

AFGROW Round Robin

Corner Crack at Center and Offset Hole

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Lackeys

- **Purpose**
- **Challenges**
- **Analysis Variables**
- **Test Geometry**
- **Loading Spectrum**
- **Crack Growth Rate Data**
- **Participants**
- **Results**
- **Conclusions**

Purpose

(AFGROW USER WORKSHOP 2017)

- **Determine the variability of users, given the same loading spectrum, material data, and Initial Flaw Size (IFS) to predict the evolution of the crack front shape and the total life of a given geometry using the AFGROW framework as the life prediction tool.**

- **The results will be published on the AFGROW Web Page following the Workshop**

- **Ability to accurately predict the life and natural crack shape progression of an initial corner crack as it grows through-the-thickness of a plate**
 - **How many points along the crack front are used to make these predictions?**
 - **Where should these points be located along the crack front?**
 - **Should we attempt to account for lack of constraint at free surfaces?**
 - **Do the marker cycles create a load interaction effect?**

- **Stress Intensity Factor (K) Solution**
 - **Classic Models**
 - **Advanced Models**
 - **Other external K-solvers**
- **Load interaction model**
- **Shape Evolution (a/c variable or constant)**

Test Geometry

(AFGROW USER WORKSHOP 2017)

Max Spectrum Stress		12 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-1	1	Width	4.0070	4.0040	Yes	SAFE Caliper 500-196-30	
-1	2	Thickness	0.2515	0.2511	Yes	SAFE Mike 59/30032	
-1	3	Hole Diameter	0.4757	0.4756	Yes	SAFE Inside Mike 13-576-4	
-1	4	Length	-	16.0250	-	24" Mito Caliper	
-1	7	Notch Width	-	0.0085	-	Nikon Microscope (W/ DRO)	
-1	8	Notch Length	-	0.0244	-	Nikon Microscope (W/ DRO)	
-1		Initial crack (bore)	-	0.0380	-	Nikon MM-60 (APES)	
-1		Initial crack (surface)	-	0.0262	-	Nikon MM-60 (APES)	
-1		Alternate IC (bore)	-	0.0472	-	Nikon MM-60 (APES)	
-1		Alternate IC (surface)	-	0.0319	-	Nikon MM-60 (APES)	

Max Spectrum Stress		12 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-2	1	Width	4.0070	4.0040	Yes	SAFE Caliper 500-196-30	
-2	2	Thickness	0.2515	0.2511	Yes	SAFE Mike 59/30032	
-2	3	Hole Diameter	0.4757	0.4755	Yes	SAFE Inside Mike 13-576-4	
-2	4	Length	-	16.0330	-	24" Mito Caliper	
-2	7	Notch Width	-	0.0083	-	Nikon Microscope (W/ DRO)	
-2	8	Notch Length	-	0.0218	-	Nikon Microscope (W/ DRO)	
-2		Initial crack (bore)	-	0.0315	-	Nikon MM-60 (APES)	
-2		Initial crack (surface)	-	0.0257	-	Nikon MM-60 (APES)	
-2		Alternate IC (bore)	-	0.0384	-	Nikon MM-60 (APES)	
-2		Alternate IC (surface)	-	0.0307	-	Nikon MM-60 (APES)	

Max Spectrum Stress		12 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-3	1	Width	4.0030	4.0030	Yes	SAFE Caliper 500-196-30	
-3	2	Thickness	0.2510	0.2511	Yes	SAFE Mike 59/30032	
-3	3	Hole Diameter	0.4758	0.4751	Yes	SAFE Inside Mike 13-576-4	
-3	4	Length	-	16.0310	-	24" Mito Caliper	
-3	7	Notch Width	-	0.0078	-	Nikon Microscope (W/ DRO)	
-3	8	Notch Length	-	0.0200	-	Nikon Microscope (W/ DRO)	
-3		Initial crack (bore)	-	0.0313	-	Nikon MM-60 (APES)	
-3		Initial crack (surface)	-	0.0255	-	Nikon MM-60 (APES)	
-3		Alternate IC (bore)	-	0.0521	-	Nikon MM-60 (APES)	
-3		Alternate IC (surface)	-	0.0354	-	Nikon MM-60 (APES)	

Max Spectrum Stress		12 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-1	1	Width	4.0015	4.0010	Yes	SAFE Caliper 500-196-30	
-1	2	Thickness	0.2510	0.2508	Yes	SAFE Mike 59/30032	
-1	3	Hole Diameter	0.4762	0.4761	Yes	SAFE Inside Mike 13-576-4	
-1	4	Offset Distance	-	3.1620	-	SAFE Caliper 500-196-30	
-1	5	Length	-	16.0090	-	24" Mito Caliper	
-1	6	Notch Width	-	0.0079	-	Nikon Microscope (W/ DRO)	
-1	7	Notch Length	-	0.0128	-	Nikon Microscope (W/ DRO)	
-1		Initial crack (bore)	-	0.0227	-	Nikon MM-60 (APES)	
-1		Initial crack (surface)	-	0.0189	-	Nikon MM-60 (APES)	
-1		Alternate IC (bore)	-	0.0414	-	Nikon MM-60 (APES)	
-1		Alternate IC (surface)	-	0.0319	-	Nikon MM-60 (APES)	

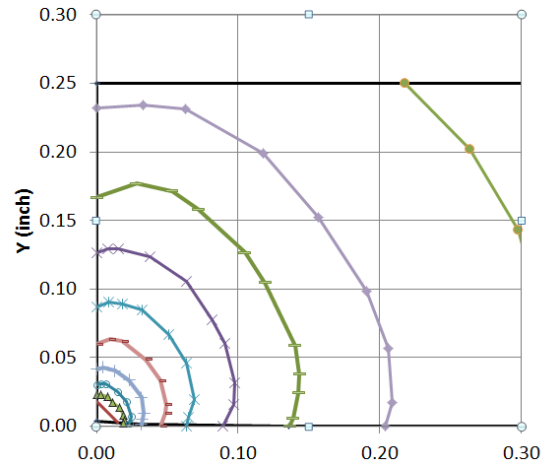
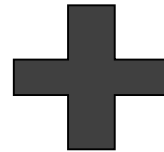
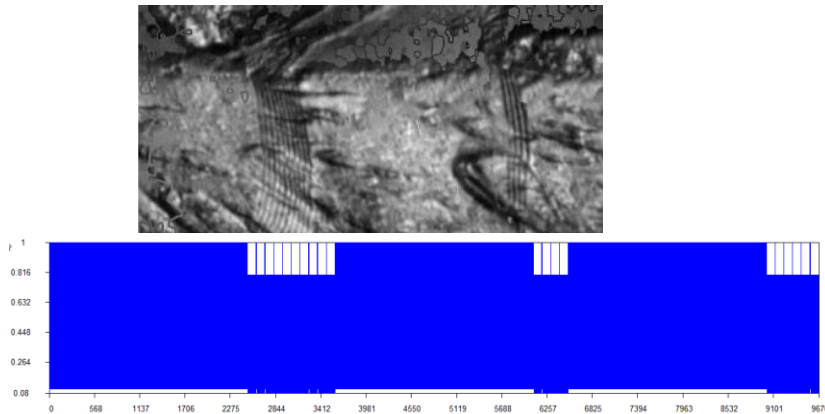
Max Spectrum Stress		12 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-2	1	Width	4.0025	4.0010	Yes	SAFE Caliper 500-196-30	
-2	2	Thickness	0.2510	0.2509	Yes	SAFE Mike 59/30032	
-2	3	Hole Diameter	0.4760	0.4760	Yes	SAFE Inside Mike 13-576-4	
-2	4	Offset Distance	-	3.1680	-	SAFE Caliper 500-196-30	
-2	5	Length	-	16.0180	-	24" Mito Caliper	
-2	6	Notch Width	-	0.0081	-	Nikon Microscope (W/ DRO)	
-2	7	Notch Length	-	0.0142	-	Nikon Microscope (W/ DRO)	
-2		Initial crack (bore)	-	0.0386	-	Nikon MM-60 (APES)	
-2		Initial crack (surface)	-	0.0238	-	Nikon MM-60 (APES)	
-2		Alternate IC (bore)	-	0.0542	-	Nikon MM-60 (APES)	
-2		Alternate IC (surface)	-	0.0358	-	Nikon MM-60 (APES)	

