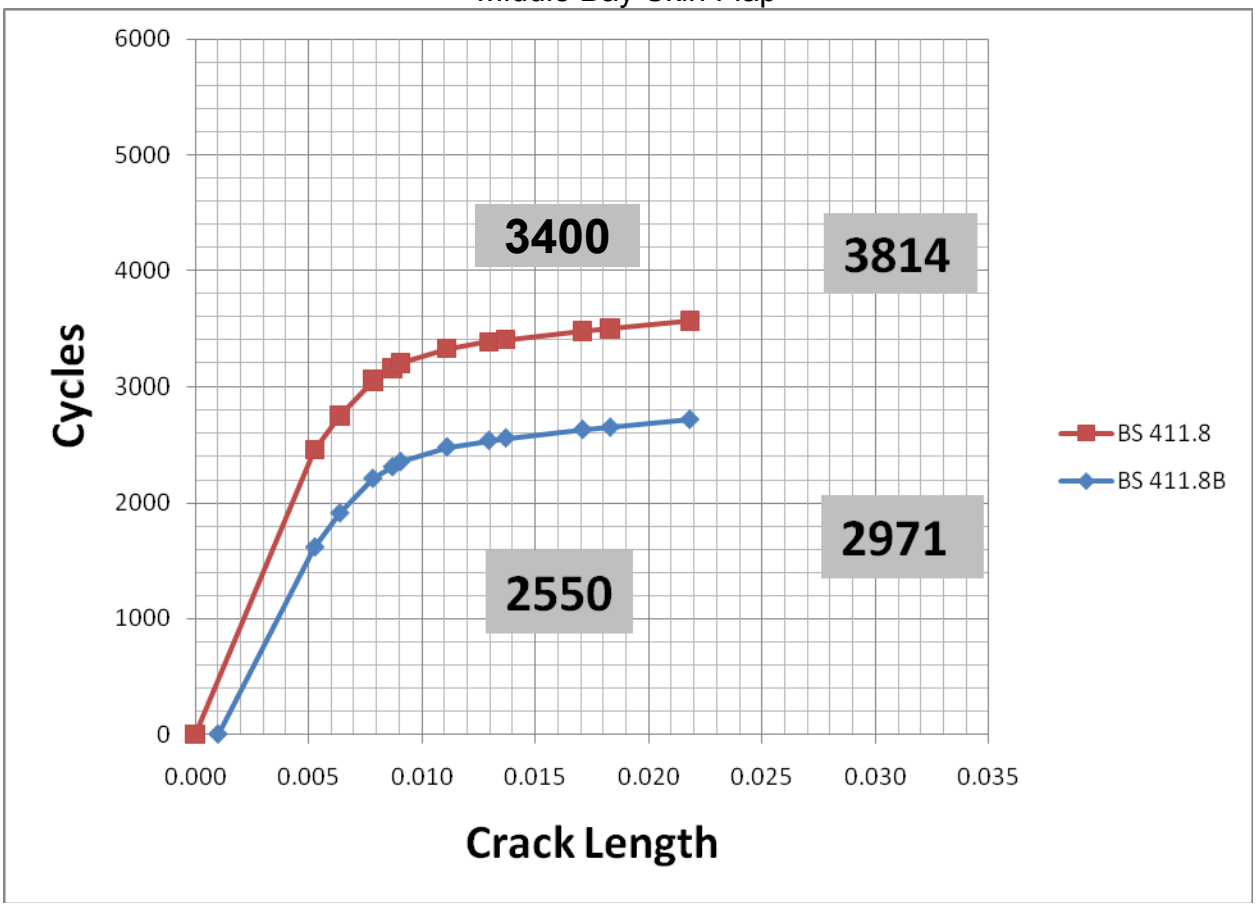
BS 383.85

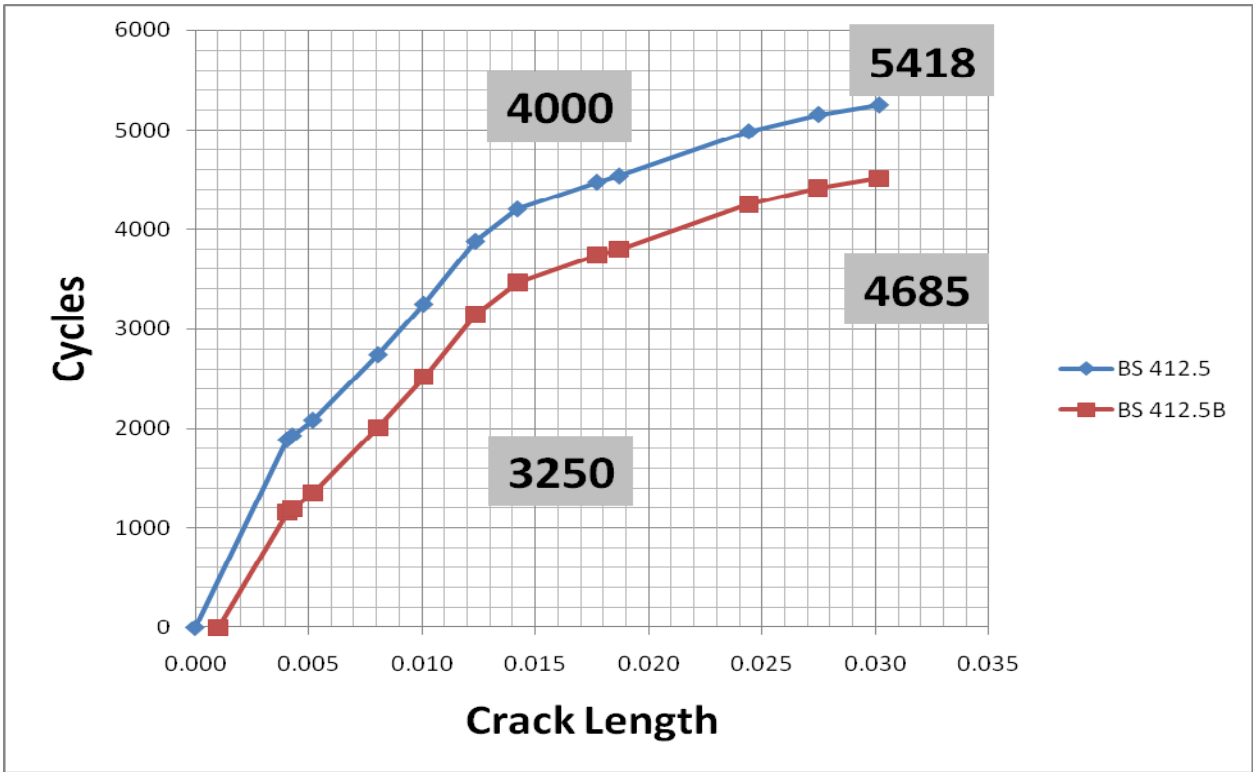
Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00000	0.00E+00			0.0	0
3233	0.00386	3.49E-06	1.75E-06	0.00386	2209.5	2209
3235	0.00516	2.41E-06	2.95E-06	0.00130	440.2	2649
3237	0.00772	2.69E-06	2.55E-06	0.00256	1004.0	3653
3238	0.00850	2.55E-06	2.62E-06	0.00079	300.8	3954
3239	0.01110	2.55E-06	2.55E-06	0.00260	1019.5	4973
3242	0.01303	4.14E-06	3.35E-06	0.00193	576.3	5549
3243	0.01642	3.75E-06	3.95E-06	0.00339	858.1	6407

