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The Influence of Dimensional Deviations on the Performance of Welded 304L and 17-4 Stainless Steels

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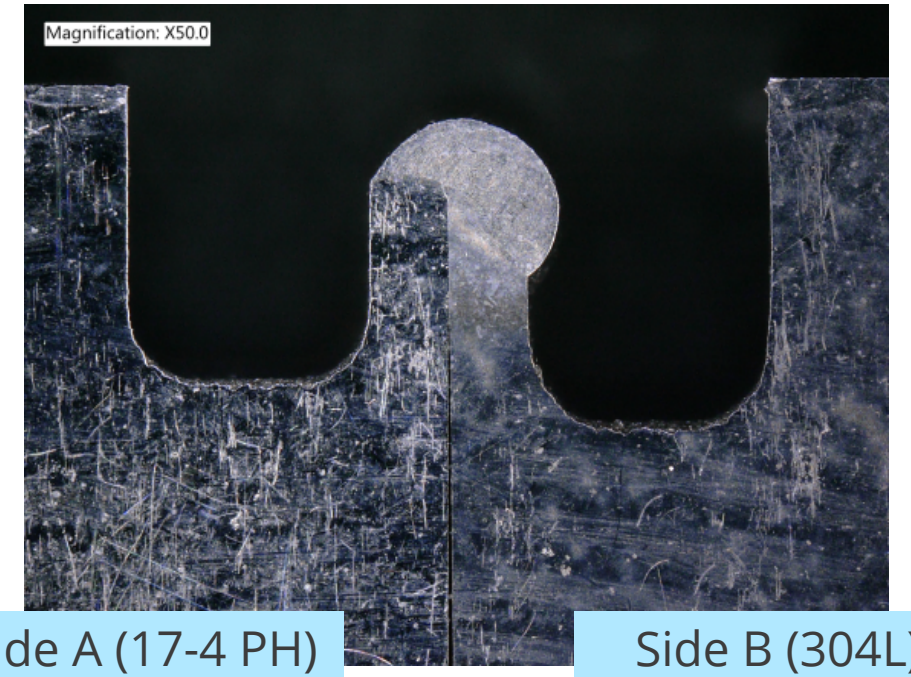
Problem Statement

- Welds of varied geometries, weld depths, and porosities
- Quantification of boundary conditions
- Separation of performance

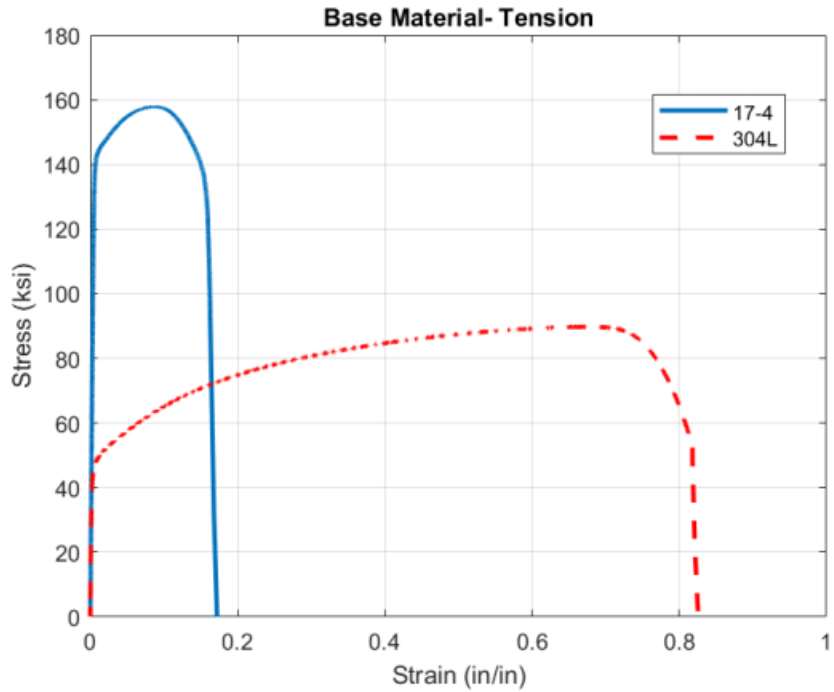
- Given weld configuration
  - 17-4 welded to 304L
  - GTAW (TIG) weld, no filler material

