A-10 Durability Analysis

SOUTHWEST RESEARCH INSTITUTE®

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AFGROW User Workshop
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Agenda

- Background
- Selected CPs and Reasoning
- Fracture Analysis
- Durability Analysis
- Comparison
- Durability Analysis Issues
- Sensitivity Study
- Conclusions
- Current Efforts

Background

- 2019 Request from A-10 ASIP Office
- Desire a Durability Analysis for each CP connected to cracking during a FSFT
- No history of durability analysis for A-10
- JSSG-2006
- Strain-Life approach and Crack Growth
- SwRI T-38 Durability Analysis

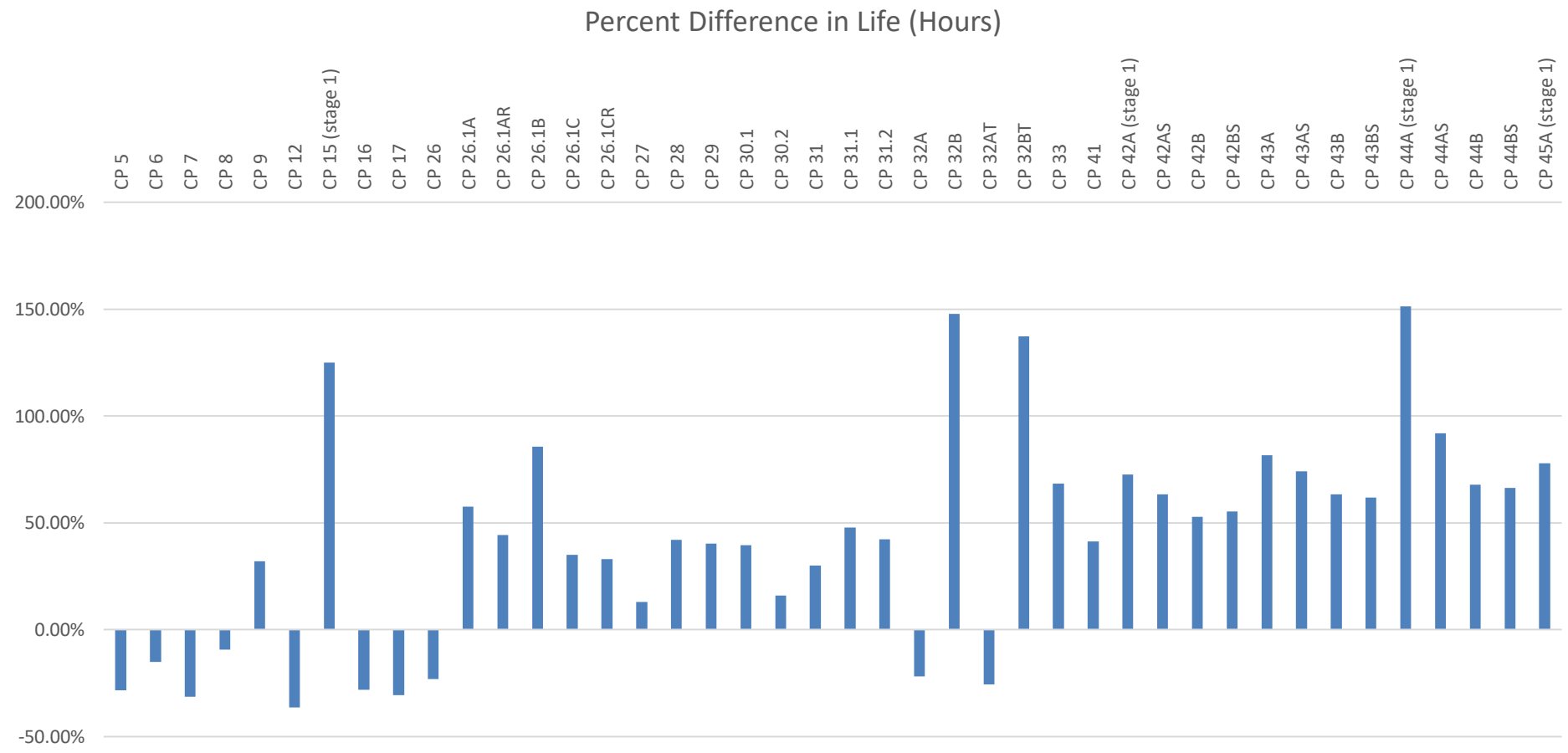
Selected CPs and Reasoning

- Currently 224 CPs on A-10
- 130 CPs in list provided by A-10 Office of CPs with FSFT
- 53 CPs that resulted in Cracking
- 83 CPs - Final list of CPs to analyze

Fracture Analysis

- IFS of 0.01" for all CPs
- AFGROW COM used for analysis
- Compared results to current DTA report
  - Change in Life (hours)
  - Change in Critical Crack Size
- No continuing damage included in the analysis
  - Request from the A-10 office