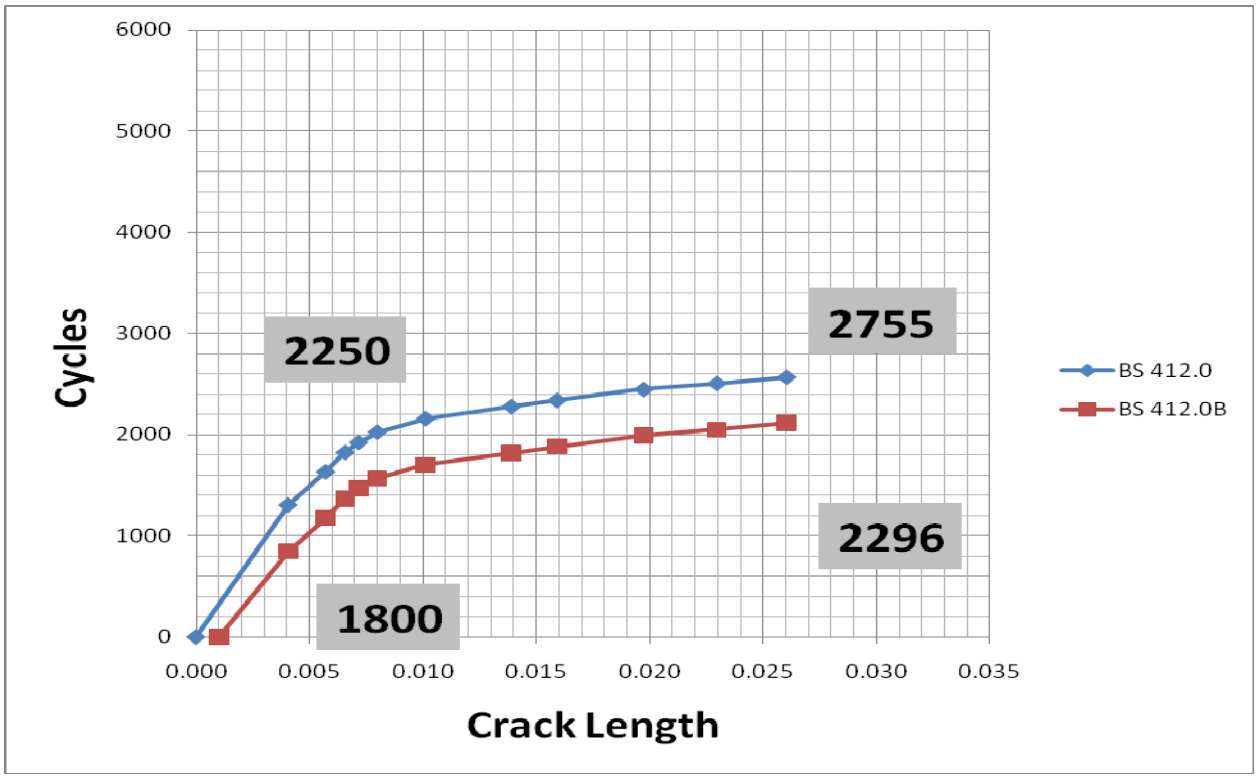
BS 383.85
Offset

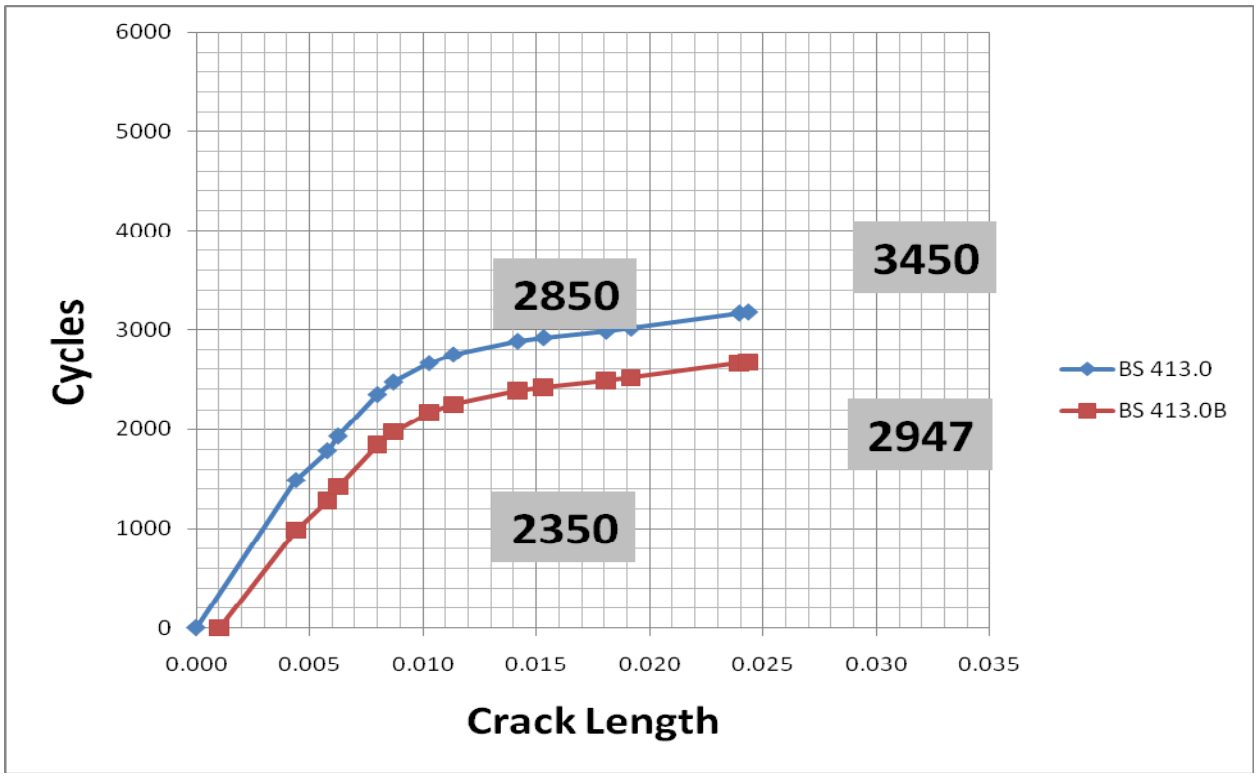
Image	Crack Length (in)	da/dN (in/cycle)	Average da/dN	Crack Interval	Interval Cycles	Cumulative Cycles
origin	0.00100	1.00E-06			0.0	0
3233	0.00386	3.49E-06	2.25E-06	0.00286	1272.5	1272
3235	0.00516	2.41E-06	2.95E-06	0.00130	440.2	1712
3237	0.00772	2.69E-06	2.55E-06	0.00256	1004.0	2716
3238	0.00850	2.55E-06	2.62E-06	0.00079	300.8	3017
3239	0.01110	2.55E-06	2.55E-06	0.00260	1019.5	4036
3242	0.01303	4.14E-06	3.35E-06	0.00193	576.3	4612
3243	0.01642	3.75E-06	3.95E-06	0.00339	858.1	5470