Weld depth is important

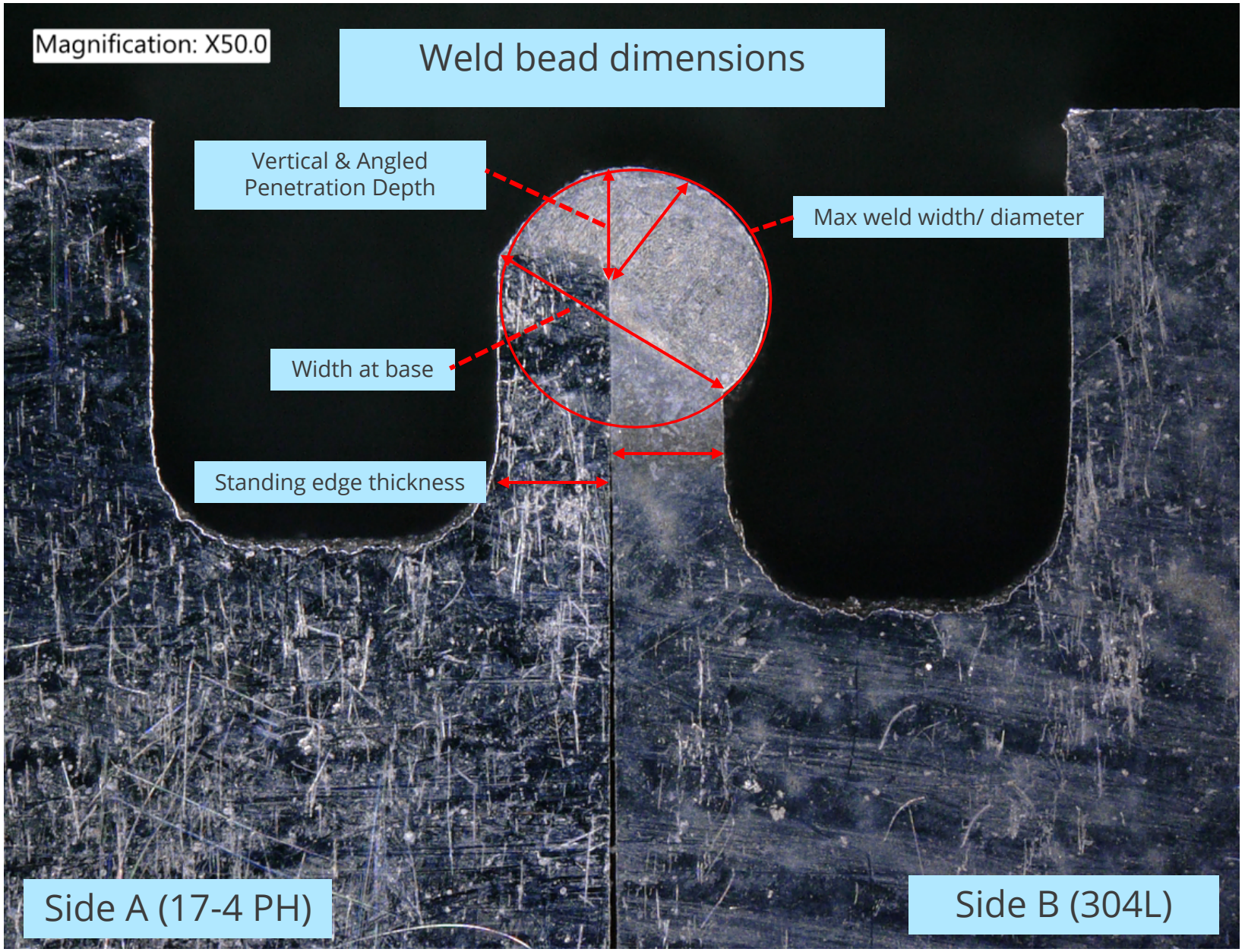
How does geometry influence performance?