Fracture Analysis



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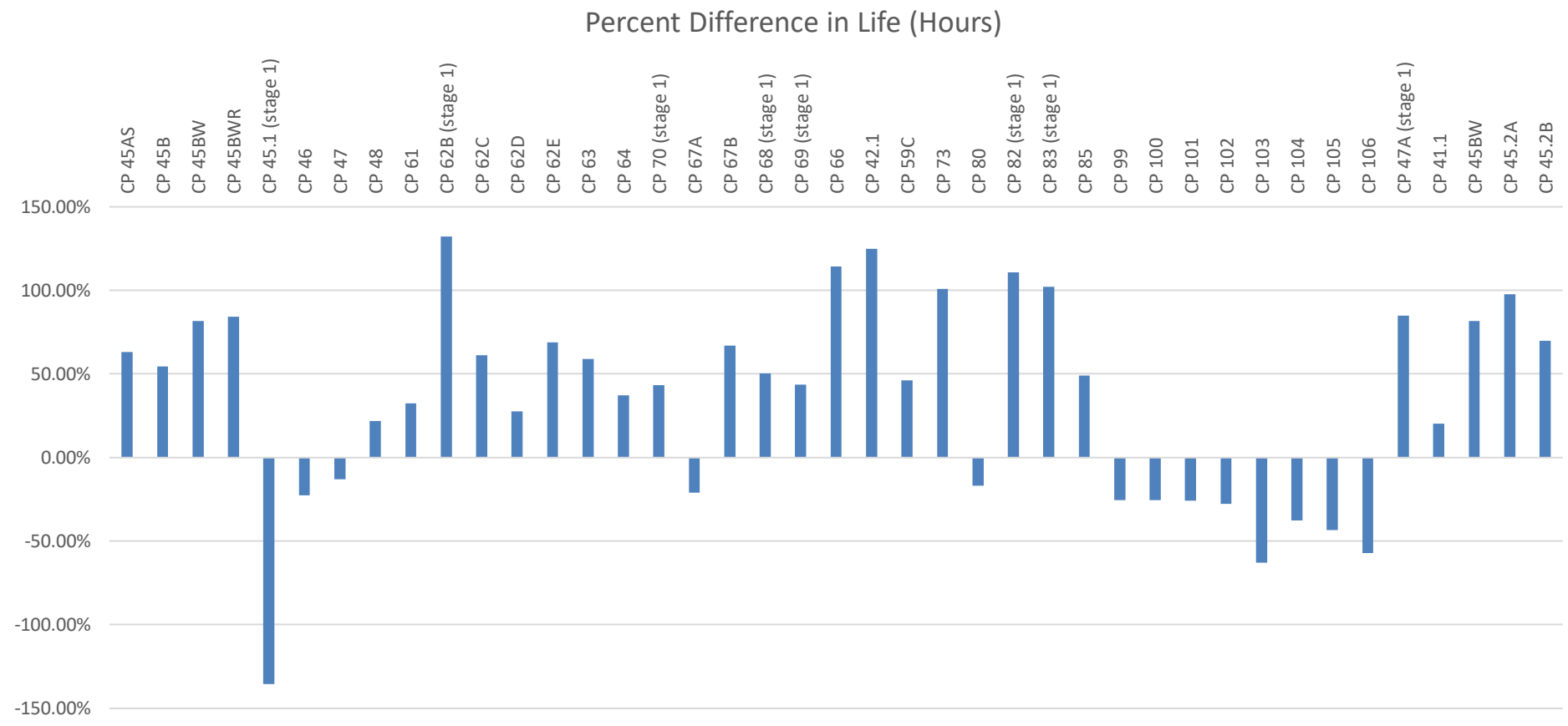