Max Spectrum Stress		9 ksi					
Serial	Feature	Description	SwRI Measure	SAFE Measure	Pass?	SAFE Tool Used	
-3	1	Width	4.0015	4.0015	Yes	SAFE Caliper 500-196-30	
-3	2	Thickness	0.2510	0.2510	Yes	SAFE Mike 59/30032	
-3	3	Hole Diameter	0.4762	0.4760	Yes	SAFE Inside Mike 13-576-4	
-3	4	Offset Distance	-	3.1660	-	SAFE Caliper 500-196-30	
-3	5	Length	-	16.0120	-	24" Mito Caliper	
-3	6	Notch Width	-	0.0080	-	Nikon Microscope (W/ DRO)	
-3	7	Notch Length	-	0.0164	-	Nikon Microscope (W/ DRO)	
-3		Initial crack (bore)	-	0.0385	-	Nikon MM-60 (APES)	
-3		Initial crack (surface)	-	0.0229	-	Nikon MM-60 (APES)	
-3		Alternate IC (bore)	-	0.0557	-	Nikon MM-60 (APES)	
-3		Alternate IC (surface)	-	0.0323	-	Nikon MM-60 (APES)	

Loading Spectrum

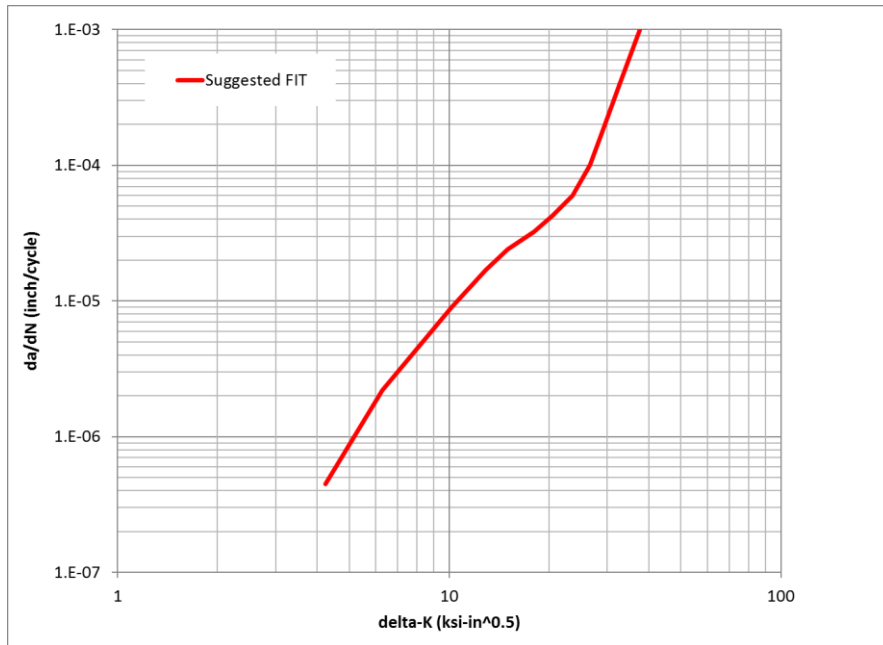
(AFGROW USER WORKSHOP 2017)

- Marking load sequence used to capture crack length and aspect ratio data.



Crack Growth Rate Data

(AFGROW USER WORKSHOP 2017)



da/dN vs. DK	
Suggested FIT	
R = 0.1	
da/dN	DK
4.50E-07	4.236
2.20E-06	6.281
9.00E-06	10.148
1.70E-05	12.900
2.40E-05	15.000
3.25E-05	18.000
4.25E-05	20.500
6.00E-05	23.500
1.00E-04	26.600
2.00E-04	29.500
4.00E-04	32.750
1.00E-03	37.500
2.00E-03	40.250
1.00E-02	45.000
2.00E-02	46.500
1.00E-01	48.500

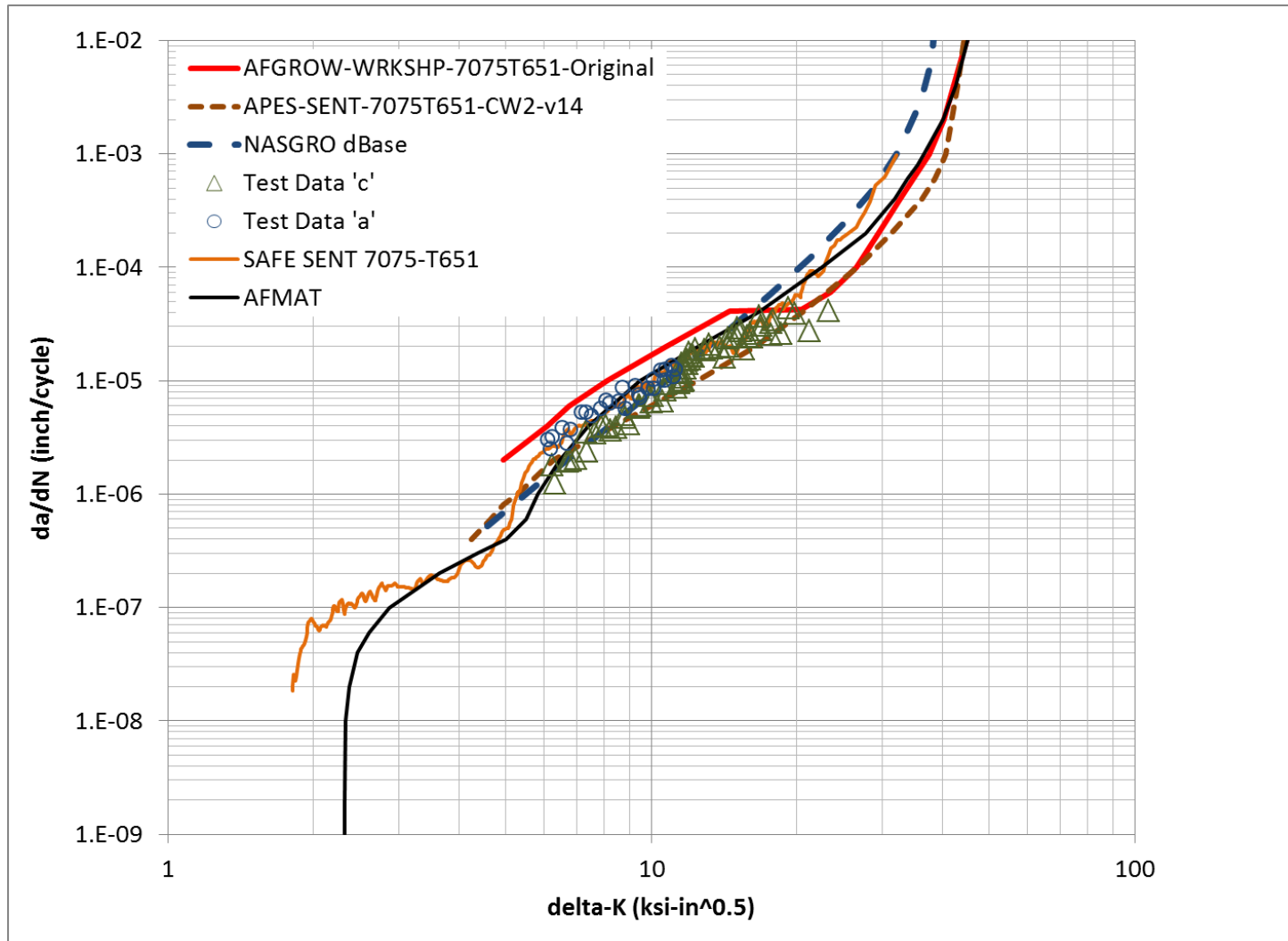
A note on material data....