Side A (17-4 PH) Side B (304L)

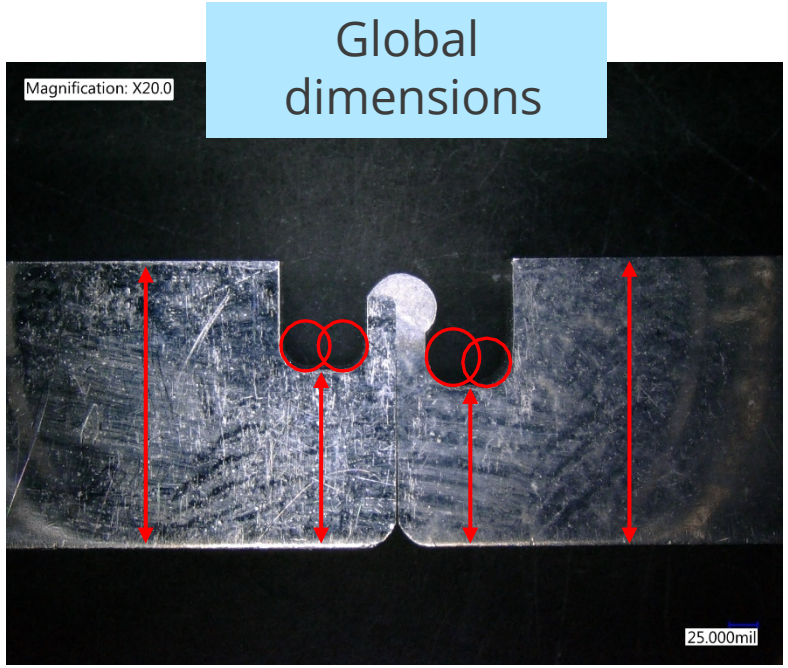


Pre-Test Measurements



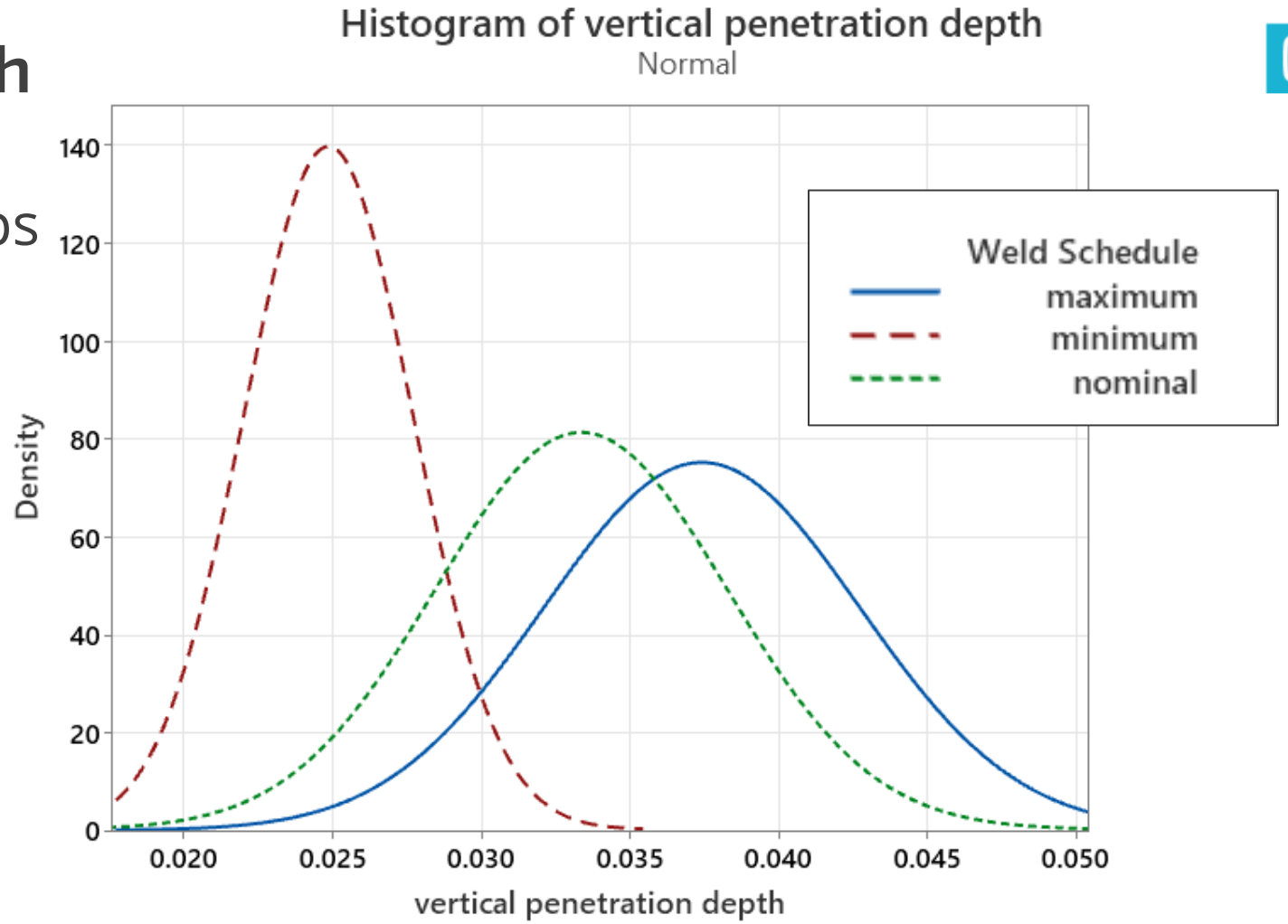
Different weld schedules give 3 intentional groups of weld depth:

