Weld Challenge 2A Life Prediction – RHS Joints under Variable Amplitude Loading

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Fatigue Life Prediction Procedures

- Battelle JIP mesh-insensitive structural stress method and master S-N curve was used by Ford Motor Company, Caterpillar, and Battelle
- Battelle and Caterpillar used JIP structural stress research code
- Ford Motor Company used its in-house FLOW incorporating Battelle's structural stress method
- This presentation summarizes the three organization's blind life predictions for the FD&E Weld Challenge 2A under variable amplitude loading
- Although the underlying method is the same, the results represent independent implementations of the same method at each organization

Ford/Battelle FLOW Based Life Prediction Procedure

- Generate finite models based on geometry given
- Perform mesh-insensitive structural stress analysis for each weld toe line at unit load
- Structural stress scaling and rain flow counting
- Damage summation using the master S-N curve and life prediction



Modeling Considerations for Weld Challenge 2A versus Challenge 1

- Overall specimen geometry: same as before (Challenge 1)
- Weld end is much bigger in Challenge 2A







Finite Element Modeling: Challenge 2A versus 1

Weld Representation at Weld Ends *Challenge 2A (2004) Model 1*





Weld Representation at Weld Ends *Challenge 1 (2003)*







Weld Representation for Small Weld Ends – Model 2

Representation of Full and Partial Penetration Fillet Welds and Failure Definitions







Full penetration weld

Partial penetration weld

<u>Failure definition:</u> Through-thickness failure

Mesh-Insensitivity Demonstration – The Structural Stress Method



Mesh-Insensitivity Demonstration



Distance from the 2X6 Tube Top End, mm

Identification of Critical Locations after Searching Two Weld Toe Lines



Observations:

- If the weld ends are big (modeled as posted in the website), weld end failure occurs on 4"x4"
- if the weld ends are as small as those for Challenge 1, failure occurs at 2"X6" weld toe corner

Effects of Weld End Fatigue Crack Development on Structural Stress Distributions





Variable Amplitude (VA) Load Cases

1. 19.2 times the grapple skidder torque history (GSTH)
2. 27.1 times the grapple skidder torque history



GSTH with load magnification 19.2

Max load = 27160 N Min Load = -20327 N No. of reversals = 5728

Load Range Histogram Plots for GSTH with 19.2 Magnification



Table – Peak load ranges and their occurrences for GSTH with 19.2 magnification

Load Range (P)	No. of occurences		
47950	1		
38980	1		
35945	1		
33703	1		
31460	2		
27700	1		
26973	2		
26245	1		
25450	1		
24725	1		
24005	2		
23210	5		
22485	2		
21757	3		
20970	5		

Load Range (P)	No. of occurences			
20243	1			
19447	3			
18720	4			
17995	7			
17206	7			
16480	8			
15735	14			
15000	11			
14238	20			
13488	15			
12737	31			
11986	20			
11236	35			
10495	34			
9734	50			

WELD – NOMENCLATURE



Fatigue Life Prediction – Weld Challenge 2A Model 1 with Big Weld End



Weld	Life in blocks		Failure location	
condition	19.2 times GSTH VA	27.1 times GSTH VA		
1) Full weld	1044	364	weld end, lower toe (4x4)	
penetration	3273	1143	weld corner, upper toe $(2x6)$	
2) Partial penetration	786	274	weld end, lower toe $(4x4)$	
	2065	721	weld corner, upper toe (2x6)	

Life Contour Plot – Weld Challenge 2A Using Model 1



Fatigue Life Predictions with Various Weld End Conditions



Failure location: (same for all the three cases)



Note: Case 1) represents a case if a crack at the weld end becomes undetected during testing, the 2"x6" weld toe corner becomes a secondary critical location

Caterpillar's Trial

-We are a member in Structural Stress JIP, but are still in "Research" area.

-Non-automated tools are available for Cal.

- ABAQUS
- JIP Post Processor
- CAT's Data Analysis Tool Kit (Rainflow Counting)

Elements around the weld end is slightly different to cooperate with the post processor.

Results Comparison w/ Last Year's



⁴X4 Weld Toe

2X6 Weld Toe

Life Prediction

	At Weld End (19.2)	At corner (19.2)	At Weld End (27.1)	At corner (27.1)
Mean	1095.7	3016.4	379.8	1040.7
Upper 95	6228.2	17635.1	2130.5	5910.5
Lower 95	196.7	536.5	68.6	186.9



Structural Redundancy 1

When a small crack (5 mm) is developed at weld end,



the corner becomes the highest stress point.

Structural Redundancy 2

When another small crack (5 mm) is developed at the corner,



Distance from the 2X6 Tube Top End, mm

the corner is still the highest stress location.

 \rightarrow Further crack development may occur at the corner.

Conclusions

- Weld end appears much bigger for Weld Challenge 2A than that for Challenge 1
- As a result, the most critical location is at the 4"x4" weld toe and the secondary critical location is at 2"x6" weld toe corner
- Mean lives for the 4"x4" weld end: GSTH with 19.2X/27.1X: 1044/364 blocks
- Mean lives for the 2"x6" weld toe corner: GSTH with 19.2X/27.1X: 3273/1143 blocks
- The difference in life between 4x4 weld end and 2x6 corner is still within the typical scatter in welded joints. Thus, one of the two critical locations, or both, could dominate final lives.