(AFGROW USER WORKSHOP 2017)

- **These specimens were chosen for the round robin because da/dN vs. ΔK data existed for the same lot of material.**
- **Original material model used these data and was supplied to APES and SAFE.**
 - **Thought it might be fun to see how well it worked.**
 - **“Predictions” off by factor of 2.5, but why?**
- **Only option was to translate crack shape / rate data from the three center hole specimens into da/dN vs. ΔK and compare with supplied fit.**
- **Results caused us to take pause....**

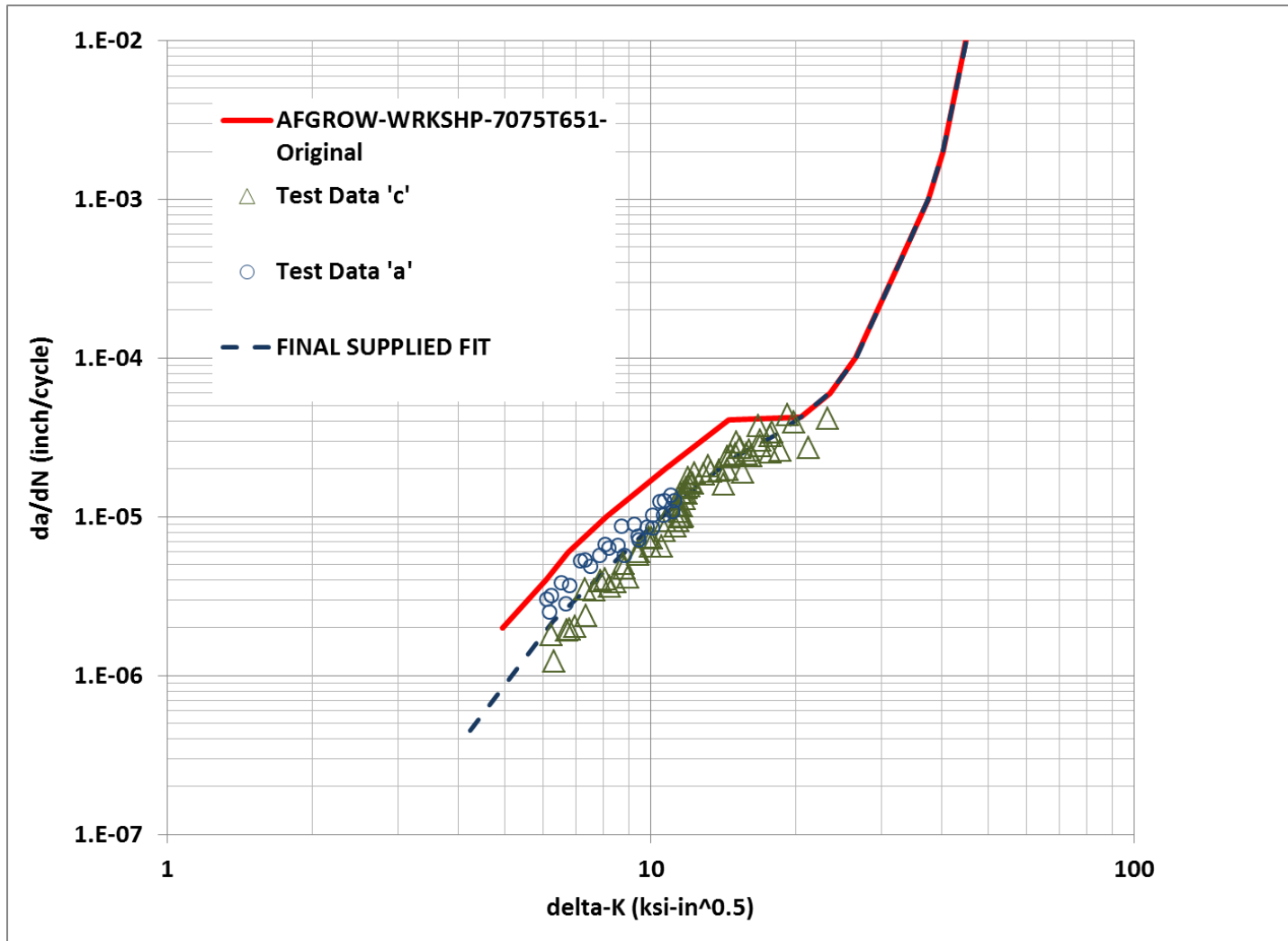
Similitude **Schmilitude**

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Final Fit Compared to Original

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Participants

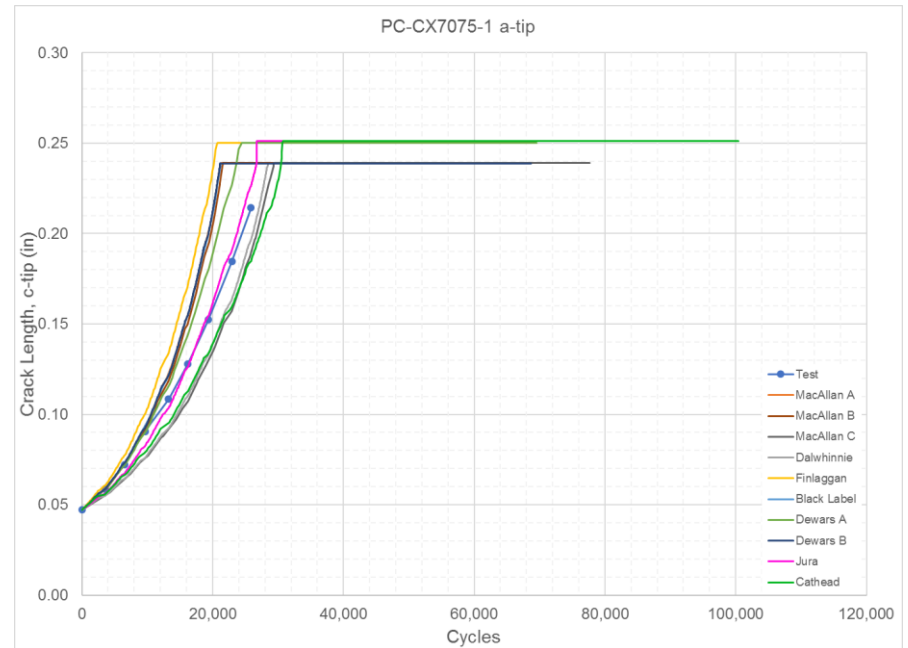
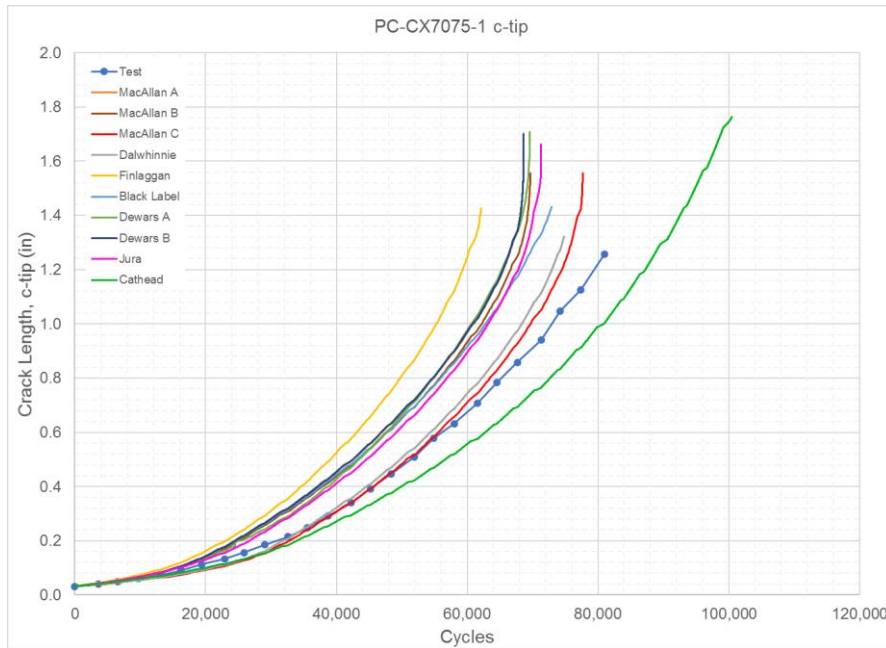
(AFGROW USER WORKSHOP 2017)

	MacAllan - A	MacAllan - B	MacAllan - C	Dalwhinne	FinLaggan	Black Label	Dewars	Jura	Cathead
K-Solution - Center K-Solution - Offset	Two Point Advanced	Two Point Advanced	Two Point Advanced	Advance Classic	FEA	Advanced w/ β Correction	FEA Advanced	Unknown	Unknown
Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No