- Minimum
- Nominal
- Maximum



Weld Penetration Depth

- Do the 3 weld schedule groups have *statistically* different weld depths?
- Simple One Way ANOVA



Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
depth	3	Maximum, Minimum, Nominal

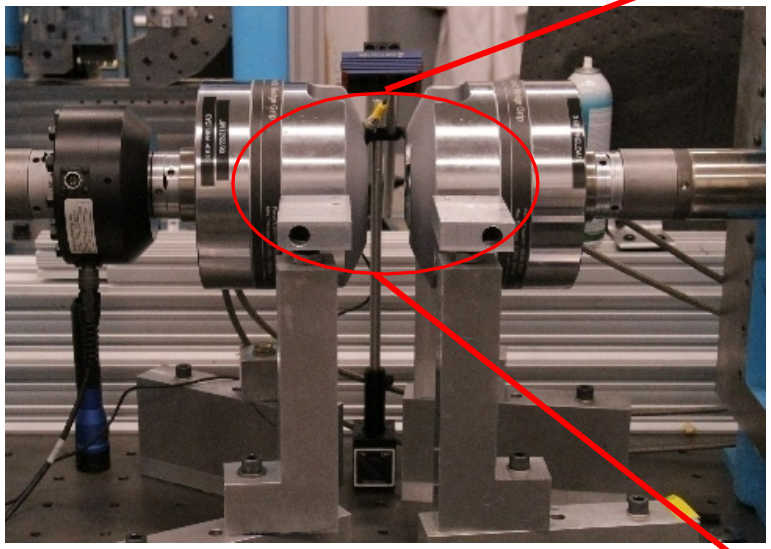
Analysis of Variance

