

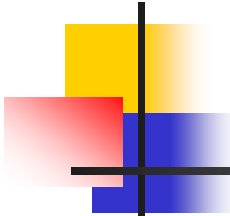
HSR-41

Improved Thermite Welds

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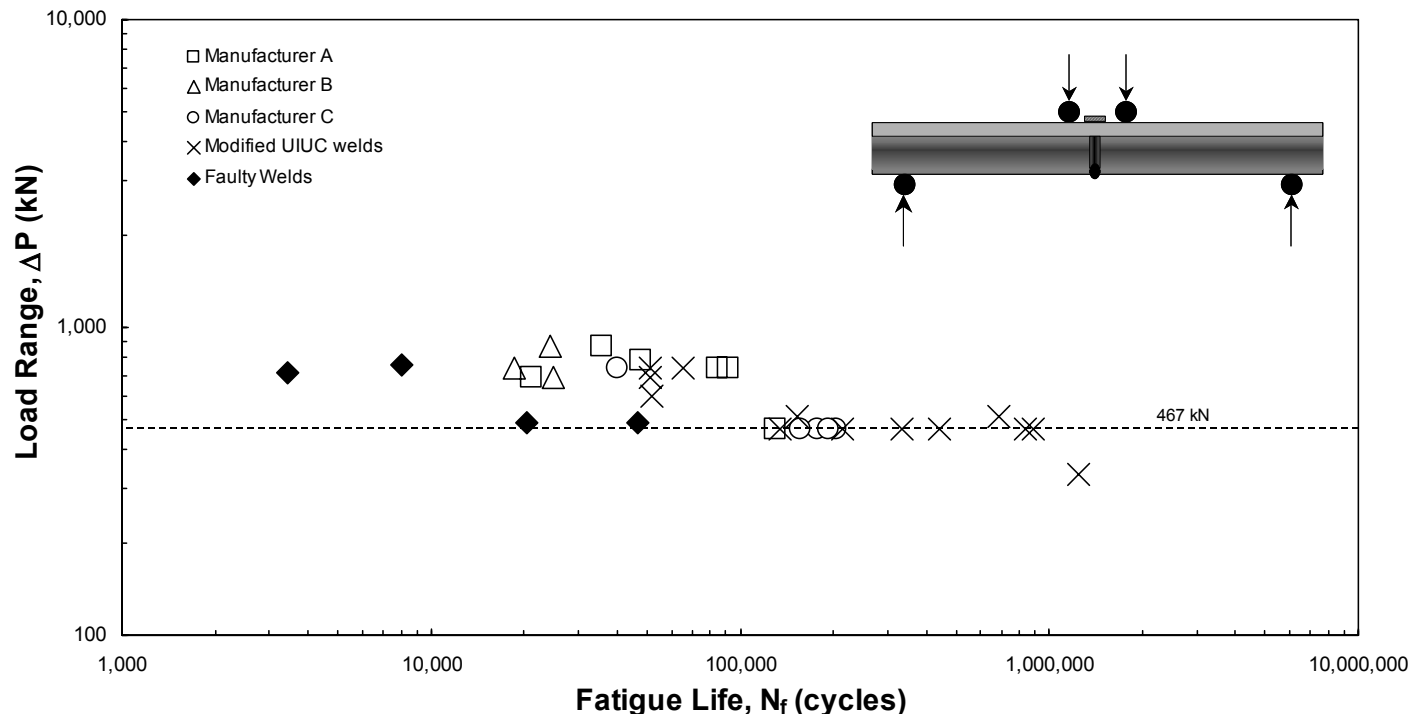
Outline

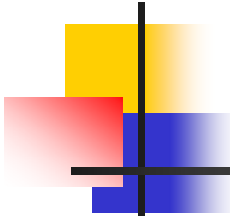


- HSR-24 Pilot study and HSR-41
 - HSR-41
 - Effects of weld toe geometry
 - Experimental results
 - Analysis of results
 - Fatigue life simulation model study
 - Field tests

HSR-24 Pilot study

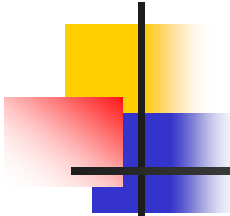
- Thermite welds are a major cause of service failures in main line track today and much of the problem is attributed to fatigue from wheel loads.
- A pilot study (HSR-24) indicated that improved performance is possible through changes in mold design – namely creating a smoother transition at the weld-toe.





HSR-41 Objectives

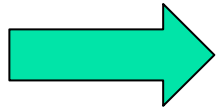
- Confirm the pilot study results through extensive experimentation
- Suggest and test further improvements
- Install the improved welds in track at TTCI for further proof of improvements.



Outline

- HSR-24 Pilot study

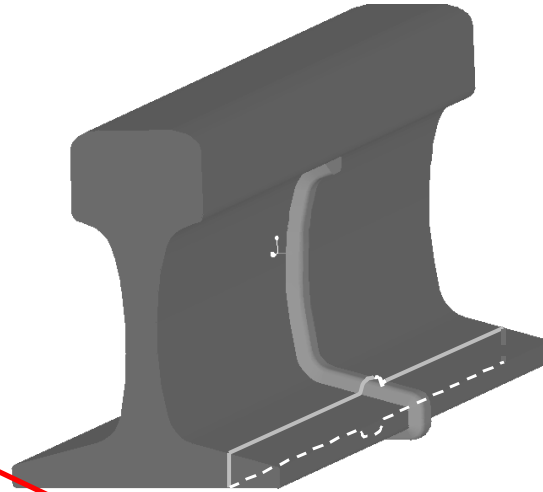
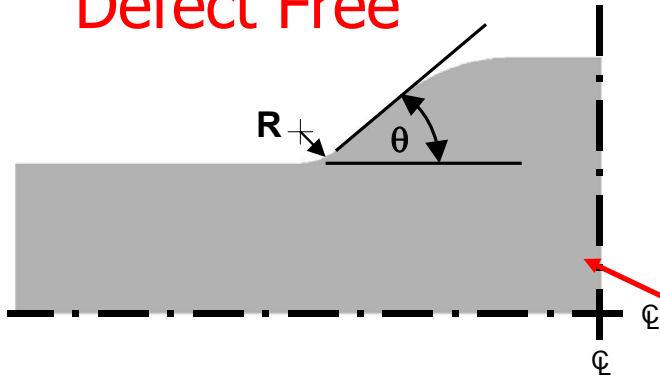
- HSR-41