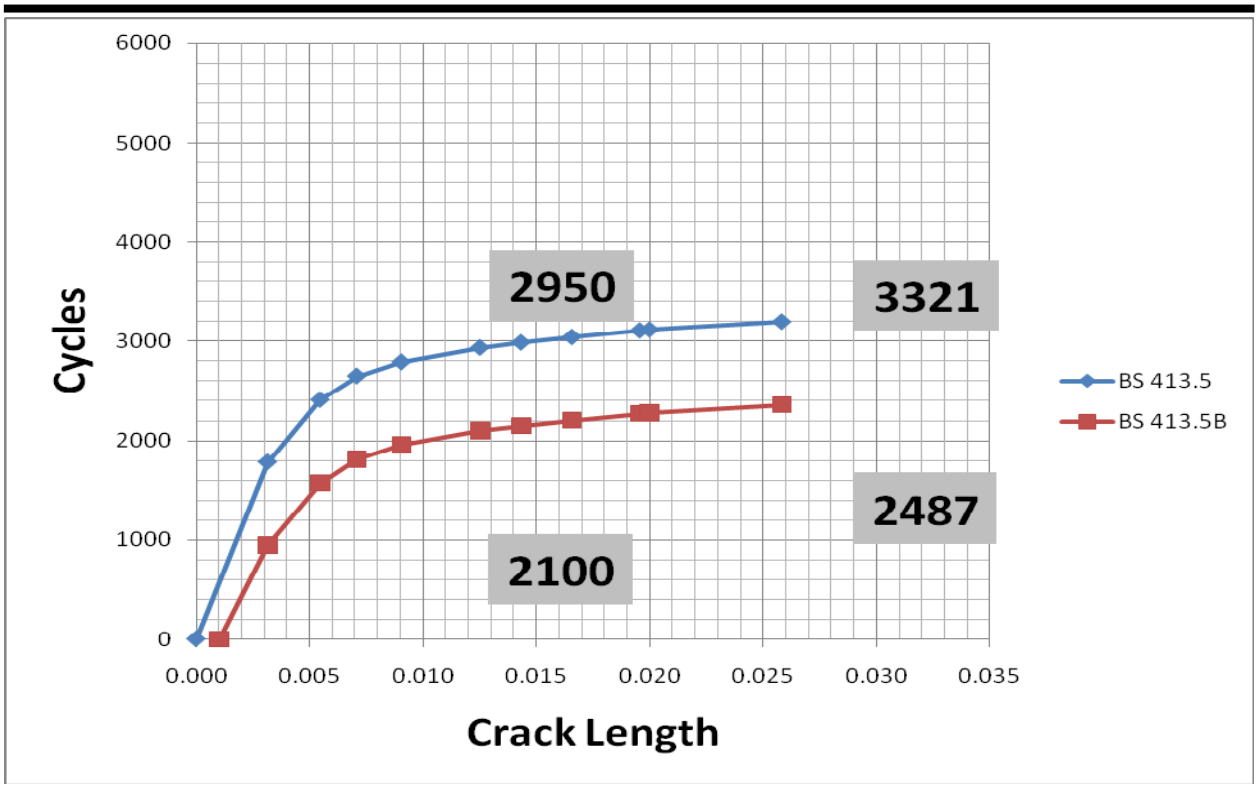
Middle Bay Skin Flap



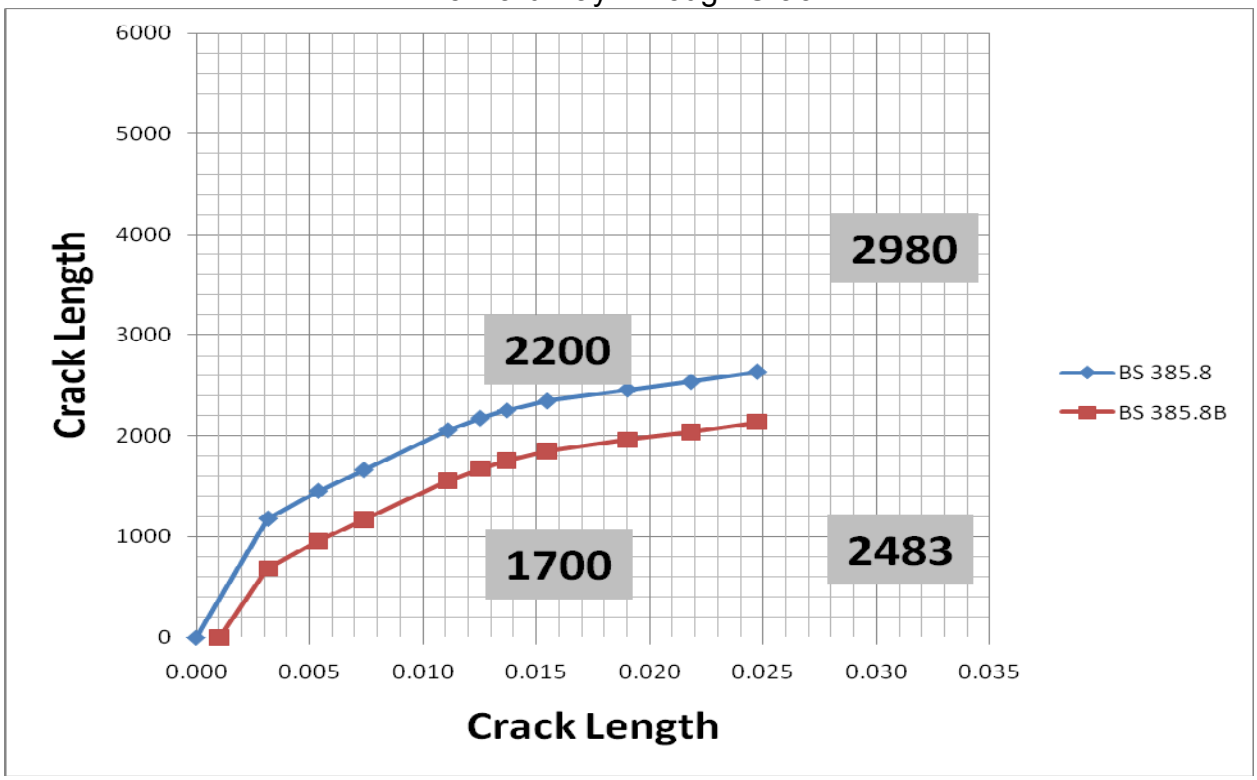


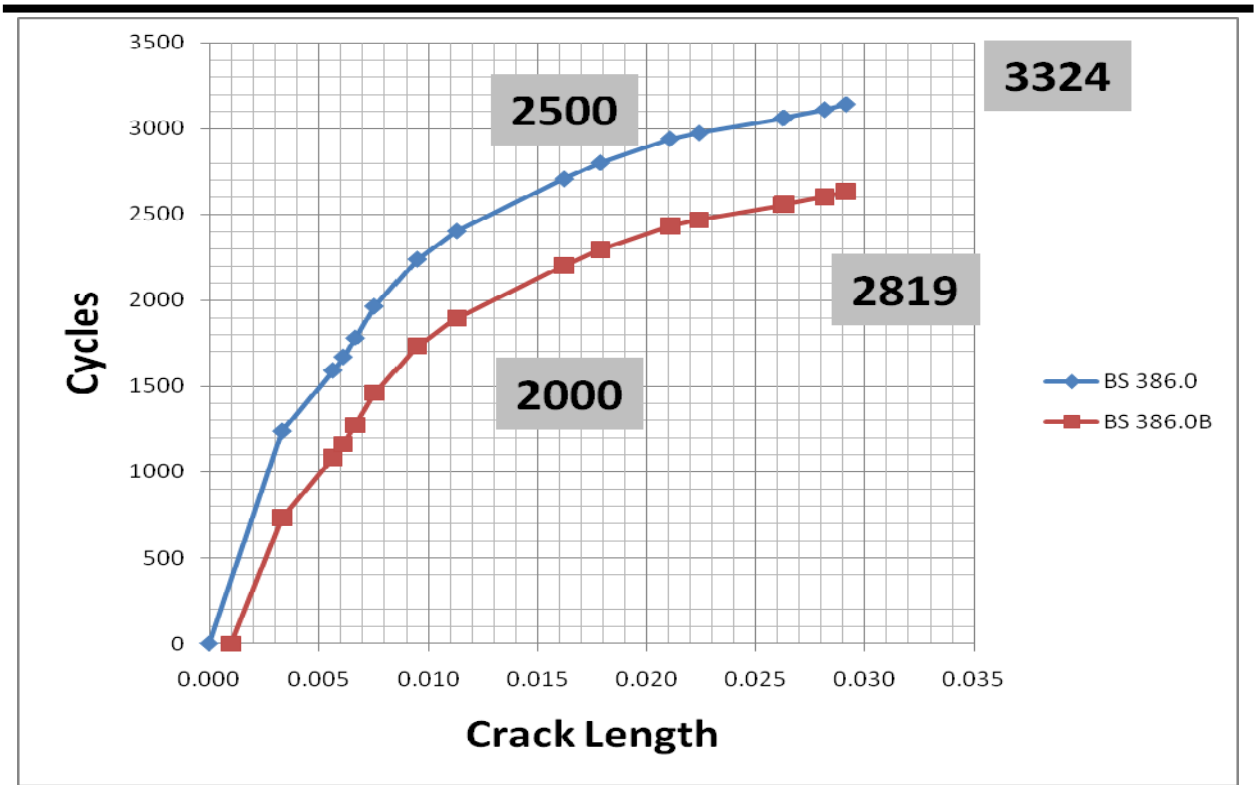

6000
5000
4000
3000
2000
1000
0
Cycles
2250
2755
2296
1800
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
BS 412.0
BS 412.0B