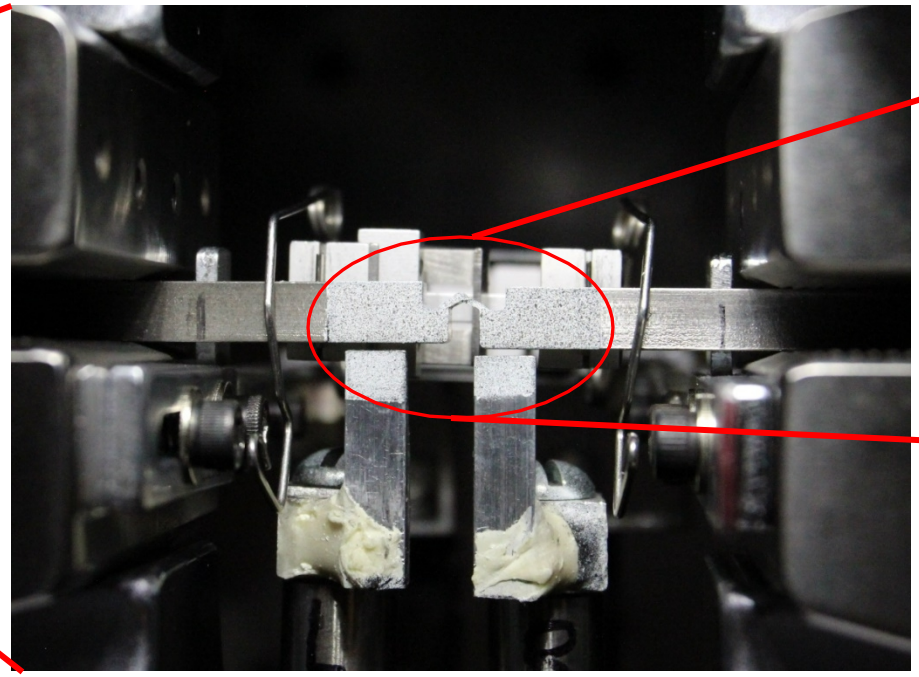
Source	DF	Adj SS	Adj MS	F-Value	P-Value
depth	2	0.000779	0.000390	29.83	0.000
Error	17	0.000222	0.000013		
Total	19	0.001001			

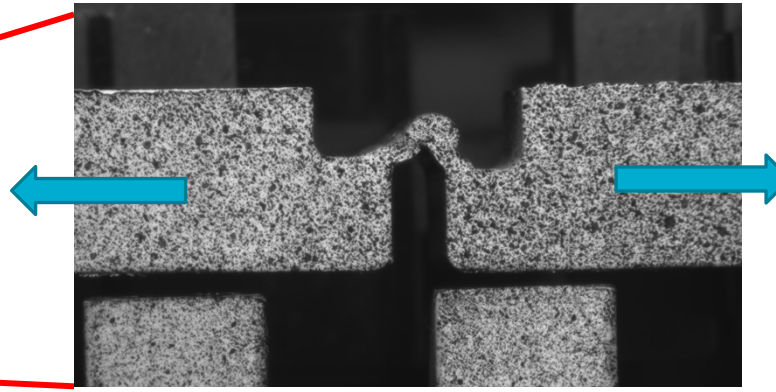
Model Summary

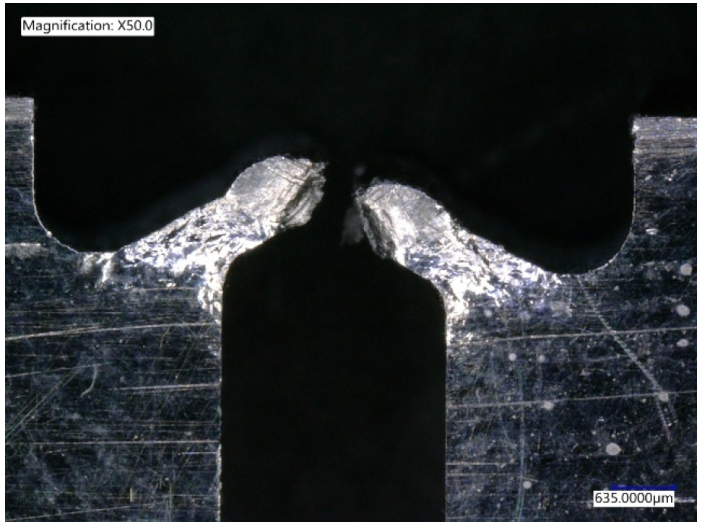
S	R-sq	R-sq(adj)	R-sq(pred)
0.0036135	77.82%	75.22%	69.97%