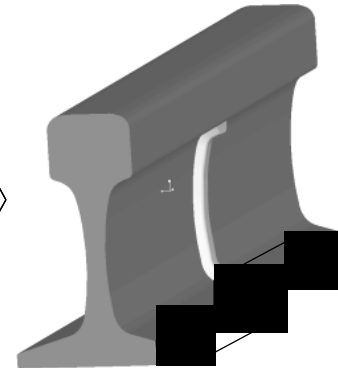
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Weld-Toe Geometry

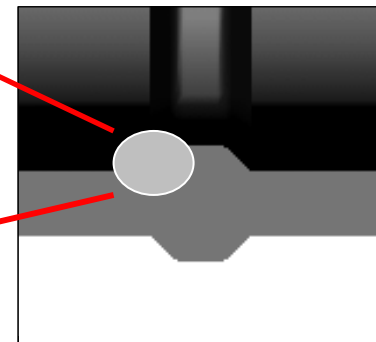
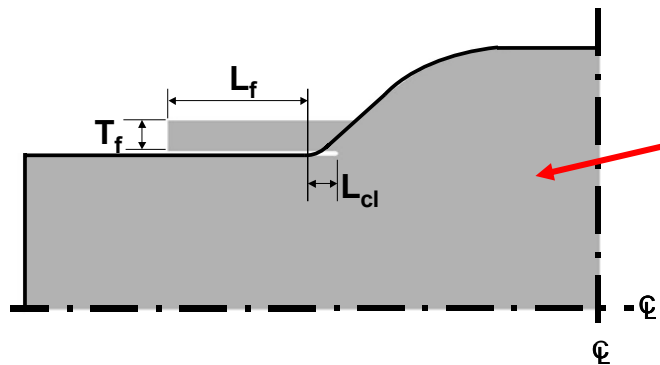
Defect Free