Results

(AFGROW USER WORKSHOP 2017)

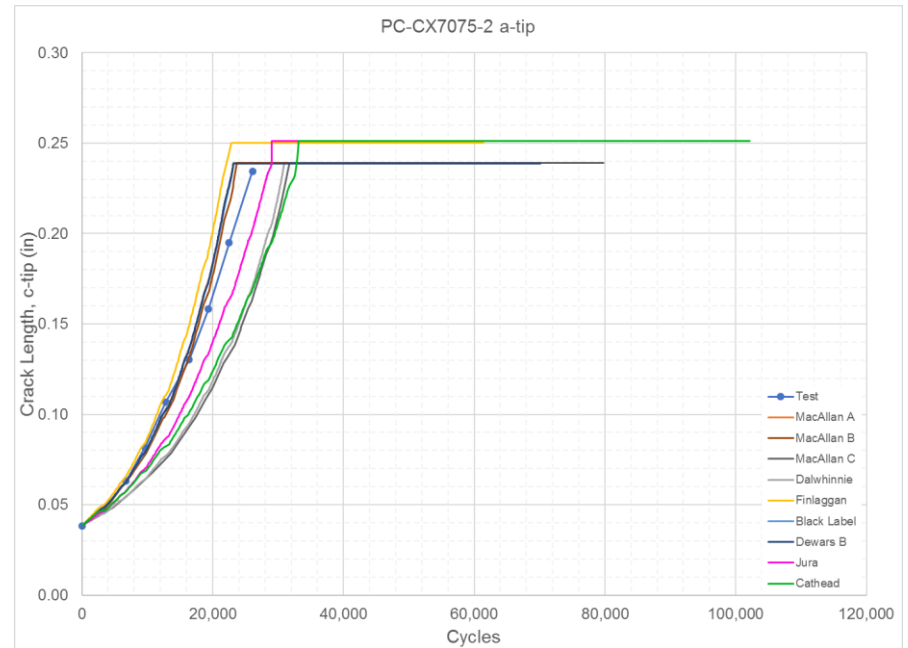
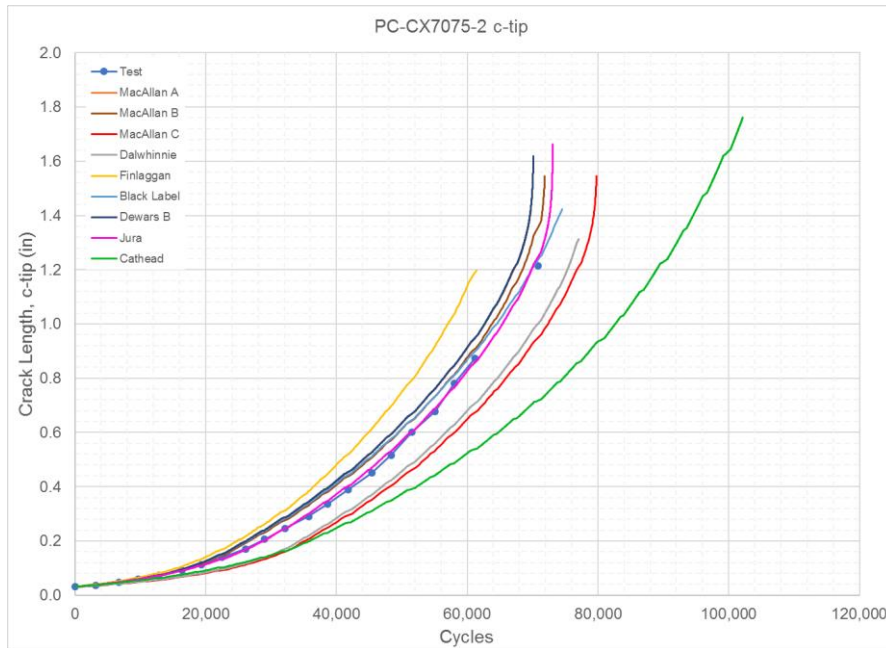
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

(AFGROW USER WORKSHOP 2017)

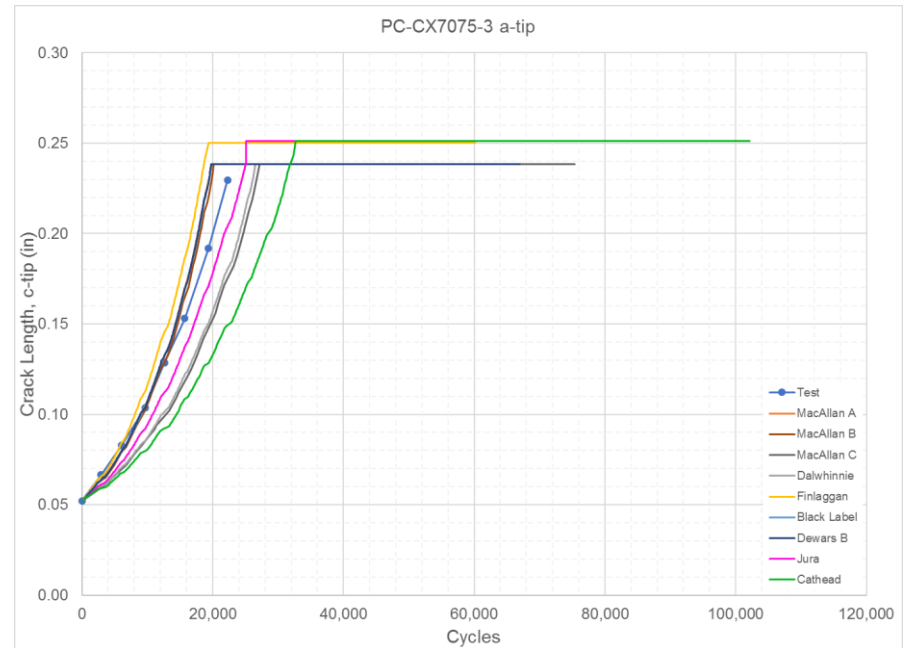
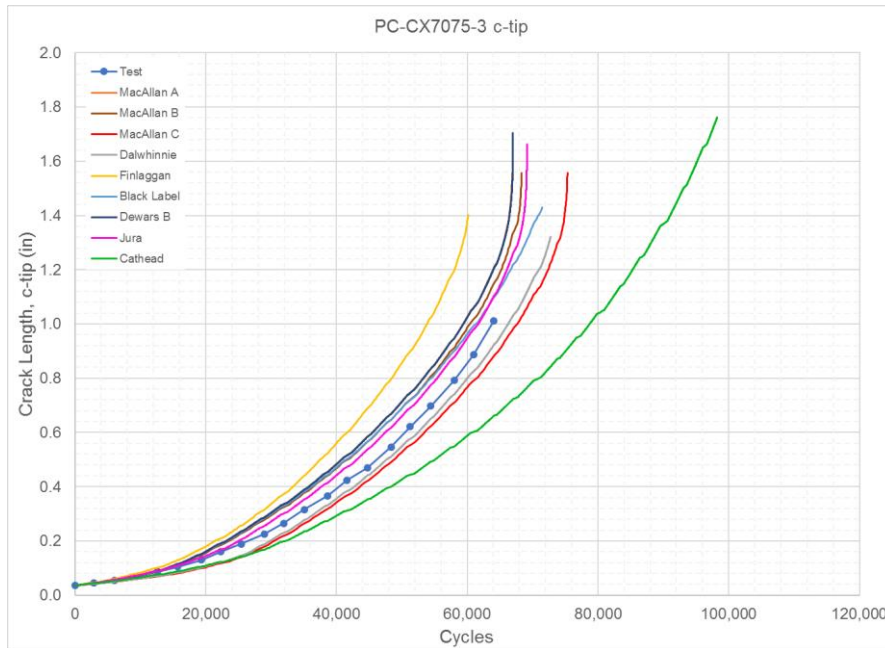
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K-Solution - Center K-Solution - Offset	Two Point Advanced	Two Point Advanced	Two Point Advanced	Advance Classic	FEA	Advanced w/ β Correction	FEA Advanced	Unknown	Unknown
Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

(AFGROW USER WORKSHOP 2017)