Tension Experiments







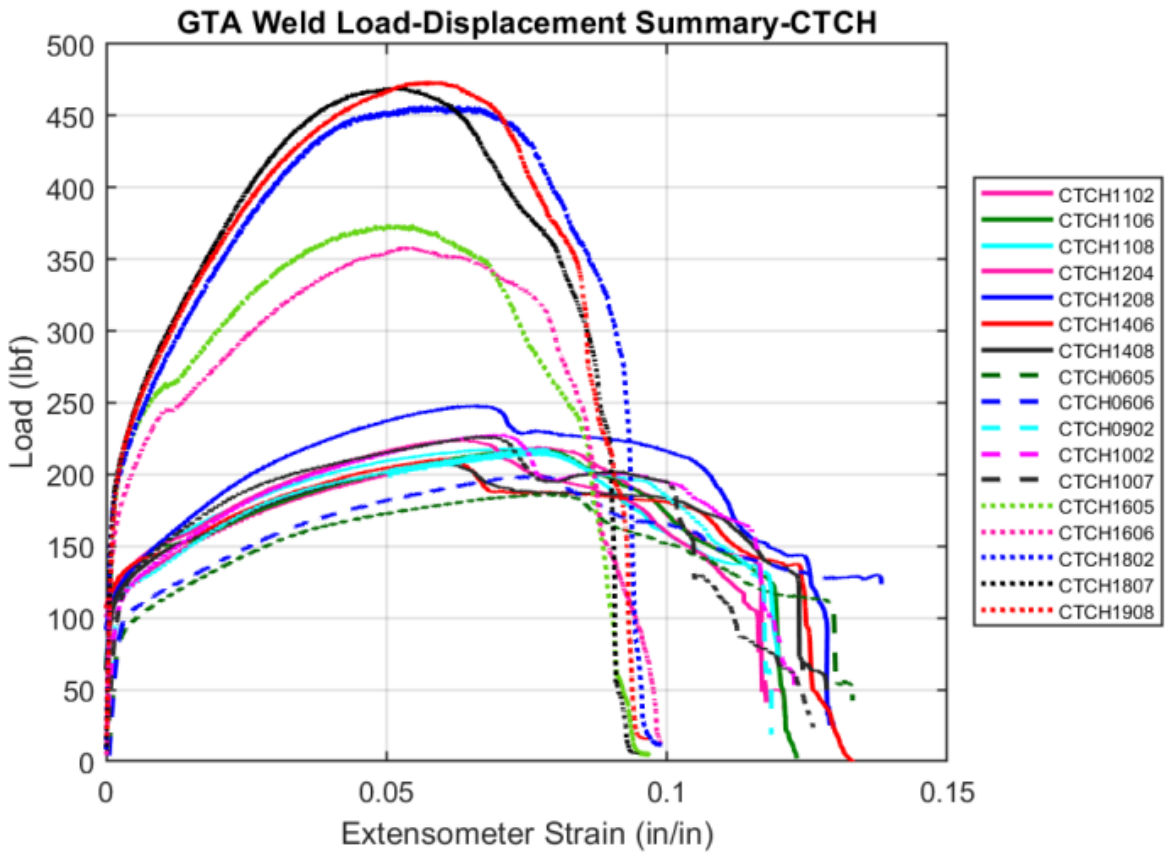


How does local geometry influence performance?

Which dimensions?
How much?

Tensile Results

- Peak Load
- Extension to Failure
- Grouping is apparent



Use Statistical Model to determine individual and combined contributions

Minitab

Minitab Inputs- Generalized Linear Model

- Similar to ANOVA, but allows covariates
- 95% confidence interval

Factor Information

Factor	Type	Levels	Values
depth	Random	3	maximum, minimum, nominal

Method

Factor coding (-1, 0, +1)

- Responses
  - Peak Load
  - Displacement to failure
- Covariates: 2 Groups (separate analyses)
  - Weld bead dimensions
    - Angled penetration depth
    - Base weld width
    - Widest width/ diameter
  - Nearby Measurements
    - Side thickness
    - Inside radius
    - Outside radius
    - Standing Edge thickness