Cut along plane



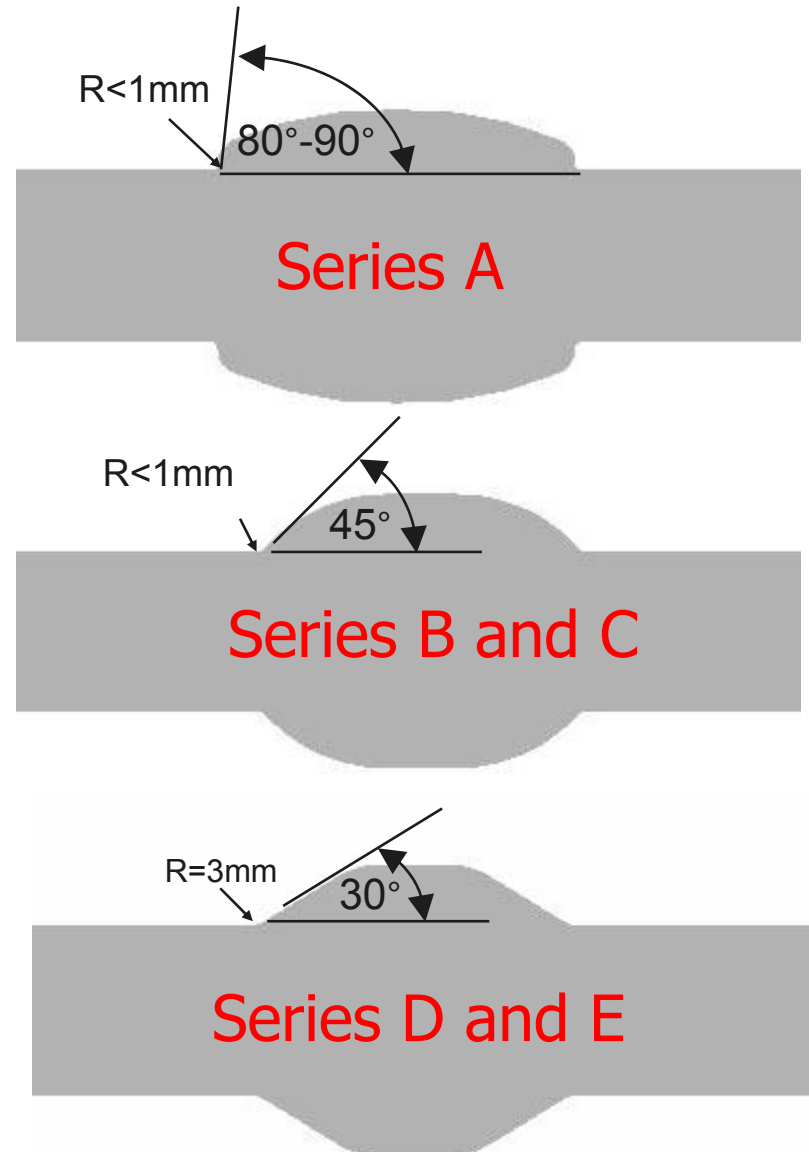
Weld-Toe Defects



Test Series

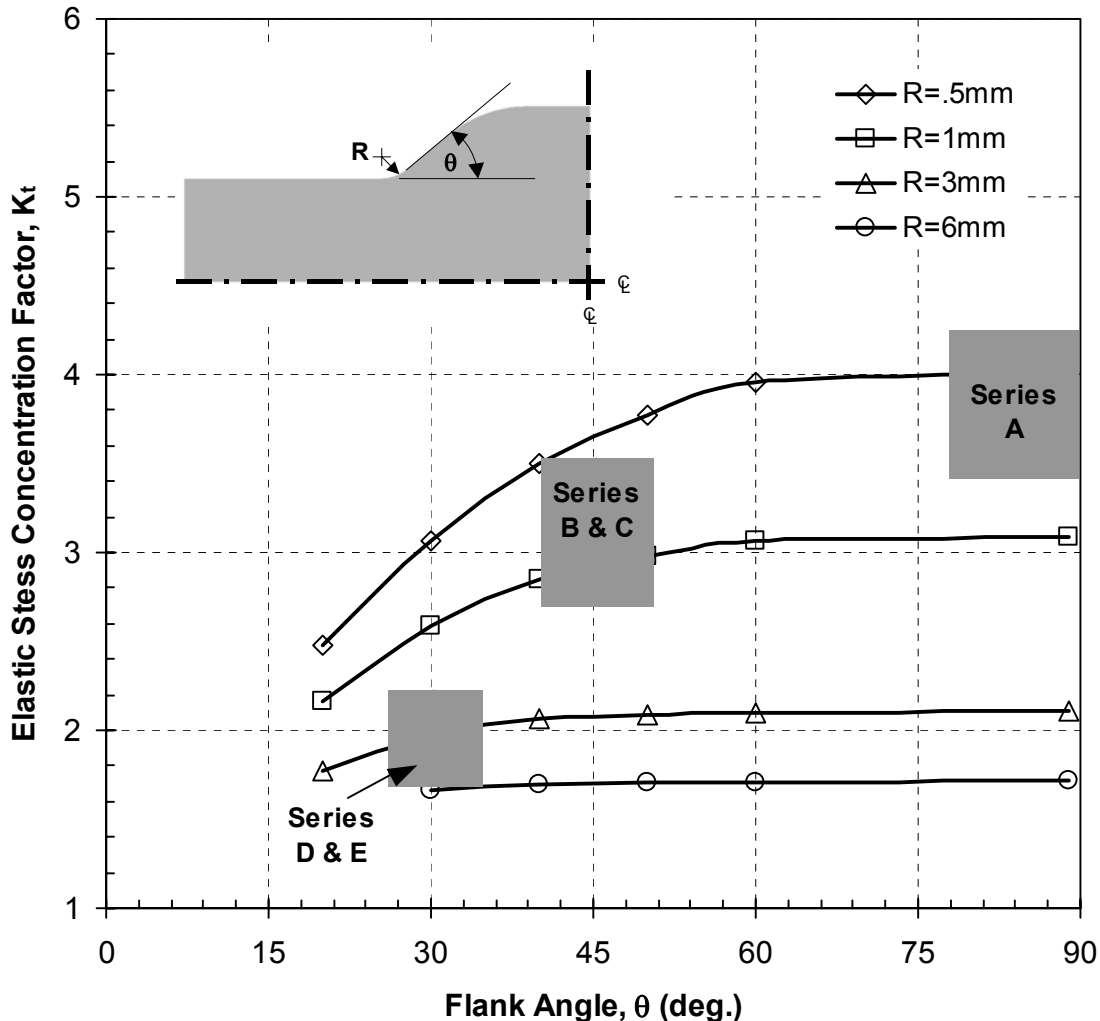
- 5 different series tested
- 3 different geometries
- C is a version of B that utilizes a 3-piece mold
- E has a larger rail gap than D
- All series consisted of 10 weld samples

Series	Gap, G (mm)	Mold Pieces (-)	Preheat (min)
A	25	2	6
B	25	2	6
C	25	3	6
D	25	3	7
E	31	3	7



Effect of Weld Geometry

Stress analysis of weld-toes using FEM



- The elastic stress concentration factor is a measure of the severity of the geometry.

$$K_t = \frac{\sigma_{local}}{S_{remote}}$$

- Big toe radius $\rightarrow$ Good
- Low flank angle $\rightarrow$ Good

Weld Shape	Stress Concentration
Series A	3.7
Series B and C	3.1
Series D and E	1.9