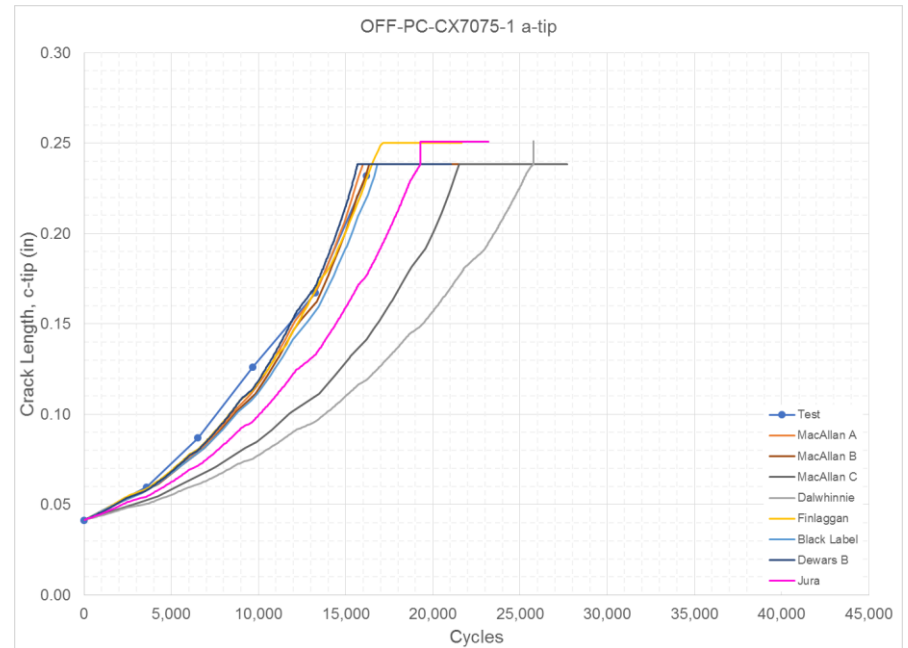
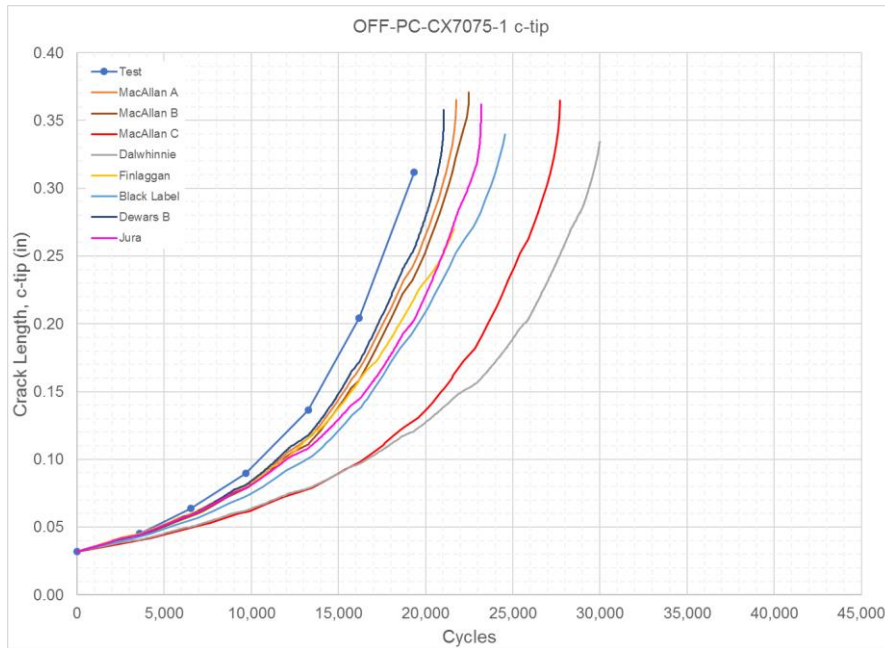
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

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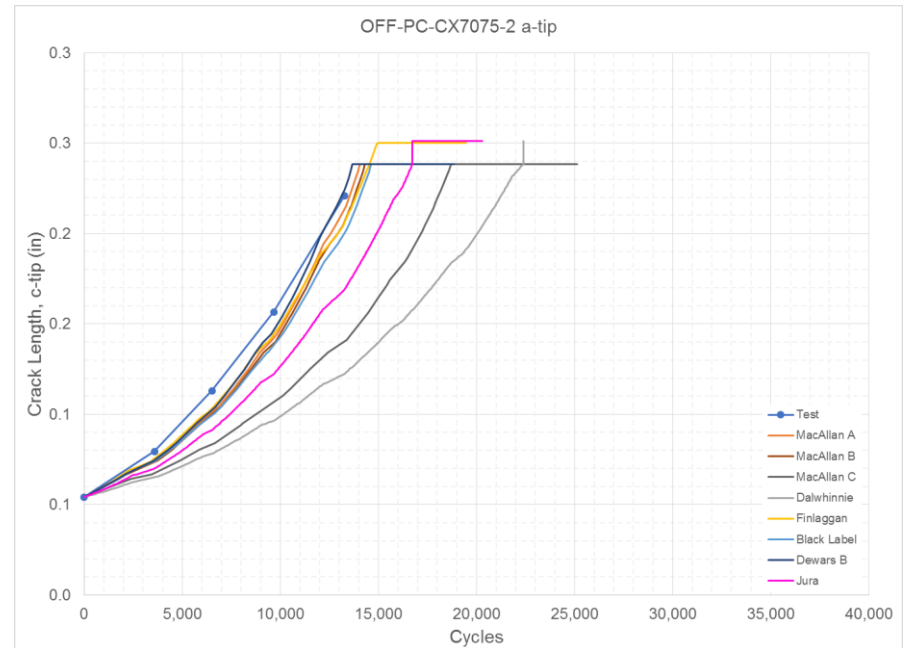
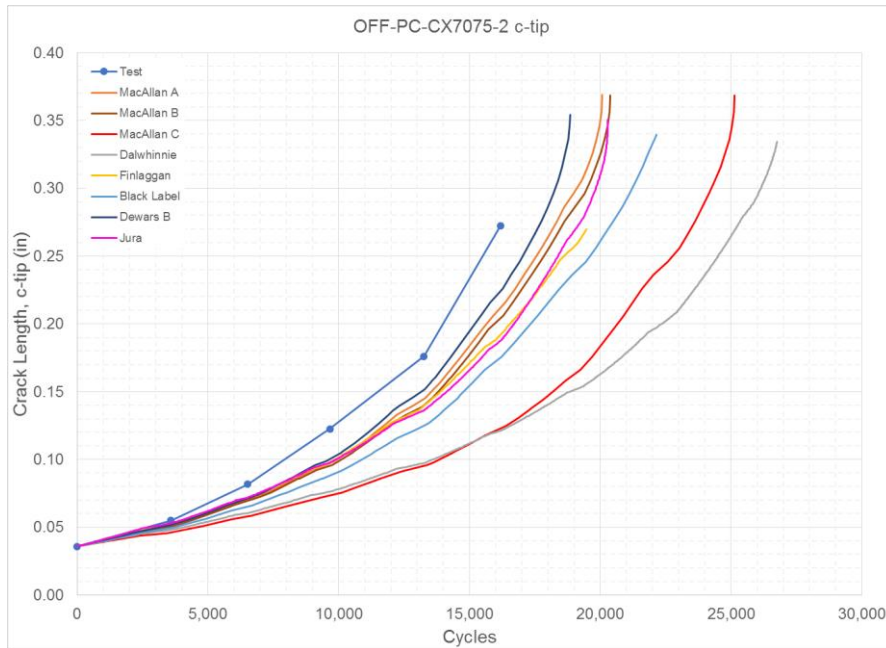
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

(AFGROW USER WORKSHOP 2017)