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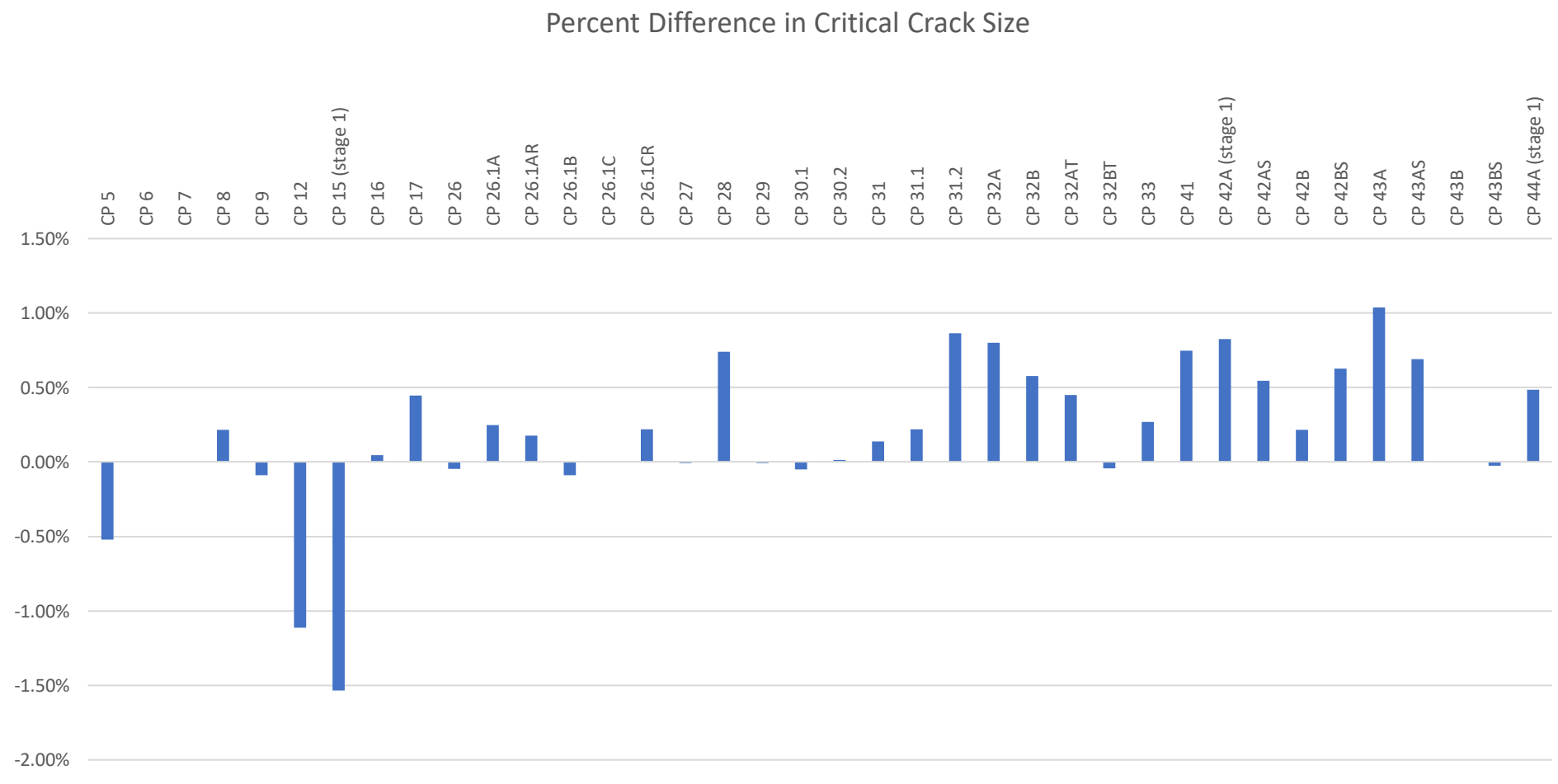
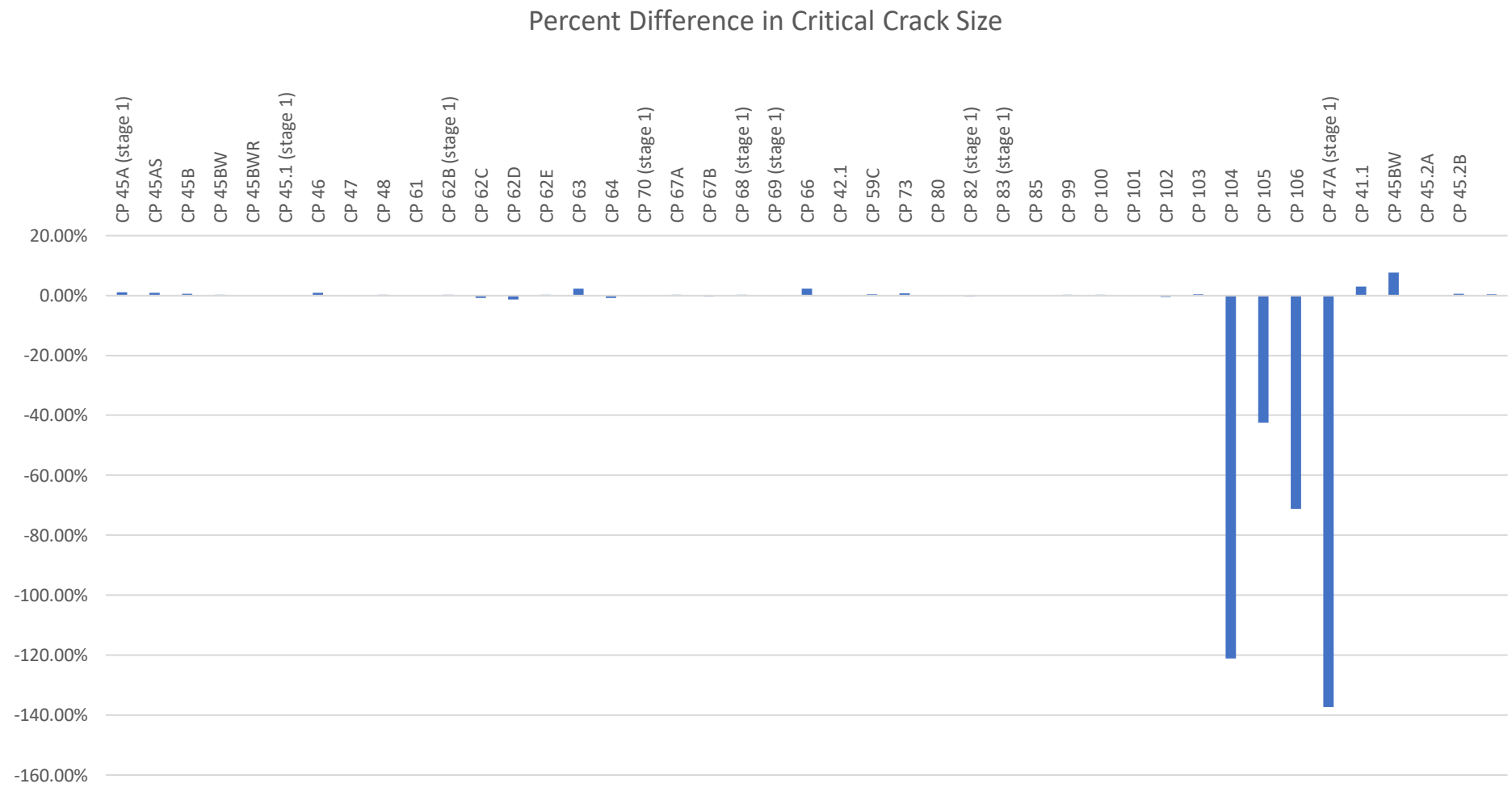


Fracture Analysis



Durability Analysis

- T-38 Methods
- AFGROW Initiation module
  - Strain-Life Approach
  - Smith, Watson, and Topper Equivalent strain equation
  - Cyclic stress-strain equation
  - Strain Life Equation
  - Material Properties
    - K' – cyclic strength coefficient
    - σ'_f - fatigue strength coefficient
    - b' – fatigue strength exponent
    - ε'_f - fatigue ductility coefficient
    - c' - fatigue ductility exponent
    - E – elastic modulus

$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2K'}\right)^{\frac{1}{n'}}$$

$$\frac{\Delta\varepsilon}{2} = \left(\frac{\sigma'_f}{E}\right)(2N_f)^{b'} + \varepsilon'_f(2N_f)^{c'}$$