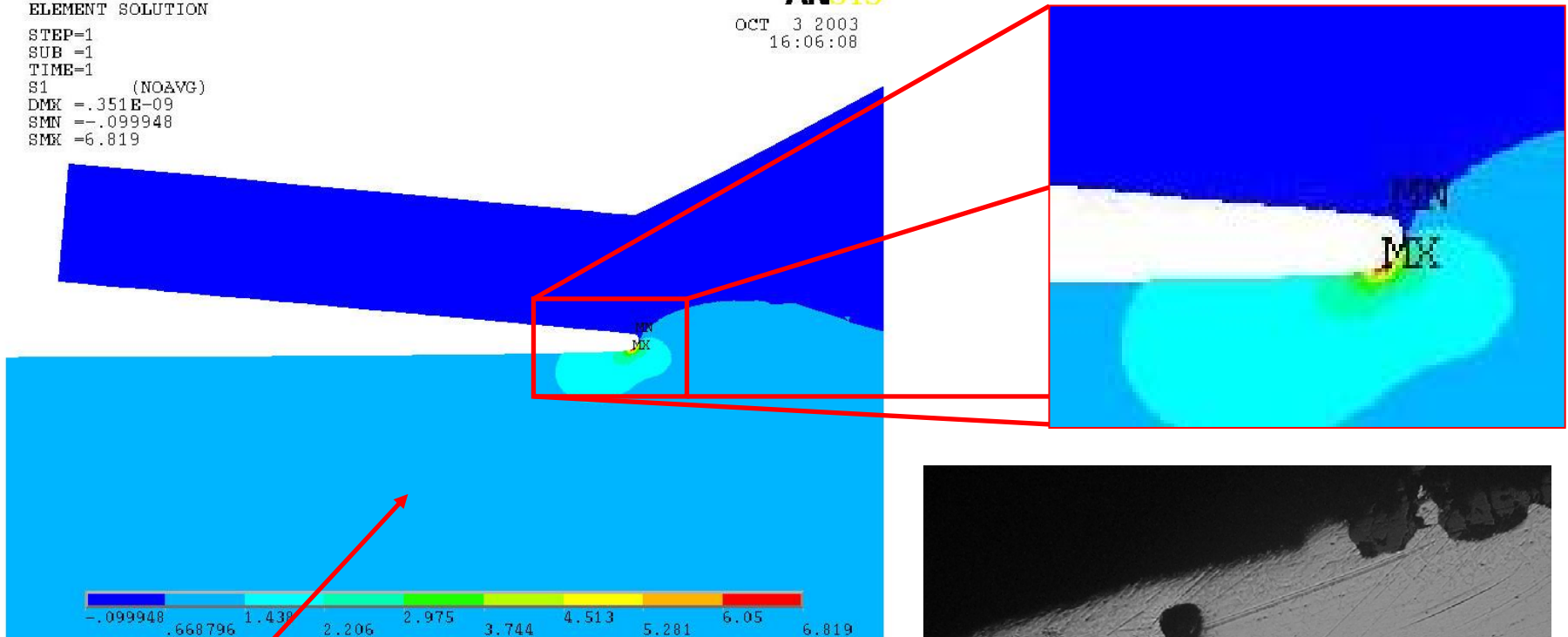
Fins as Fatigue Notches

ELEMENT SOLUTION

STEP=1
SUB =1
TIME=1
S1 (NOAVG)
DMX =.351E-09
SMN =-.099948
SMX =6.819

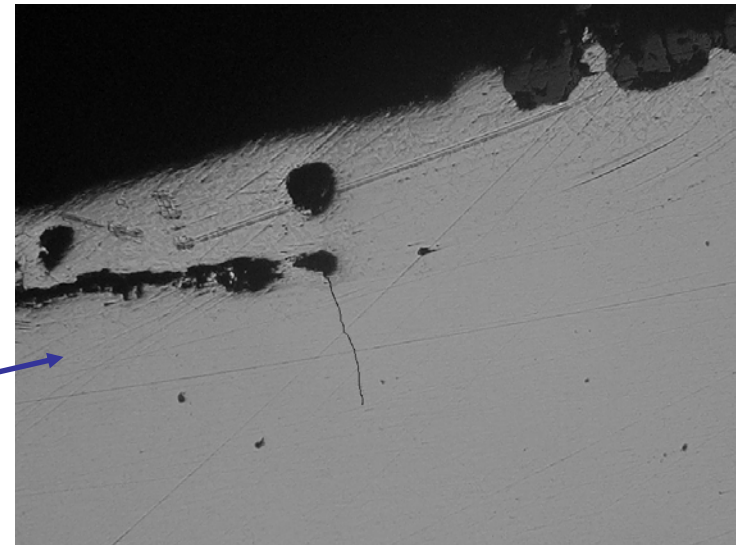
ANSYS

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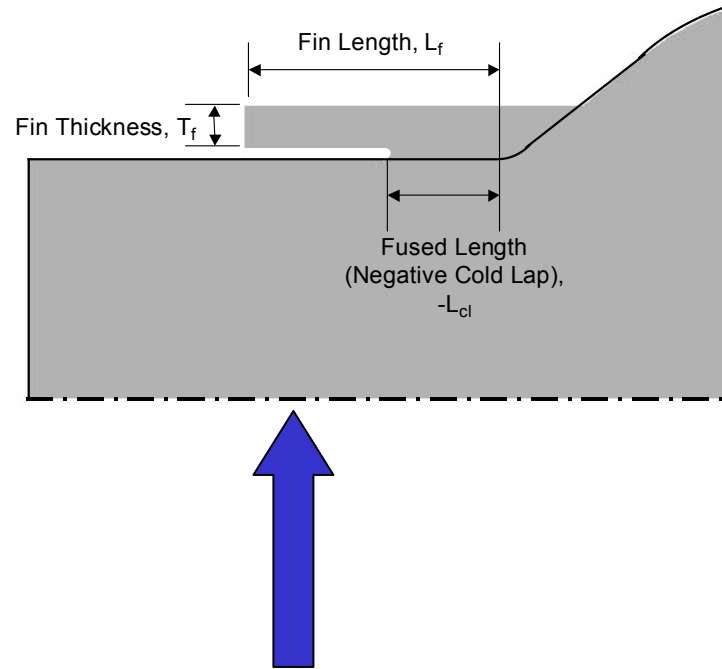
Model