P value < 0.05 is statistically significant; reject null hypothesis

Minitab Tension Results: Peak Load

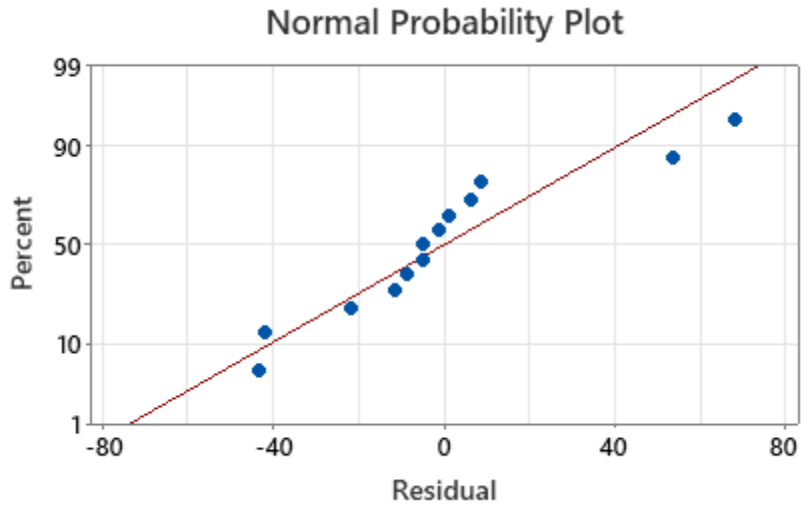
Analysis of Variance

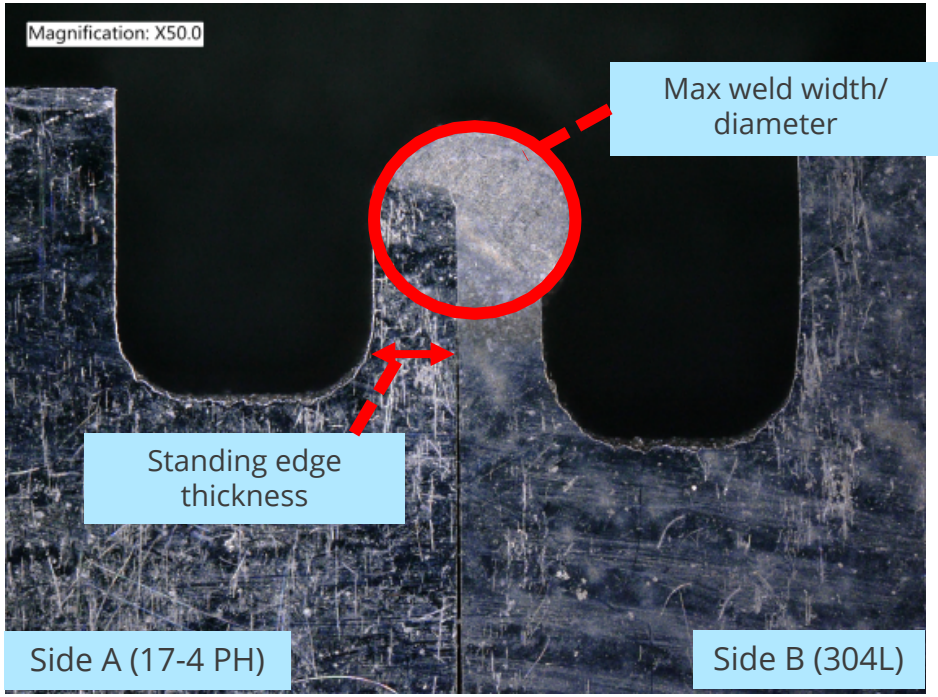
Source	DF	Adj SS	Adj MS	F-Value	P-Value
central angled penetration dept	1	2934	2934	1.71	0.232
weld width at weld base	1	4267	4267	2.49	0.159
widest width	1	29947	29947	17.48	0.004
Weld Schedule	2	4833	2417	1.41	0.306
Error	7	11992	1713		
Total	12	139833			