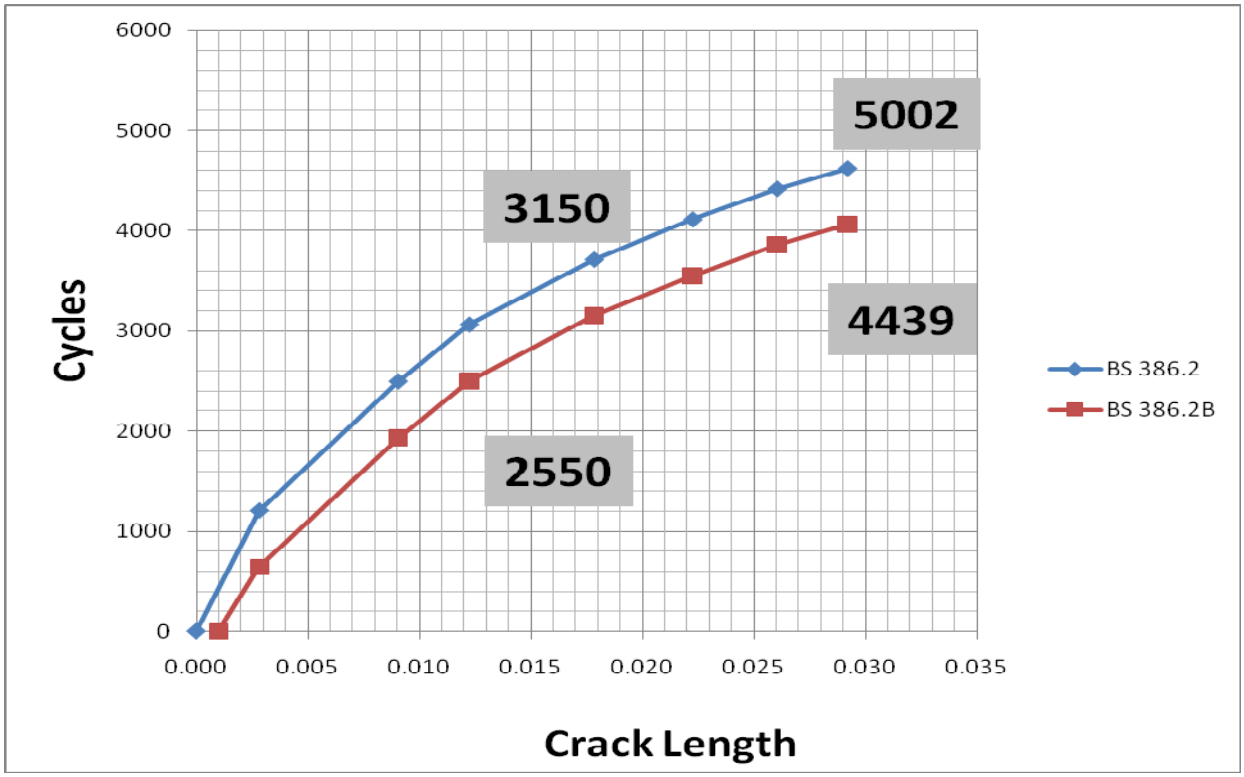

6000
5000
4000
3000
2000
1000
0
Cycles
2850
3450
2947
2350
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
BS 413.0
BS 413.0B