Experimental observation

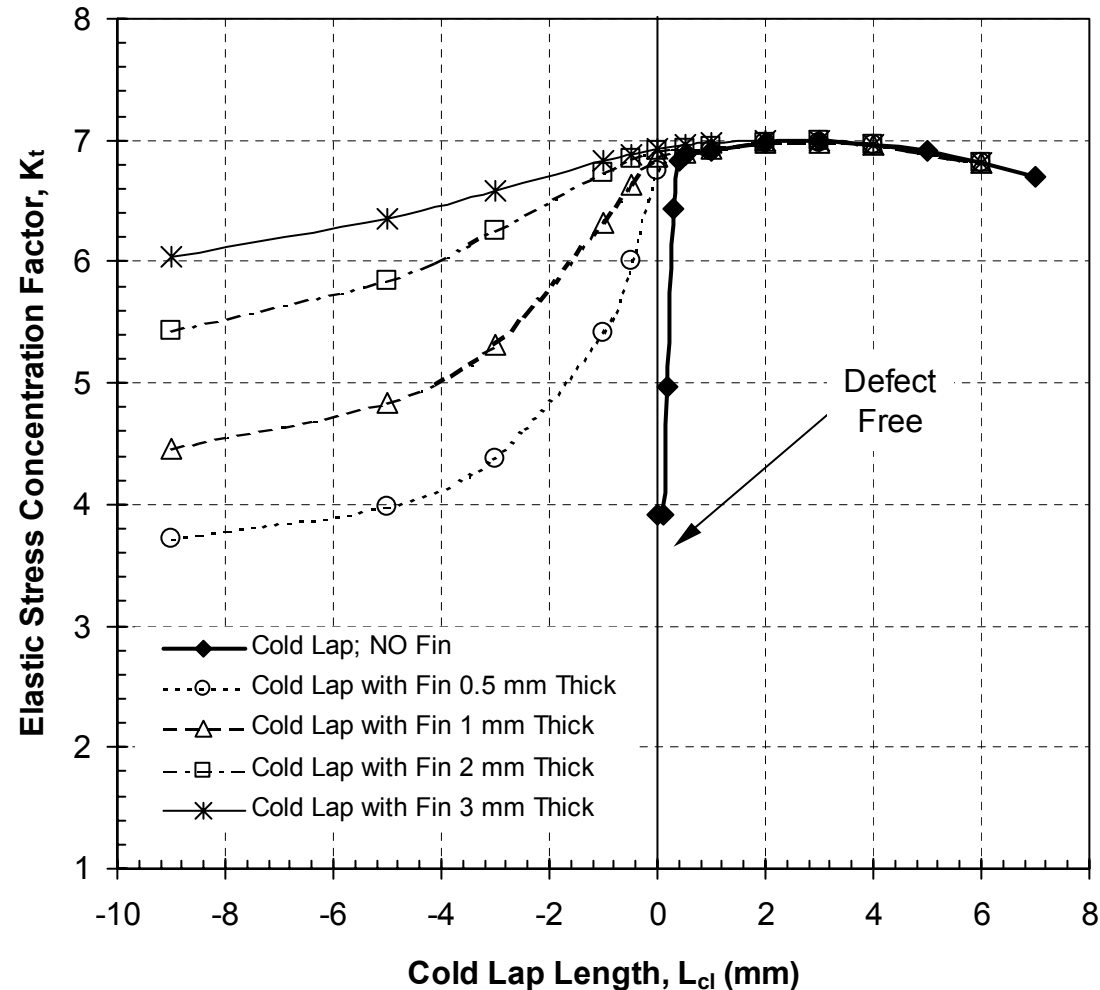


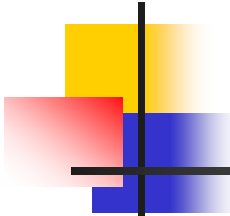
Effect of Fins and Cold Laps

Stress analysis of defects using FEM



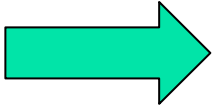
Fins usually fuse to the rail some distance beyond the toe. This is a negative cold lap ($-L_{cl}$).





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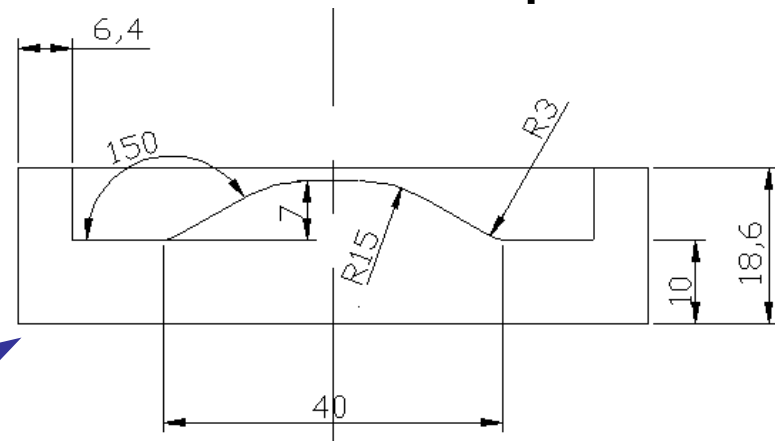


Creation of an Improved Weld

Mold pattern modifications

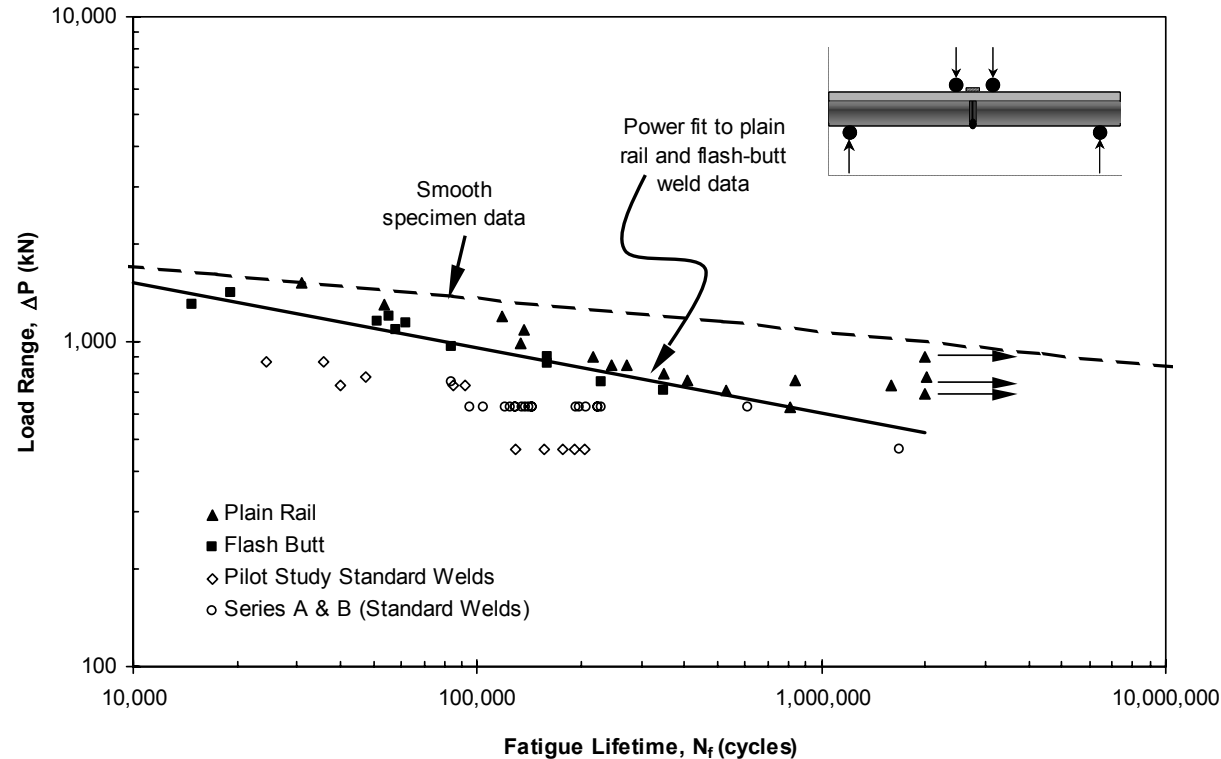
- Use of a 3-piece mold was deemed necessary to avoid fins
- Modified a mold pattern for a Series B weld
 - $R = 3 \text{ mm}$
 - $\theta = 30^\circ$
- Created a pattern for the base mold piece