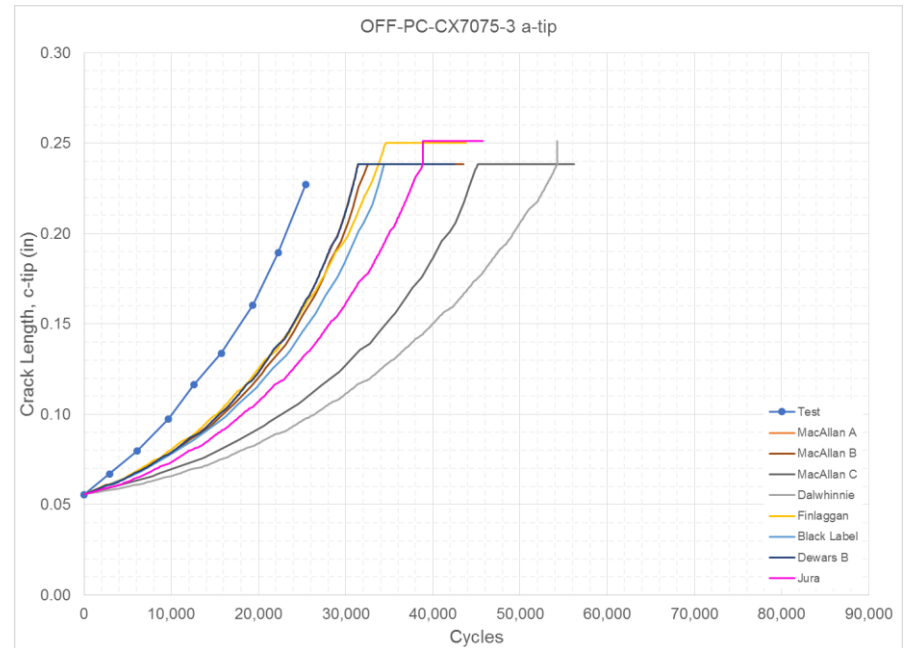
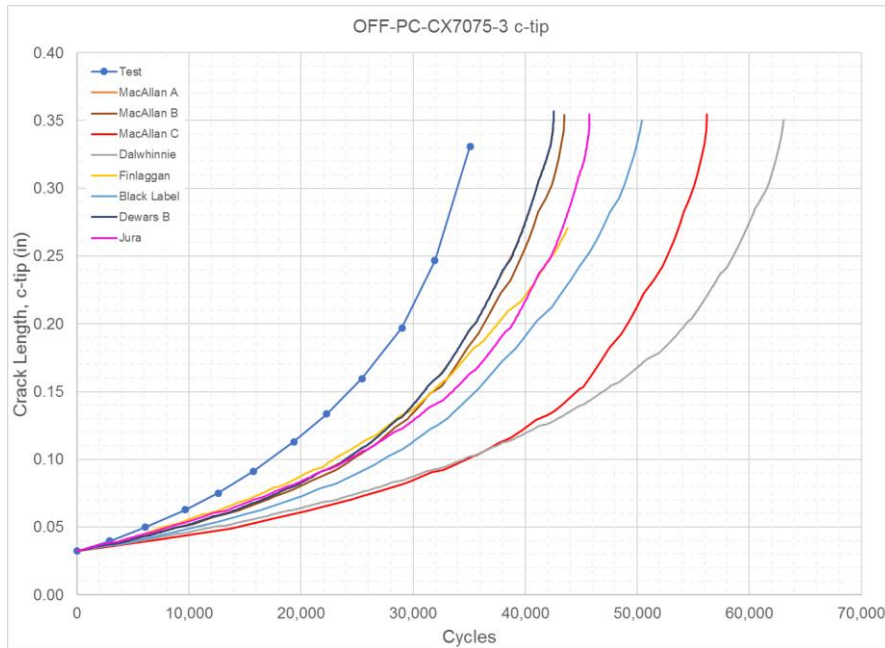
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

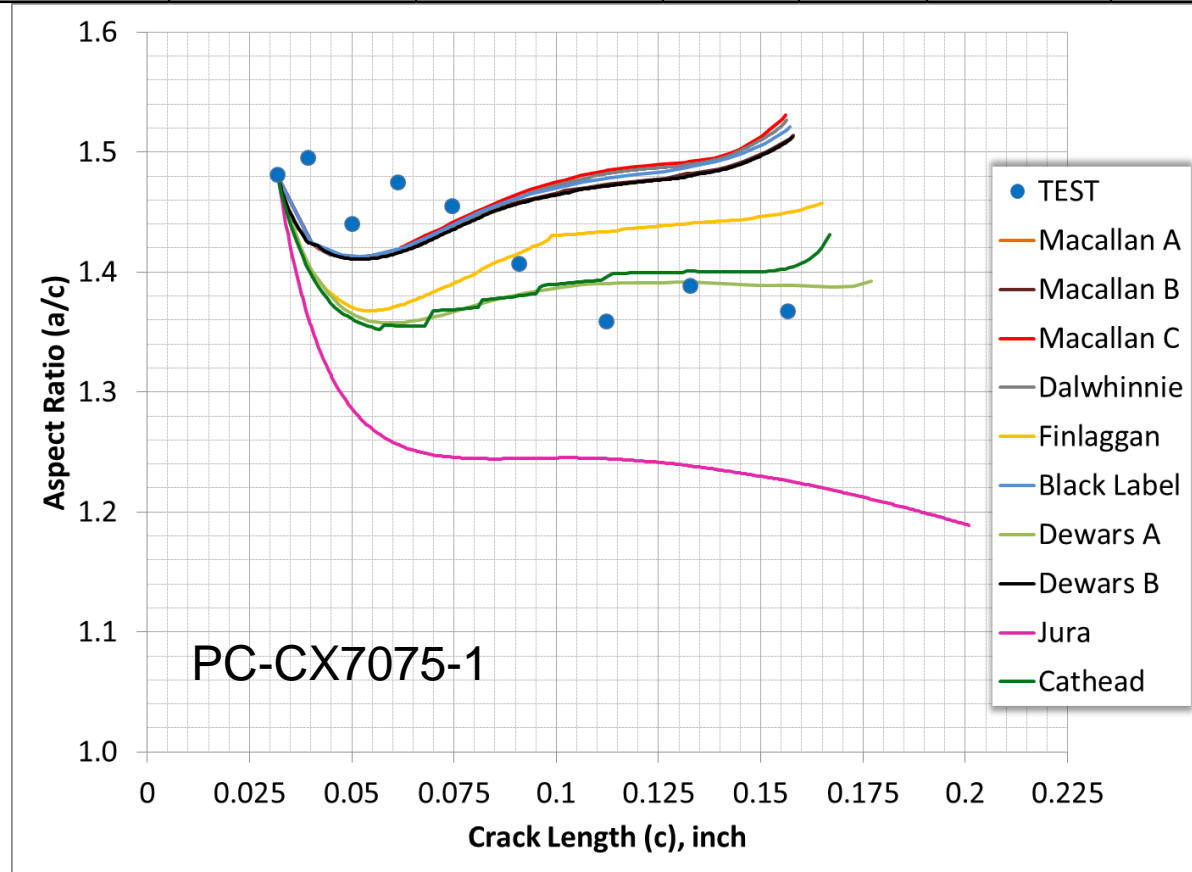
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