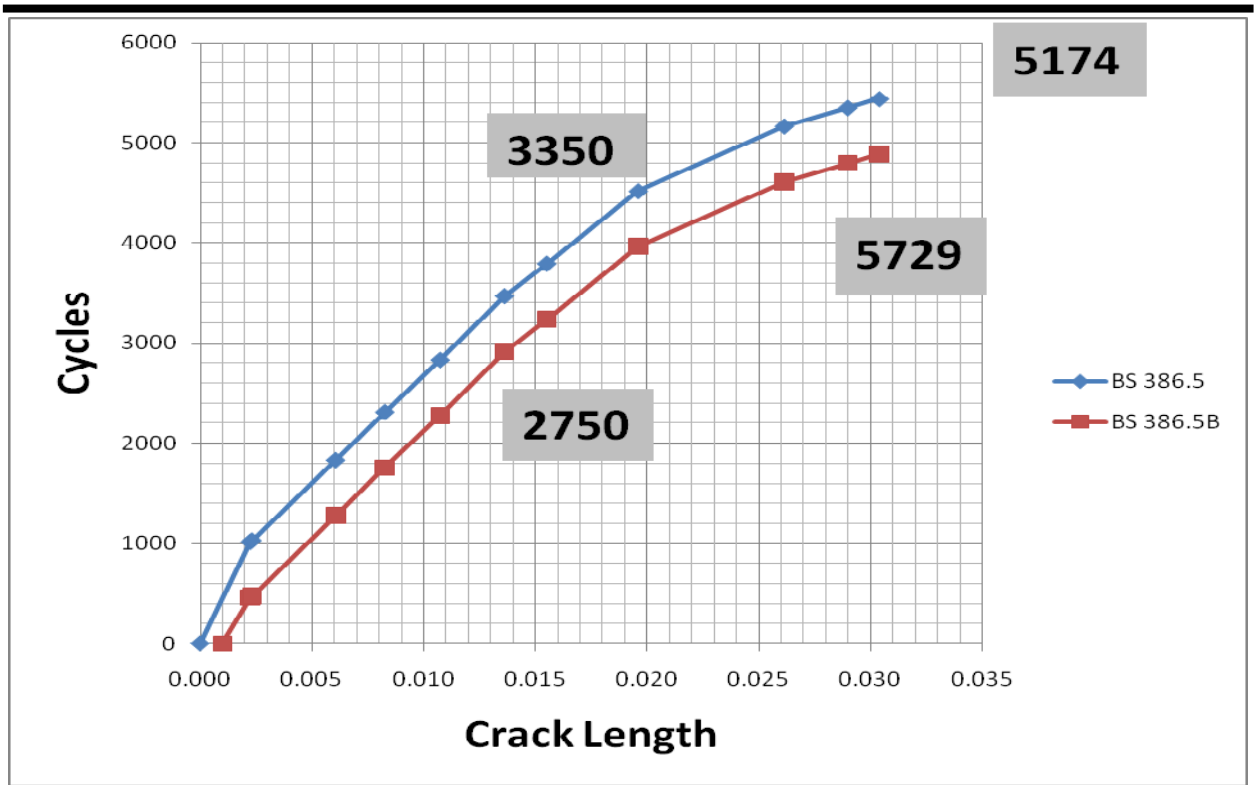


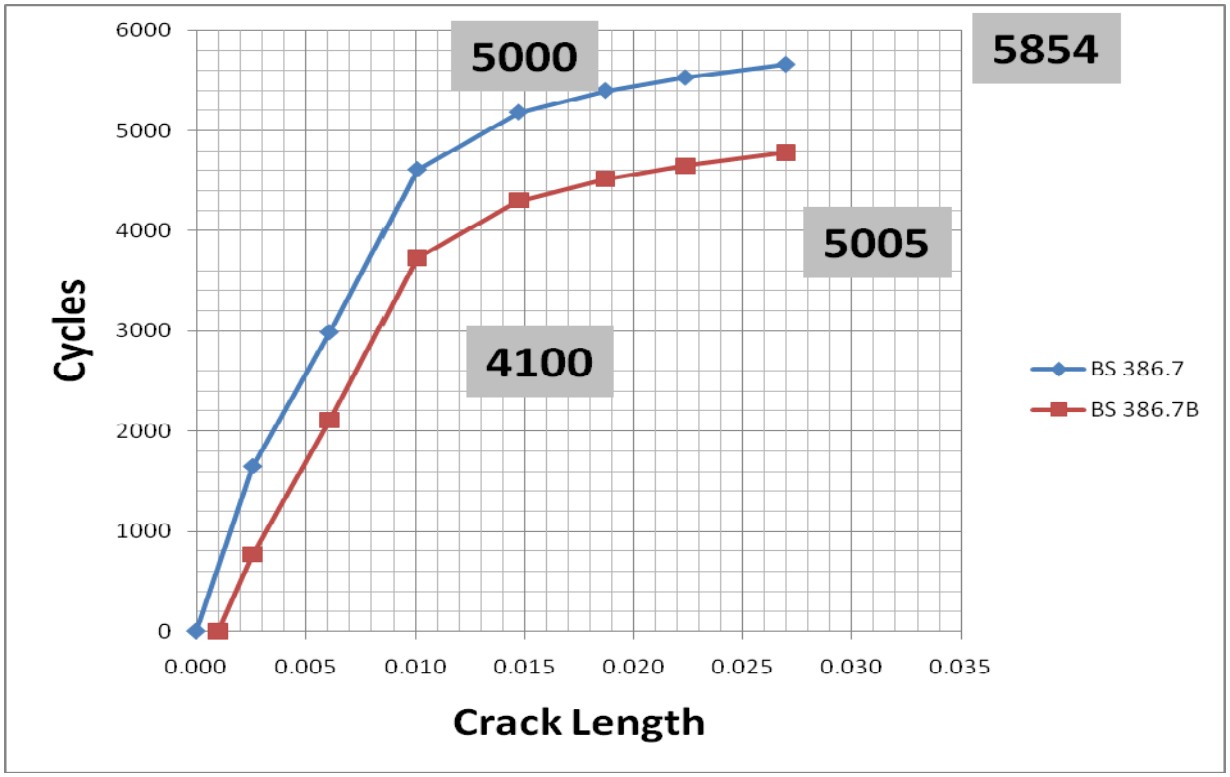
Forward Bay Through Crack

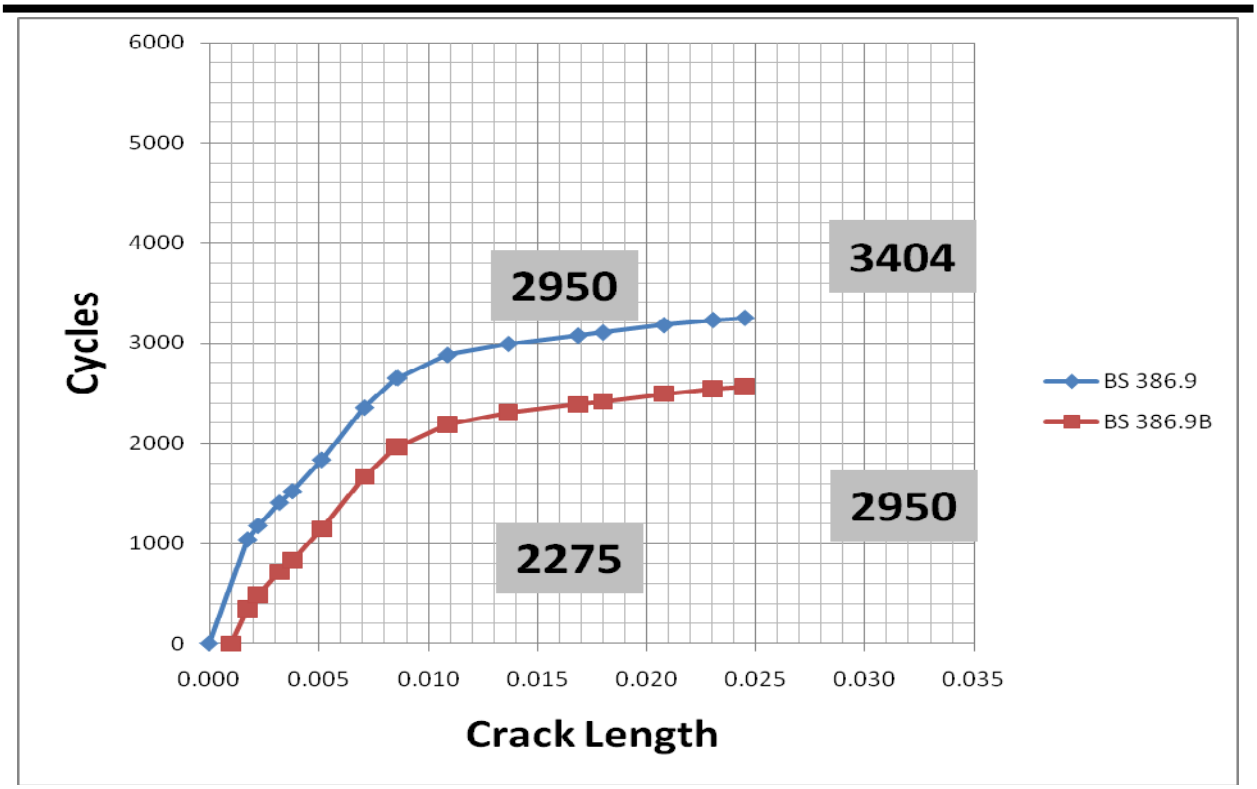


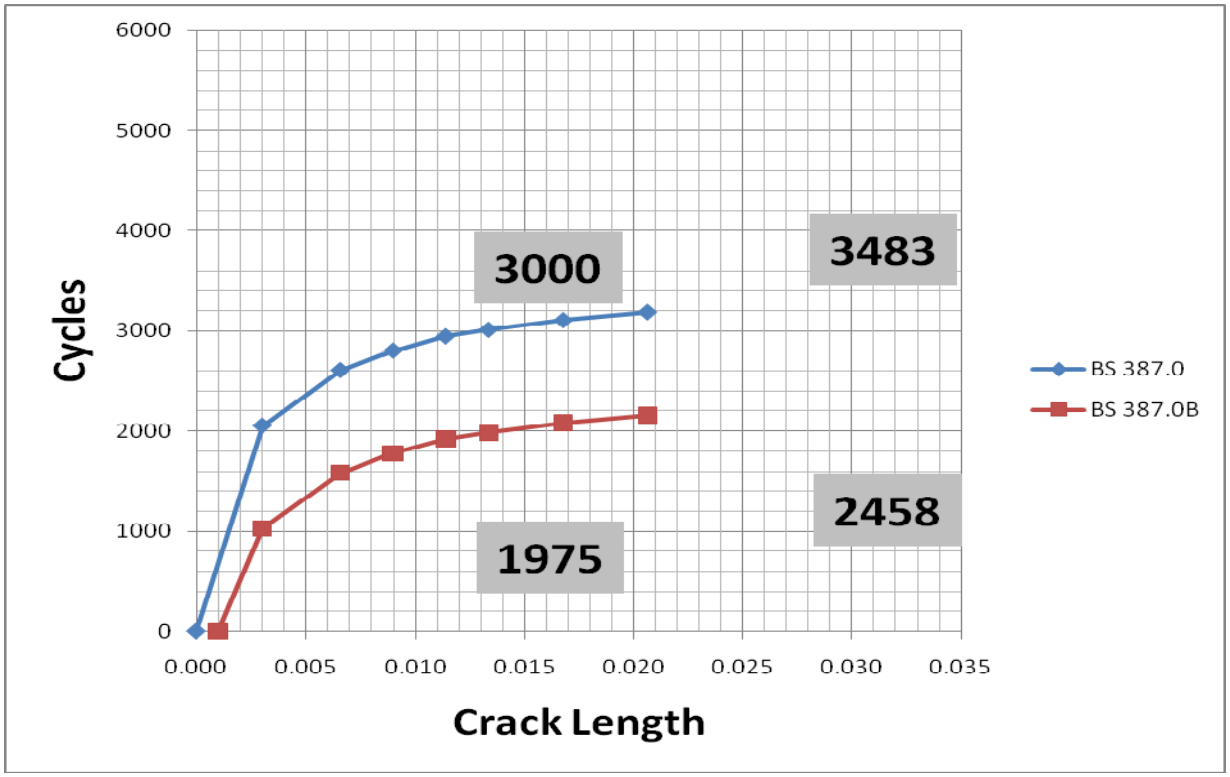

3500
3000
2500
2000
1500
1000
500
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
2500
3324
2819
2000
BS 386.0
BS 386.0B


6000
5000
4000
3000
2000
1000
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
5002
3150
4439
2550
BS 386.2
BS 386.2B


6000
5000
4000
3000
2000
1000
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
5174
3350
5729
2750
BS 386.5
BS 386.5B


6000
5000
4000
3000
2000
1000
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
5000
5854
5005
4100
BS 386.7
BS 386.7B


6000
5000
4000
3000
2000
1000
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
2950
3404
2275
2950
BS 386.9
BS 386.9B


6000
5000
4000
3000
2000
1000
0
Cycles
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Crack Length
3000
3483
1975
2458
BS 387.0
BS 387.0B

Eddy Current Crack Indication