Durability Analysis

- COM adjusted to incorporate the initiation module
  - Only good for CPs/materials with all known variables
- AFGROW run manually for remaining CPs
  - Stress-Strain Curves generated for Tabular input
  - Ramberg-Osgood Parameters calculated from mechanical property data

Material	CPs	Curve / Coef
2024-T3511	31	Tabular Input - Curves
7075-T76	2	Tabular Input - Curves
2024-T351	15	Coefficients
AMS_6526	2	Tabular Input - Curves
7075-T6	8	Coefficients
7175-T74	7	Tabular Input - Curves
2024-T3	5	Coefficients
2024-T42	5	Coefficients...Use 2024-T4
7075-T76511	1	Tabular Input - Curves
17-7PH	5	Tabular Input - Curves

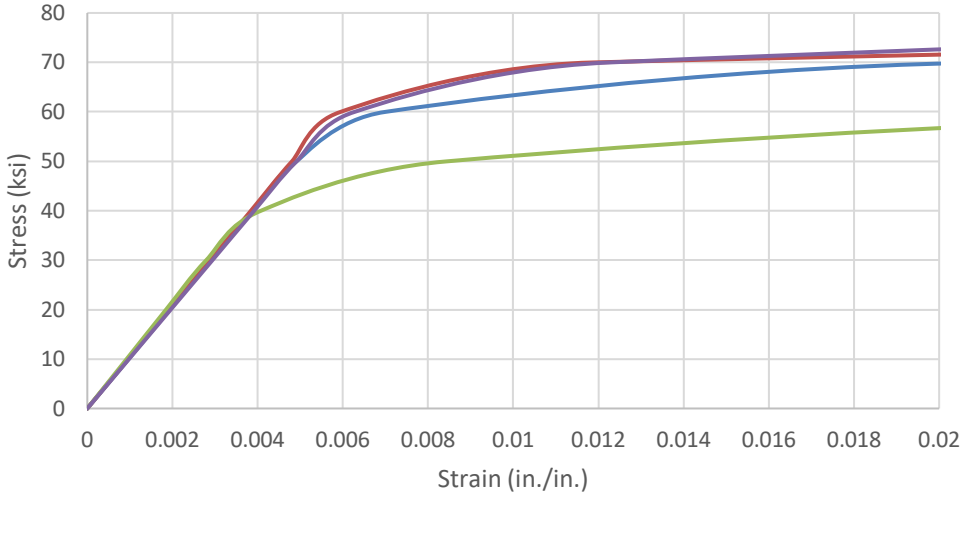
- Compared results to current DTA report
  - Change in Life (hours)

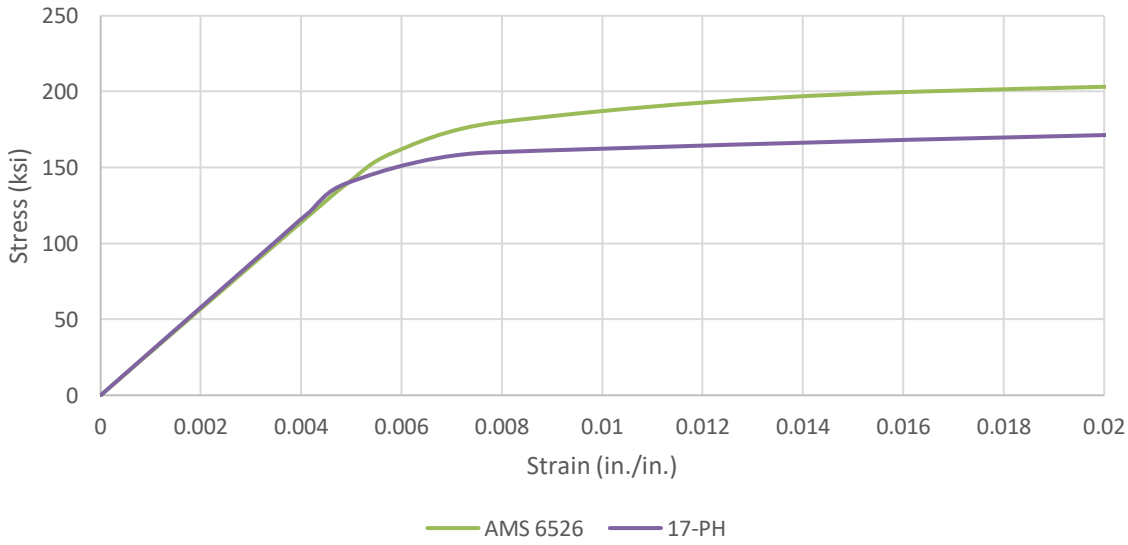
Durability Analysis – Material Properties

- Failure to find all necessary coefficients/parameters required to use the COM led to some skepticism for this method