Section through
the base
(dimensions in
millimeters)



Baseline Tests

- Performed tests on standard welds
- Accumulated published data for 4-point bend fatigue tests of rail and rail welds



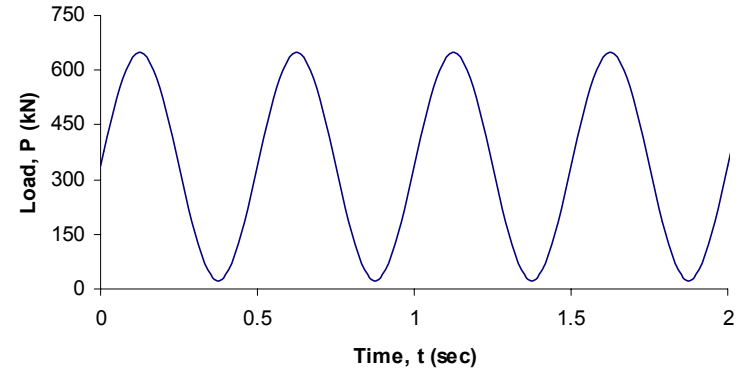
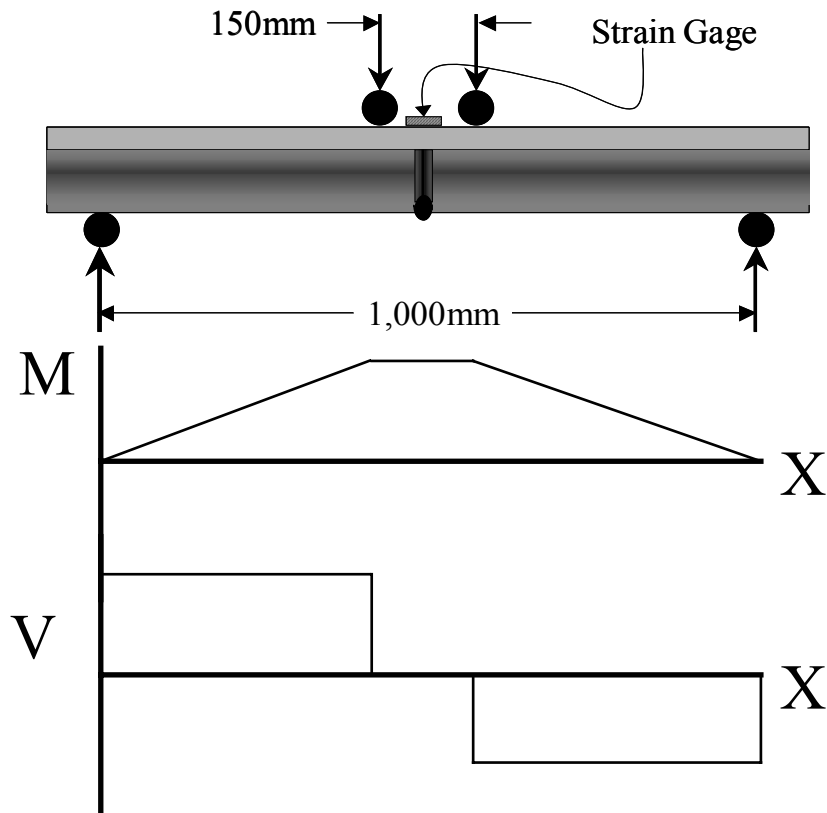
Flash-butt weld and plain rail data courtesy Dr. Gary Fry (TAMU) and Joe Kristan (TTCI)

Smooth Specimen data: Park & Fletcher, 1982 "Fatigue Behavior and Fracture Toughness of Standard Carbon and High Strength Rail Steels," 2nd International Heavy Haul Railway Conference Proceedings.