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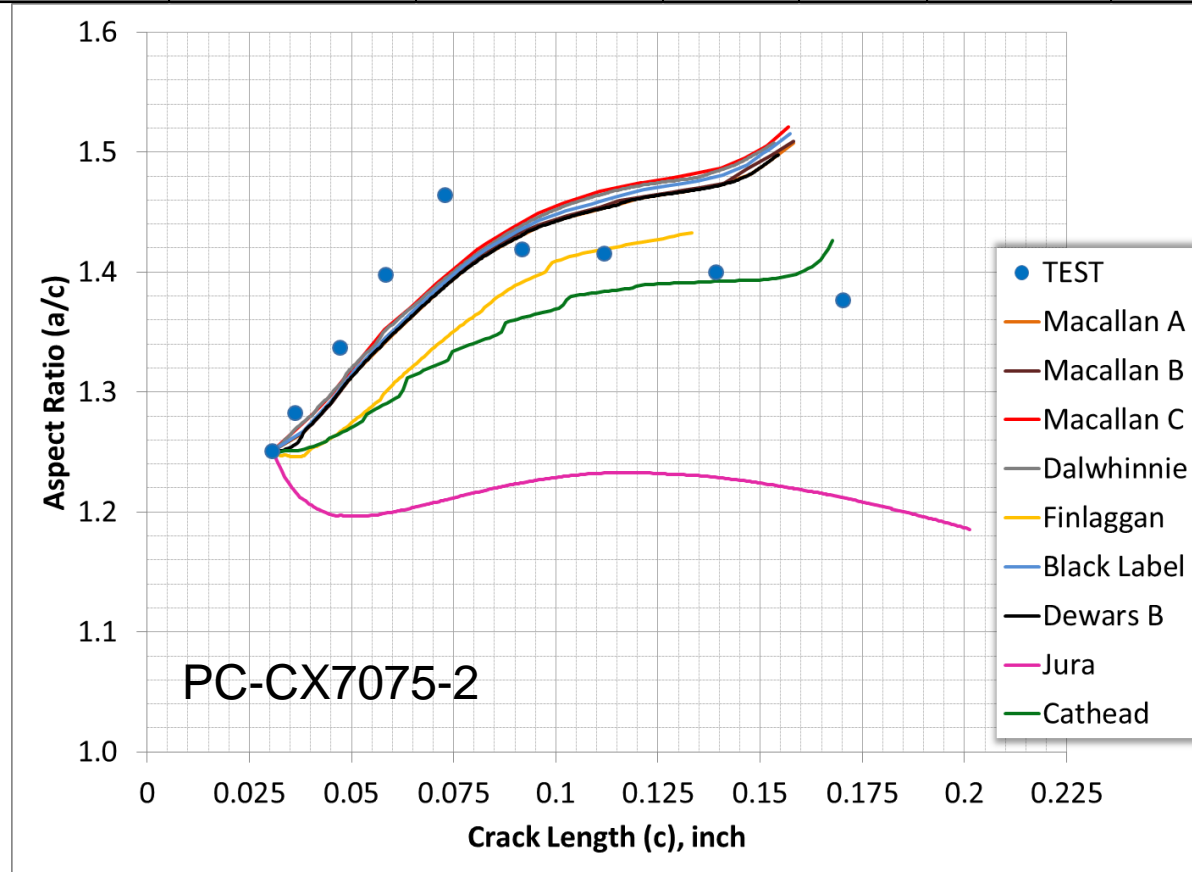
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

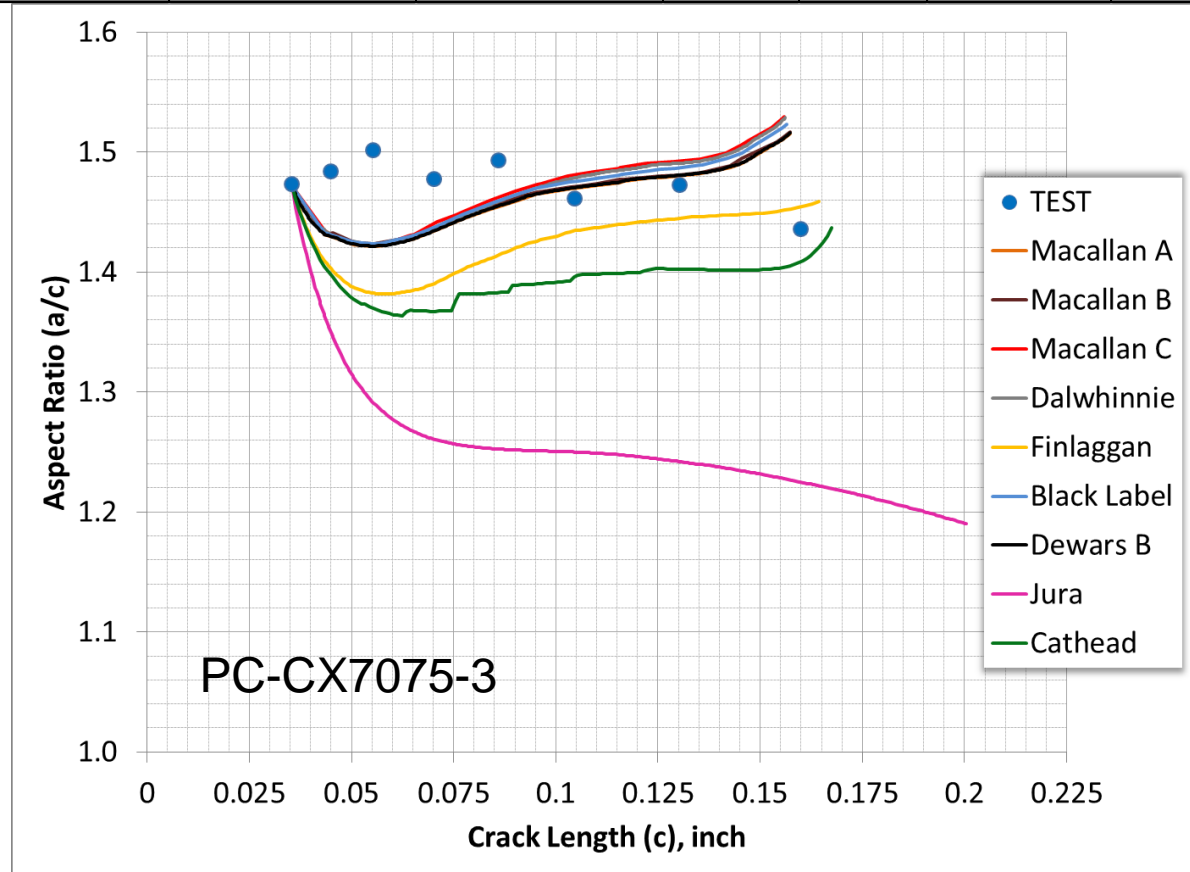
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



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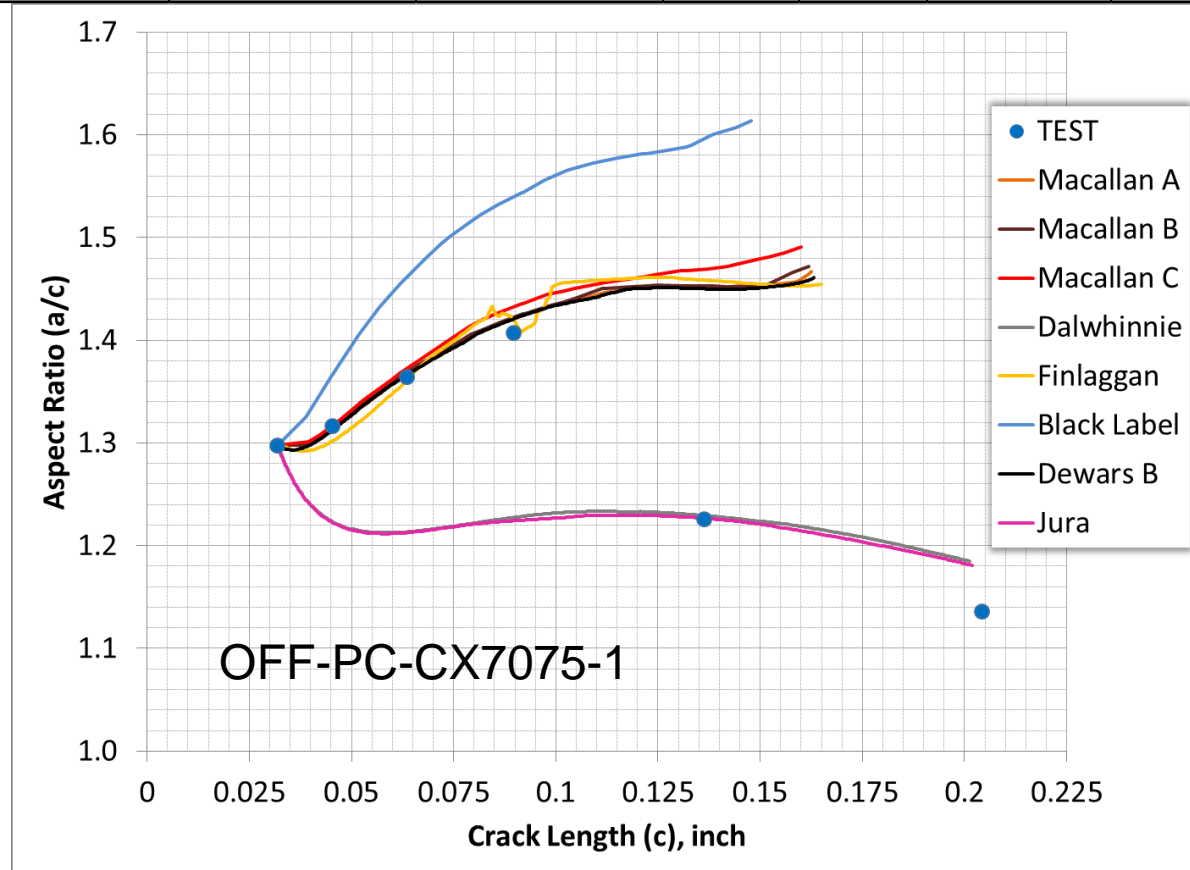
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