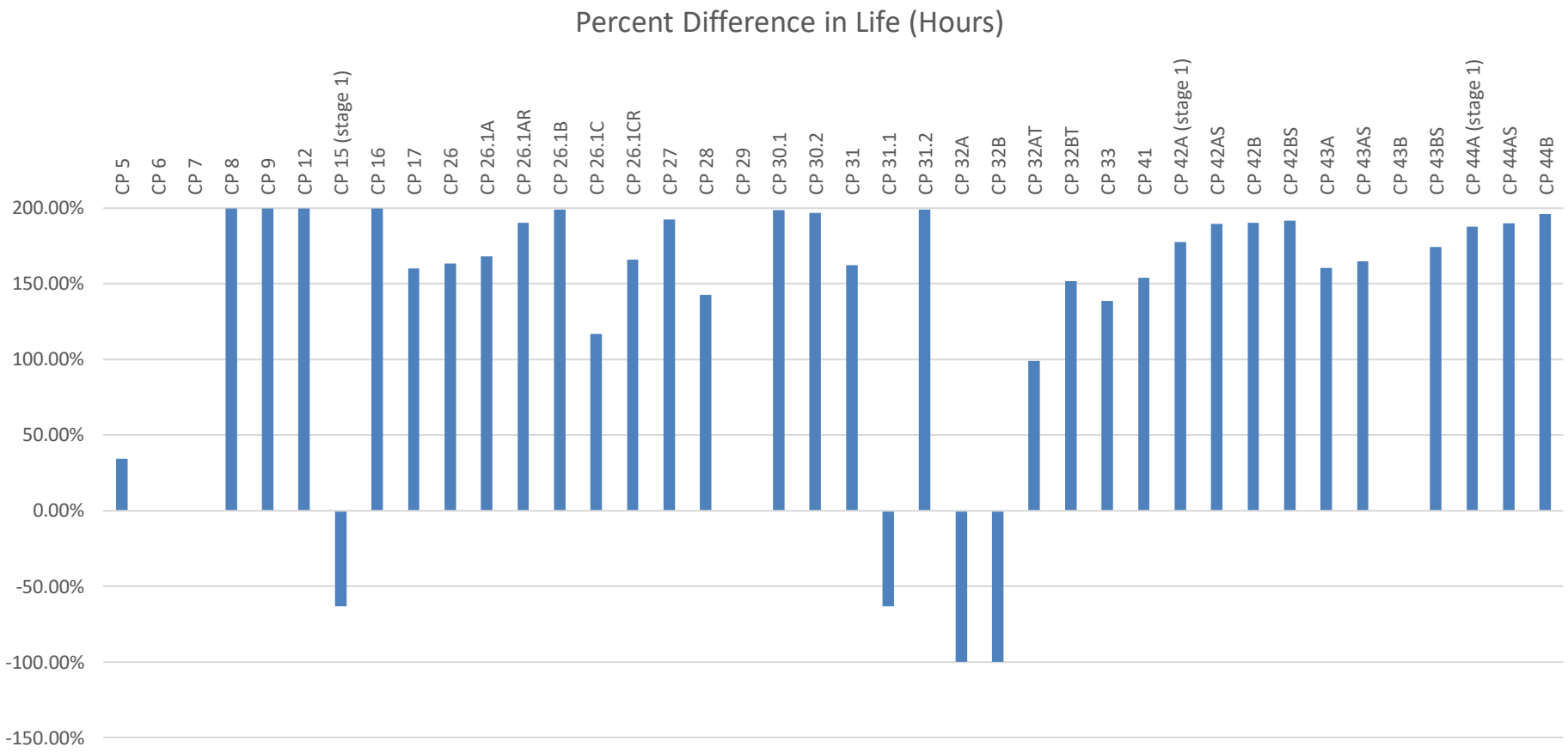
Material	CPs	Curve / Coef	Source	K'	n'	sigma'	b	epsilon'	c
2024-T3511	31	Tabular Input - Curves	MMPDS 06						
7075-T76	2	Tabular Input - Curves	MMPDS 06						
2024-T351	15	Coefficients	NASGRO, URS 469 SAE	95	0.065	159.977	-0.124	0.22	-0.5
AMS_6526	2	Tabular Input - Curves	MMPDS 06						
7075-T6	8	Coefficients	ASM Handbook, Vol 19	132	0.088	128	-0.076	0.446	-0.759
7175-T74	7	Tabular Input - Curves	MMPDS 06						
2024-T3	5	Coefficients	ASM Handbook, Vol 19	85.57	0.041	151.42	-0.114	1.765	-0.927
2024-T42	5	Coefficients…Use 2024-T4	NASGRO UTS 476 SAE	166.625	0.058	147.068	-0.11	0.21	-0.5
7075-T76511	1	Tabular Input - Curves	MMPDS 06						
17-7PH	5	Tabular Input - Curves	MMPDS 06						