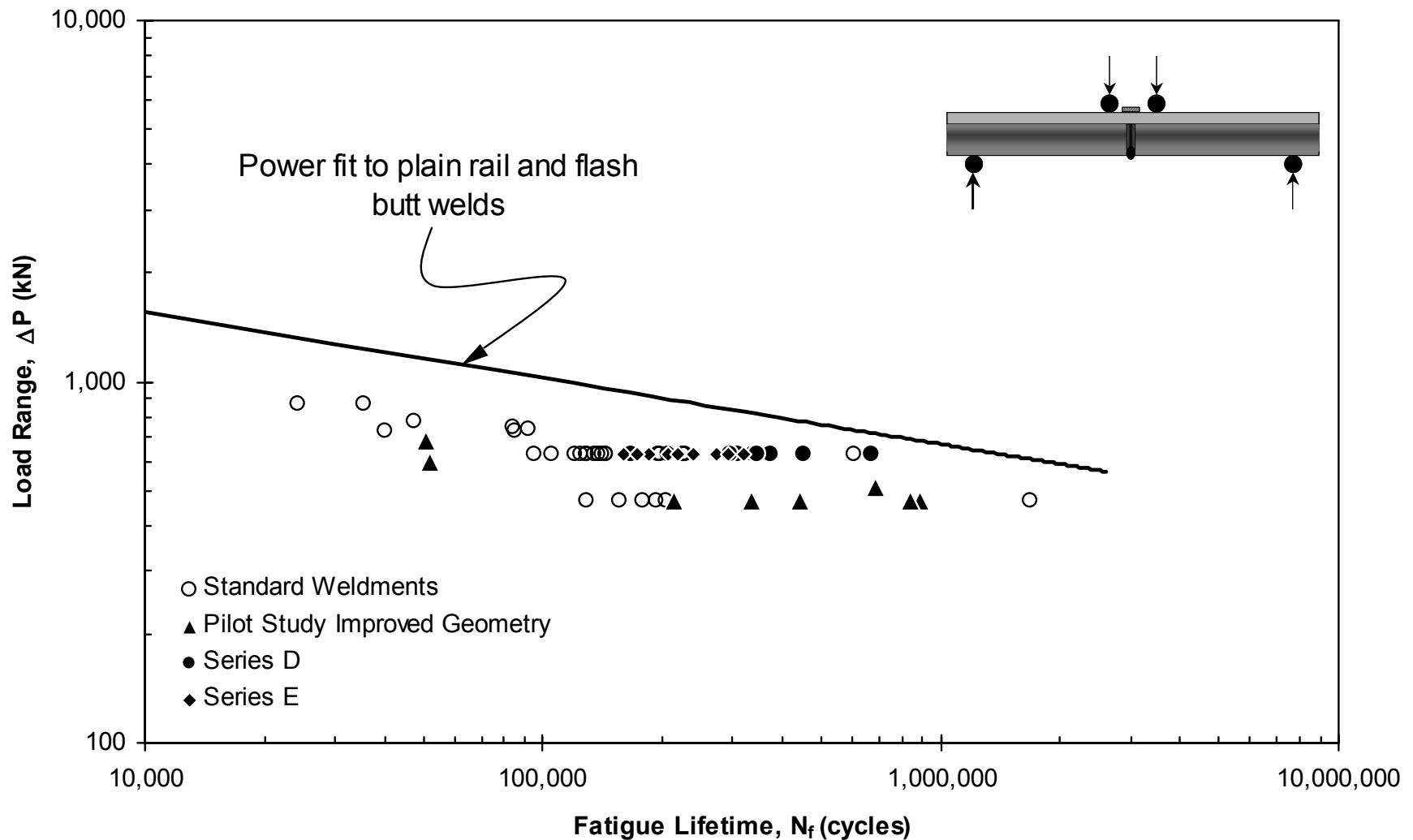
Testing – Experimental Setup

Servohydraulic load frame running
in load-control

Load Range = 628 kN in all Cases



Test Results – Load vs. Life



Linear Presentation of Results

HSR-24

Pilot Study Improved

Pilot Study Standard

Plain Rail

Flash Butt

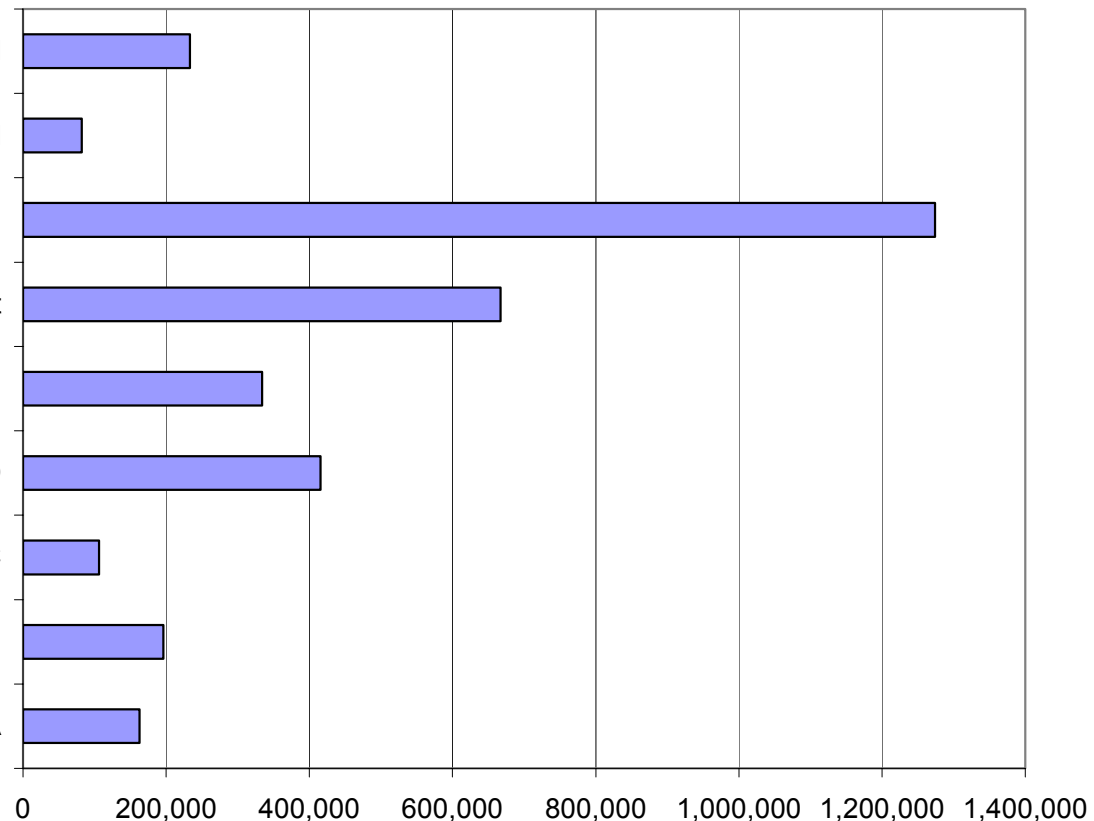
Series E

Series D

Series C

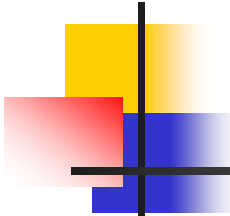
Series B

Series A

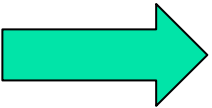


Average Fatigue Life, Nf (cycles)