R-sq: 91.42%

Source	DF	Adj SS	Adj MS	F-Value	P-Value
side a thickness	1	344	343.6	0.16	0.714
side b thickness	1	355	354.9	0.17	0.710
side a outside radius	1	549	548.8	0.26	0.646
side b outside radius	1	8112	8111.9	3.83	0.145
side b inside radius	1	529	529.0	0.25	0.652
side a standing edge thickness	1	41725	41725.4	19.68	0.021
side b standing edge thickness	1	3155	3154.8	1.49	0.310
Weld Schedule	2	16	8.1	0.00	0.996
Error	3	6359	2119.7		
Total	12	139833			

R-sq: 93.69%





P value < 0.05 statistically significant

Minitab Tension Results: Extension to Failure

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
depth	Random	3	maximum, minimum, nominal

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	R-sq
central angled penetration dept	1	0.000075	0.000075	0.86	0.384	72.39%
weld width at weld base	1	0.000044	0.000044	0.51	0.498	
widest width	1	0.000394	0.000394	4.56	0.070	
Weld Schedule	2	0.000008	0.000004	0.04	0.957	
Error	7	0.000606	0.000087			
Total	12	0.002178				

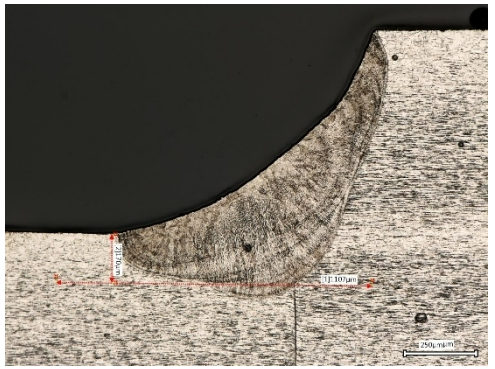
Source	DF	Adj SS	Adj MS	F-Value	P-Value	R-sq
side a thickness	1	0.000013	0.000013	0.21	0.676	91.44%
side b thickness	1	0.000012	0.000012	0.19	0.689	
side a outside radius	1	0.000000	0.000000	0.00	0.951	
side b outside radius	1	0.000144	0.000144	2.31	0.226	
side b inside radius	1	0.000010	0.000010	0.16	0.718	
side a standing edge thickness	1	0.000539	0.000539	8.68	0.060	
side b standing edge thickness	1	0.000020	0.000020	0.32	0.611	
Weld Schedule	2	0.000006	0.000003	0.05	0.950	
Error	3	0.000186	0.000062			
Total	12	0.002178				

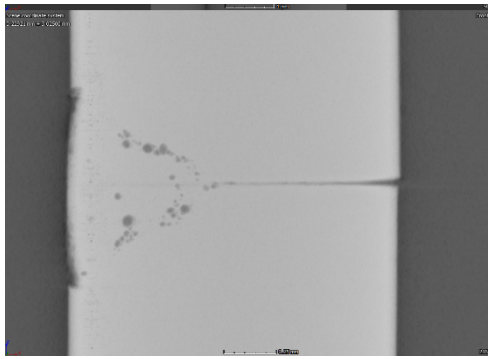
- Extension not as sensitive to Weld Schedule type
- Not enough data to determine a significant contribution

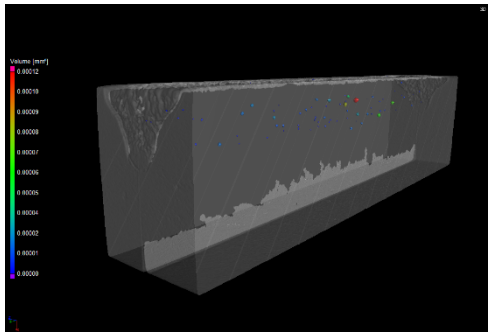
Summary

Conclusions

- Weld diameter and Side A (17-4) standing edge influence tensile peak load performance
- Extension to failure shows no clear influences from specimen dimensions







Future Work

- Other statistical methods
  - Principal Component Analysis
  - Support for continuous factor
- Expand analysis to other weld configurations
  - Offset
  - Gap
- Incorporate CT scan data

Questions?

Thank you