Durability Analysis – Material Properties





Durability Analysis Results Compared to Results in SA220R0207_RevE



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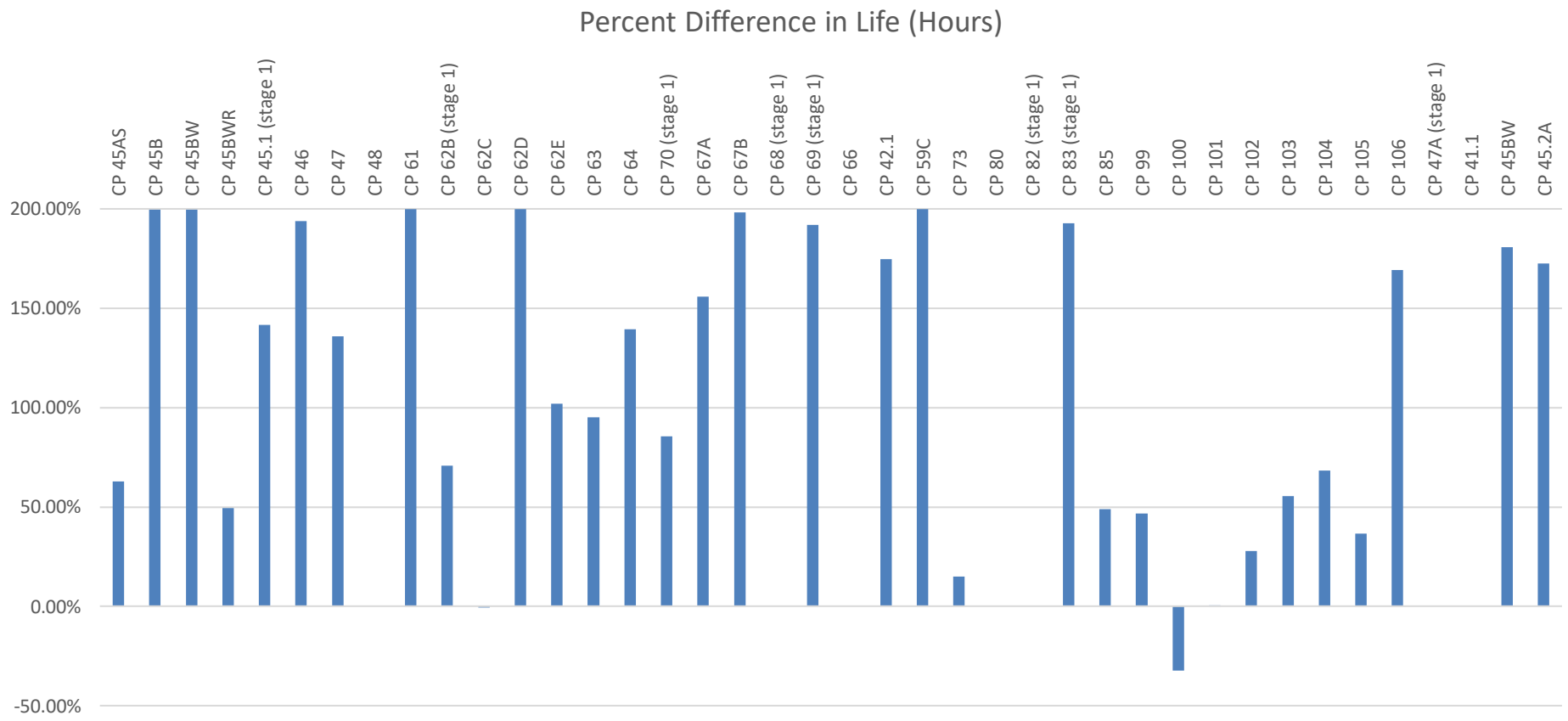
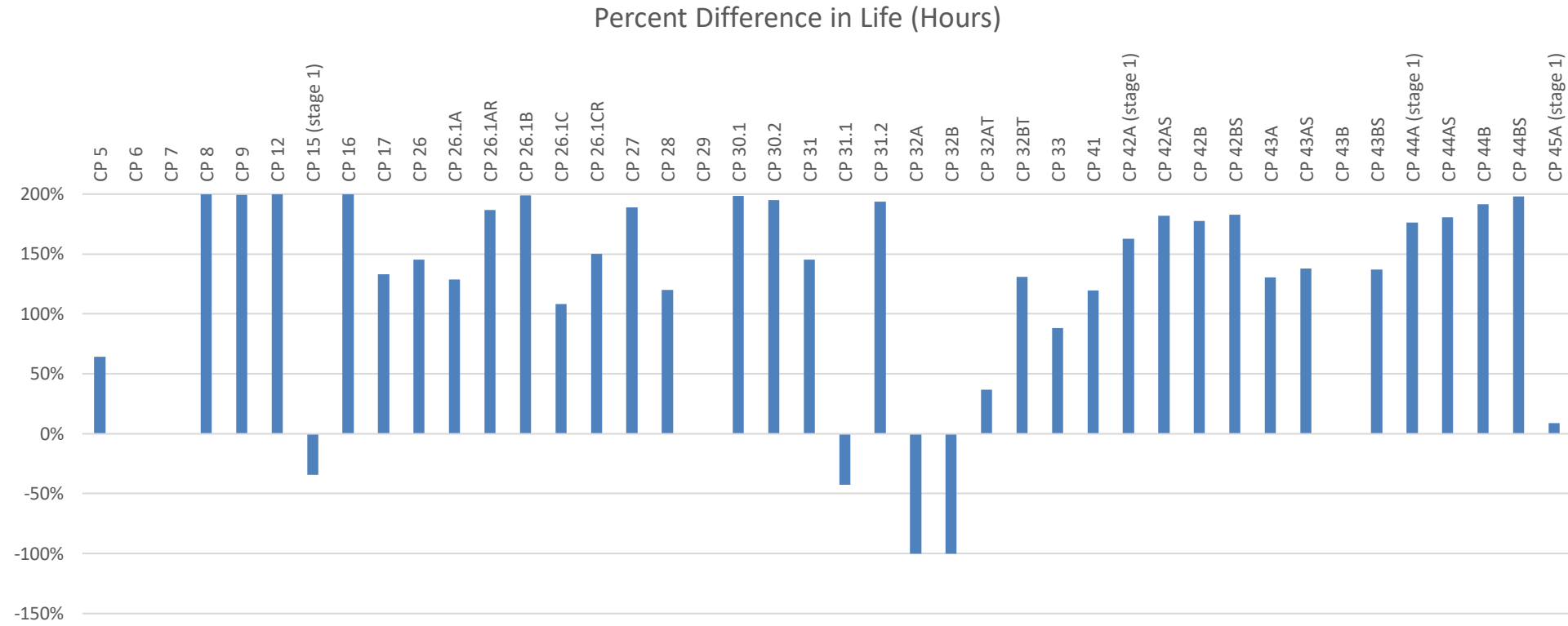


Durability Analysis Approach Compared to the Fracture Analysis Approach

- Durability Analysis Significant longer life compared to the fracture mechanics analysis