All results interpolated to a load range of 628 kN

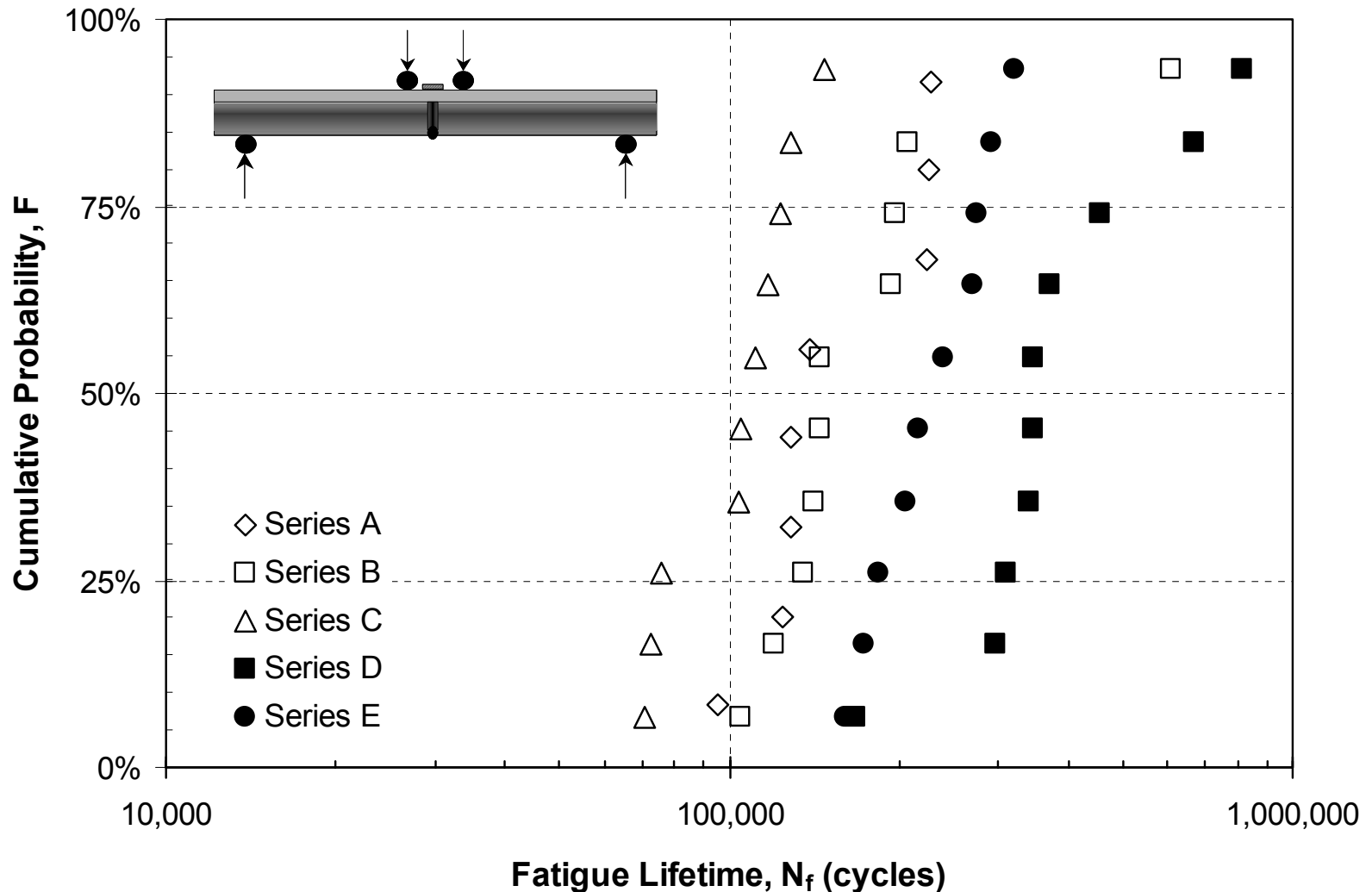


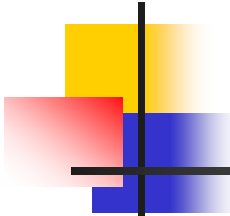
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Test Results – Statistical Analysis

All tests carried out at a load range of 628 kN

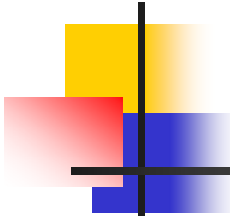




Test Results – Statistical Analysis

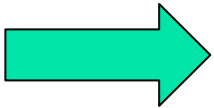
- Series D is has an average fatigue life $\approx$ 2.5 times that of Series A
- Series A and B are similar
- Series C and E performed below expectations

Series	Lognormal Distribution Parameters		Fatigue Life 95 % Confidence Limits	
	Mean, $E(N_f)$	Standard Deviation	Lower	Upper
A	162,985	56,435	121,980	194,460
B	195,926	103,008	127,678	235,546
C	106,170	27,682	87,637	120,434
D	415,316	191,717	287,160	495,152
E	234,522	56,097	197,064	263,994



Outline

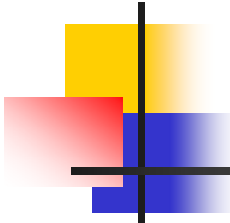
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TTCI Testing

- Testing interrupted due to an unexpected failure mode.





Summary

- Results confirm that fatigue life of thermite welds can be much improved by altering the weld toe geometry.
- Model study confirms experimental results.
- Fins probably only important for improved welds.
- Residual stresses important variable.