Results

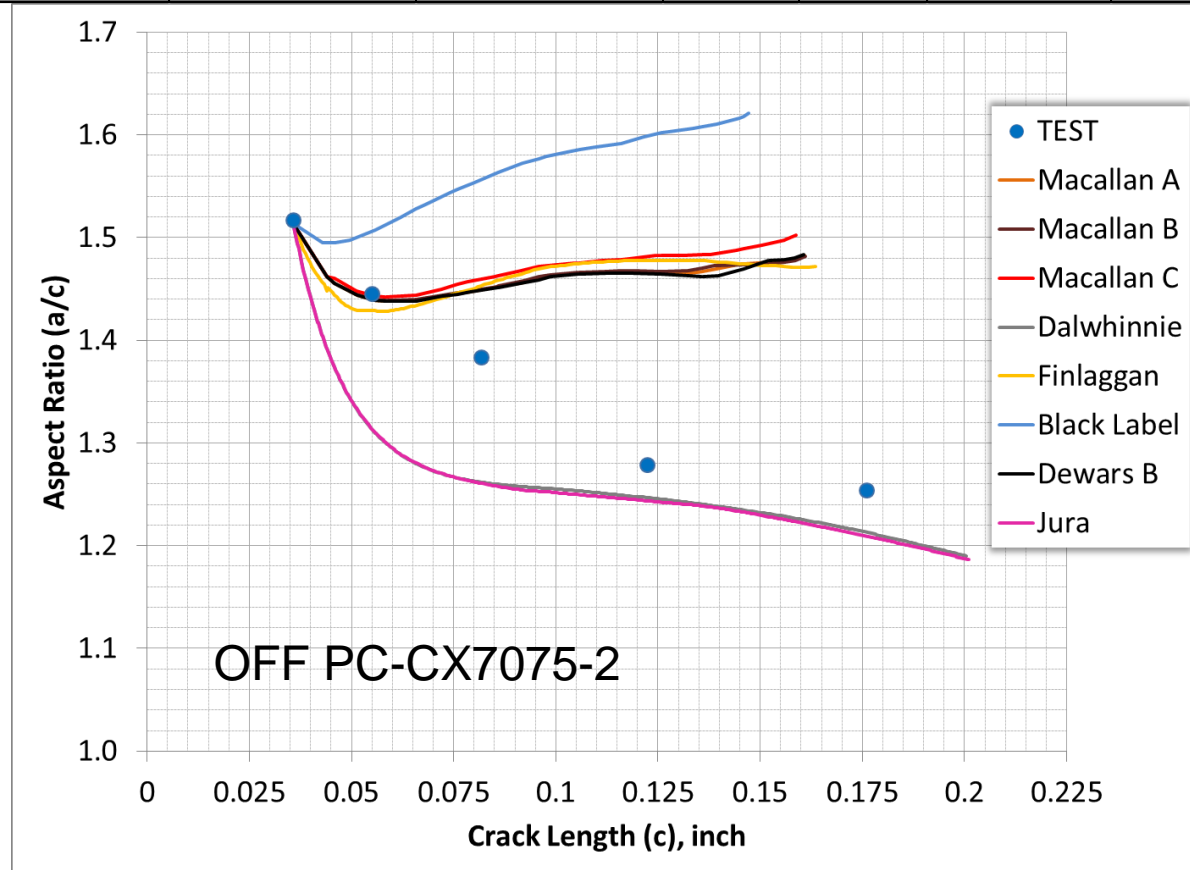
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Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



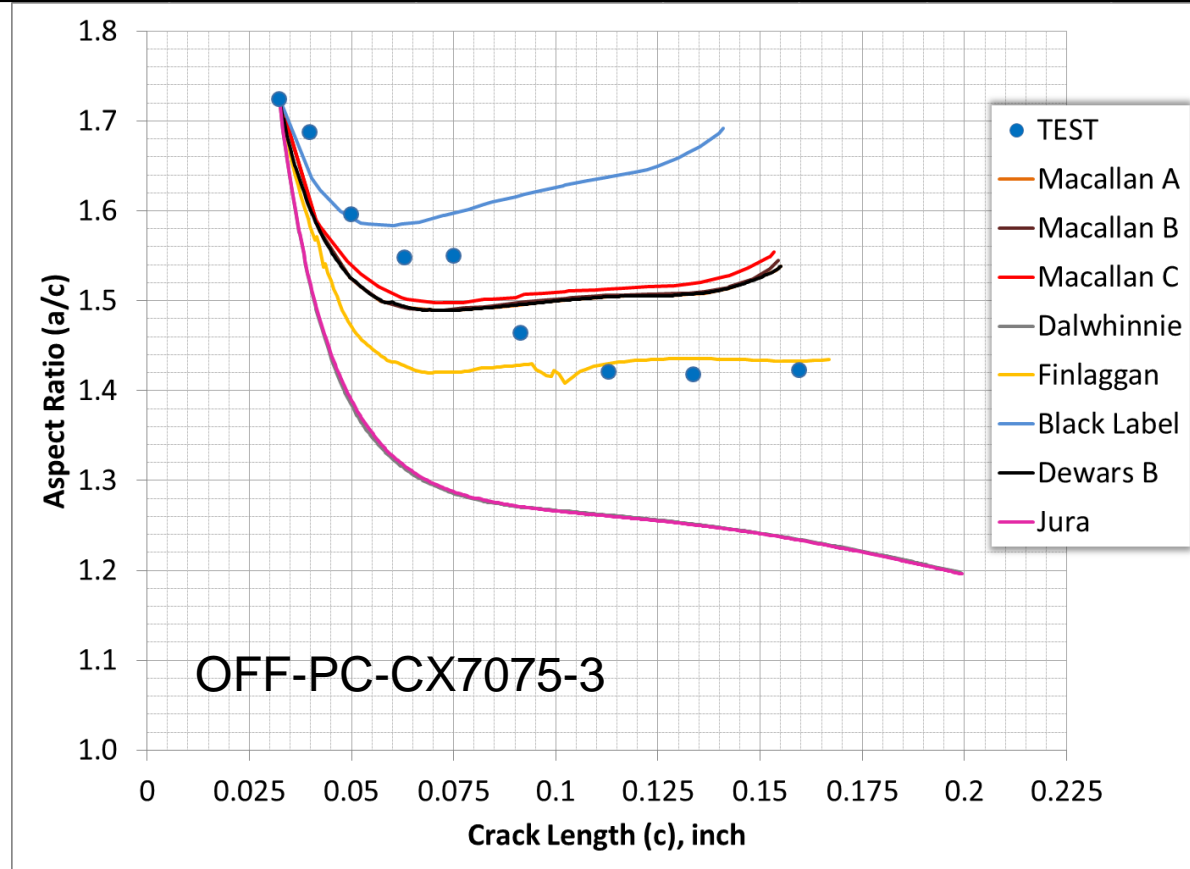
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K-Solution - Center K-Solution - Offset	Two Point Advanced	Two Point Advanced	Two Point Advanced	Advance Classic	FEA	Advanced w/ β Correction	FEA Advanced	Unknown	Unknown
Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



(AFGROW USER WORKSHOP 2017)

	MacAllan - A	MacAllan - B	MacAllan - C	Dalwhinne	FinLaggan	Black Label	Dewars	Jura	Cathead
K-Solution - Center K-Solution - Offset	Two Point Advanced	Two Point Advanced	Two Point Advanced	Advance Classic	FEA	Advanced w/ β Correction	FEA Advanced	Unknown	Unknown
Load Interaction	None	Hsu	Hsu, β_R	β_R	None	None	None	Unknown	Unknown
a/c constant	No	No	No	No	No	No	No	No	No



(AFGROW USER WORKSHOP 2017)

- **Center hole life...not bad**
- **Offset hole life...predictions unconservative majority of time**
- **Aspect ratio**
 - **Work to do....**