Durability Analysis Approach Compared to the Fracture Analysis Approach



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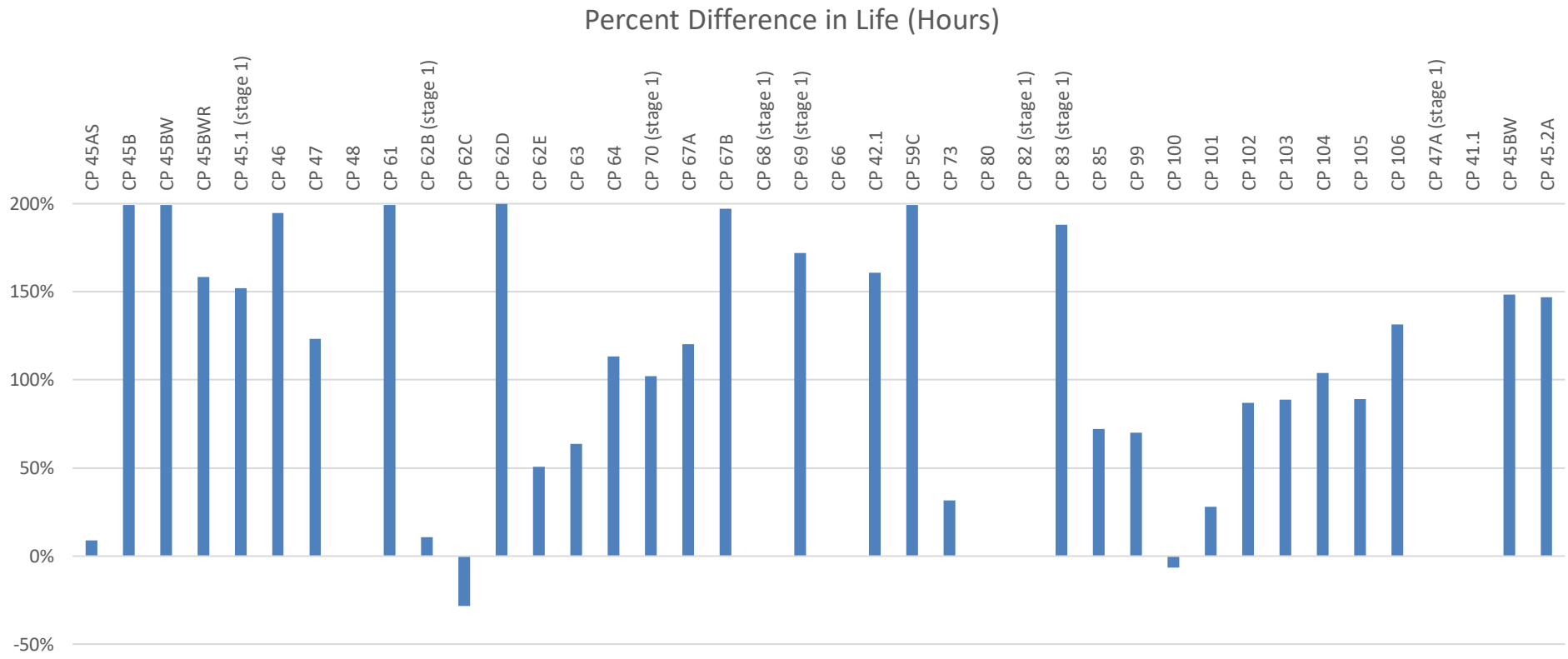
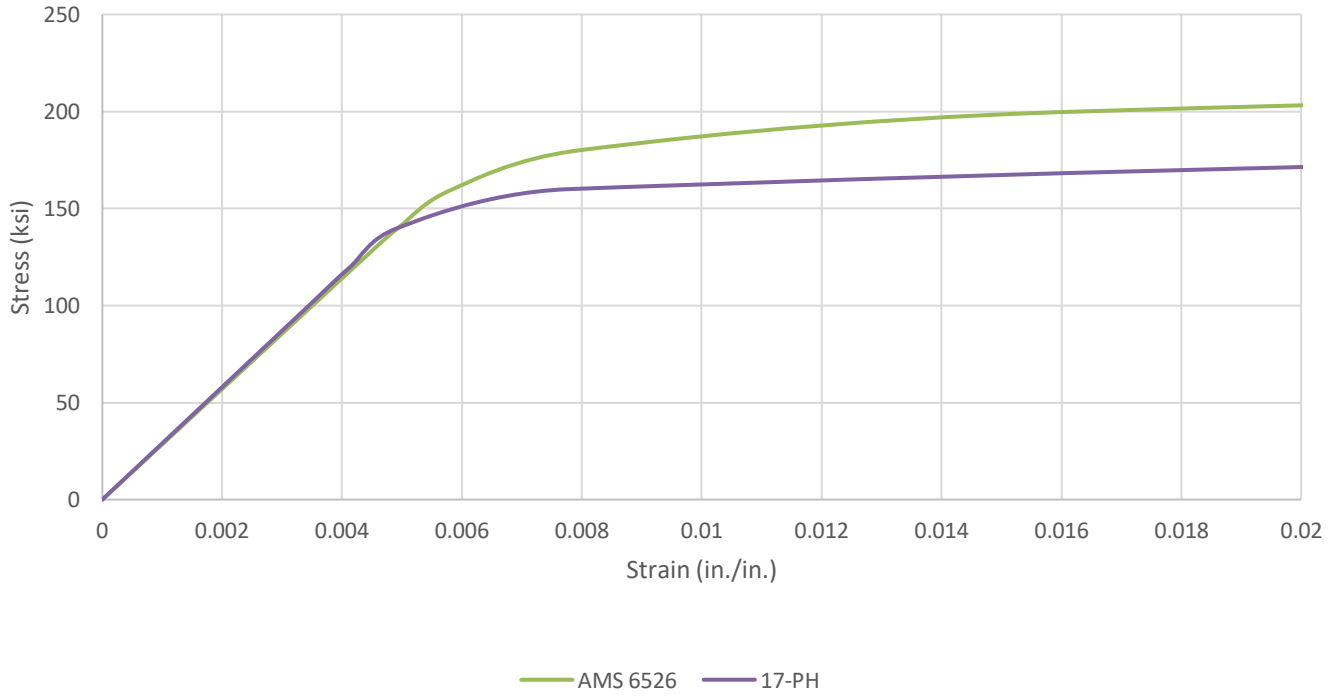


Durability Analysis Issues

- "Number of cycles to initiation great than 2.e+9"
- "Notch stress greater than K_ts"



Sensitivity Study

- How did changing the material property coefficients affect the analysis?
- Used the adjusted COM
- Increased each parameter by percentage
  - Increments of 1% then 10%
- Adjusted 1 parameter at a time
- Did for all 6 parameters

Sensitivity Study

FS Coef	Hours	% Diff
0%	2186832.4	0%
1%	1607149.6	-31%
2%	1267040.3	-53%

FS Coef	Hours	% Diff	FS Exp	Hours	% Diff	FD Coef	Hours	% Diff	FD Exp	Hours	% Diff	CycStrCoef	Hours	% Diff	Strain Exp	Hours	% Diff
0%	2186832.4	0%	0%	2186832.4	0%	0%	2186832.4	0%	0%	2186832.4	0%	0%	2186832.4	0%	0%	2186832.4	0%
1%	1607149.6	-31%	1%	1232729.9	-56%	1%	1416068.9	-43%	1%	1410571.3	-43%	1%	1362129.7	-46%	1%	1505893.6	-37%
2%	1267040.3	-53%	2%	755139.5	-97%	2%	986410.8	-76%	2%	976743.9	-77%	2%	892326.0	-84%	2%	1004620.0	-74%
3%	965066.3	-78%	3%	452375.0	-131%	3%	665289.2	-107%	3%	654340.0	-108%	3%	624477.7	-111%	3%	687173.6	-104%
4%	756157.9	-97%	4%	282457.7	-154%	4%	463850.4	-130%	4%	451907.6	-131%	4%	421555.6	-135%	4%	487206.5	-127%
5%	601603.5	-114%	5%	181048.5	-169%	5%	328789.4	-148%	5%	317186.8	-149%	5%	289821.3	-153%	5%	350122.7	-145%
6%	485871.2	-127%	6%	119295.5	-179%	6%	237522.6	-161%	6%	226365.1	-162%	6%	202993.7	-166%	6%	257559.9	-158%
7%	404106.0	-138%	7%	82064.8	-186%	7%	177510.8	-170%	7%	166710.6	-172%	7%	146019.2	-175%	7%	192345.9	-168%
8%	335851.0	-147%	8%	56794.4	-190%	8%	132851.4	-177%	8%	122818.0	-179%	8%	106116.4	-181%	8%	141344.6	-176%
9%	282986.6	-154%	9%	40286.5	-193%	9%	101165.0	-182%	9%	91919.3	-184%	9%	73701.3	-187%	9%	109045.1	-181%
10%	240683.3	-160%	10%	29073.6	-195%	10%	78060.4	-186%	10%	69486.9	-188%	10%	52025.9	-191%	10%	85104.5	-185%
15%	312727.2	-150%	15%	15324.3	-197%	15%	60118.9	-189%	15%	50534.1	-191%	15%	37864.1	-193%	15%	70347.7	-188%
20%	412503.0	-137%	20%	8780.1	-198%	20%	48083.1	-191%	20%	38199.5	-193%	20%	28156.0	-195%	20%	57520.6	-190%
25%	538761.3	-121%	25%	5340.9	-199%	25%	38930.8	-193%	25%	29180.3	-195%	25%	21295.7	-196%	25%	46873.4	-192%
30%	694675.6	-104%	30%	3403.7	-199%	30%	31883.6	-194%	30%	22505.3	-196%	30%	16413.9	-197%	30%	37990.3	-193%
35%	880154.1	-85%	35%	2239.5	-200%	35%	26118.6	-195%	35%	17383.7	-197%	35%	12777.6	-198%	35%	30151.9	-195%
40%	1111698.5	-65%	40%	1551.1	-200%	40%	21847.1	-196%	40%	13624.8	-198%	40%		-100%	40%	23270.1	-196%
45%	1390668.3	-45%	45%	1109.1	-200%	45%	18449.3	-197%	45%	10762.2	-198%	45%		-100%	45%	18193.3	-197%
50%	1719760.4	-24%	50%	818.4	-200%	50%	15708.3	-197%	50%	8533.2	-198%	50%		-100%	50%	14068.2	-197%
60%	3184248.3	37%	60%	520.2	-200%	60%	13640.3	-198%	60%	6734.9	-199%	60%		-100%	60%	10181.9	-198%
70%	5598635.9	88%	70%	351.4	-200%	70%	11858.5	-198%	70%	5318.2	-199%	70%		-100%	70%	7126.5	-199%
80%	9499418.6	125%	80%	249.2	-200%	80%	10460.7	-198%	80%	4248.3	-199%	80%		-100%	80%	4932.7	-199%
90%	15512396.5	151%	90%	182.9	-200%	90%	9285.7	-198%	90%	3401.7	-199%	90%		-100%	90%	3412.8	-199%
100%	24510228.0	167%	100%	24510228.0	167%	100%	8297.5	-198%	100%	2735.8	-200%	100%		-100%	100%	2346.3	-200%

Conclusions

- Crack growth approach is more conservative
- Strain-Life approach for durability analysis appears volatile with our current parameters
- With proper values, the initiation module may be more beneficial for a strain-life approach
- Where do we go from here…

Current Efforts

- Linear Elastic Fracture Mechanics (LEFM) Approach for Durability Analysis
- Reduced Equivalent Initial Flaw Size (EIFS)
- High Fidelity Rate in Region I
- Validation Required
  - Run numerous predictions at multiple max stresses and stress ratios
  - Compare to S-N curves
- APES

Questions

Questions?

Thank you