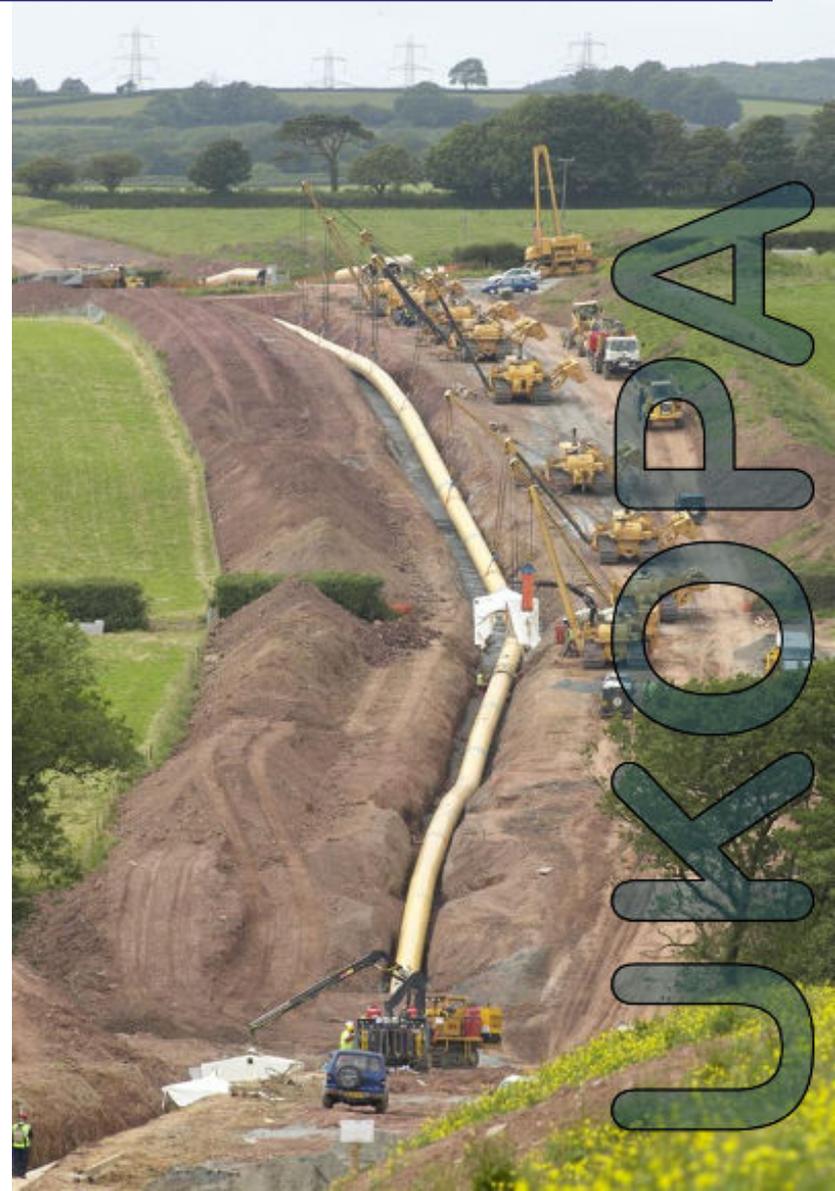


FATIGUE ASSESSMENT OF HISTORIC WELD DEFECTS IN PIPELINES

Joe York-Fisher

MSc

Supervisors: T. Rudd,
R. Johnston, E. Sackett





EPSRC

Engineering and Physical Sciences
Research Council



Background

- Vintage welds (pre-1972) assumed to be “poor quality”, yet relatively few faults
- Conservative assumptions and high safety factors
- Previous research:
 - Do not meet modern standards
 - Passed all metallurgical and mechanical tests (fatigue not tested)
 - Potentially fit for continued service
 - No Faults since 1993

Project Aims

- Assess whether current historic pipelines need to be replaced/deserve their current safety factor
- Discern key types of defects that pose the greatest danger to the fatigue life
 - Overview potential threats to fatigue life

Method

- Leftover sections from previous investigation
- X-ray radiography to locate/identify defects
- Fatigue test using “in-service” stress profile
- Analysis:
 - E-curve, microscopy, SEM/EDS, CT-Scans, FEA
- Conduct investigation in a conservative manner

Literature Review Conclusions

- Other international investigations show evidence that a safety factor of 10 is not necessary
- Expected that external macro defects would have the biggest impact
- Factors that could explain the longevity:
 - Weldment overmatching
 - Relaxation of residual stresses from cyclic loading
 - Rounded pores/inclusions impeding crack propagation

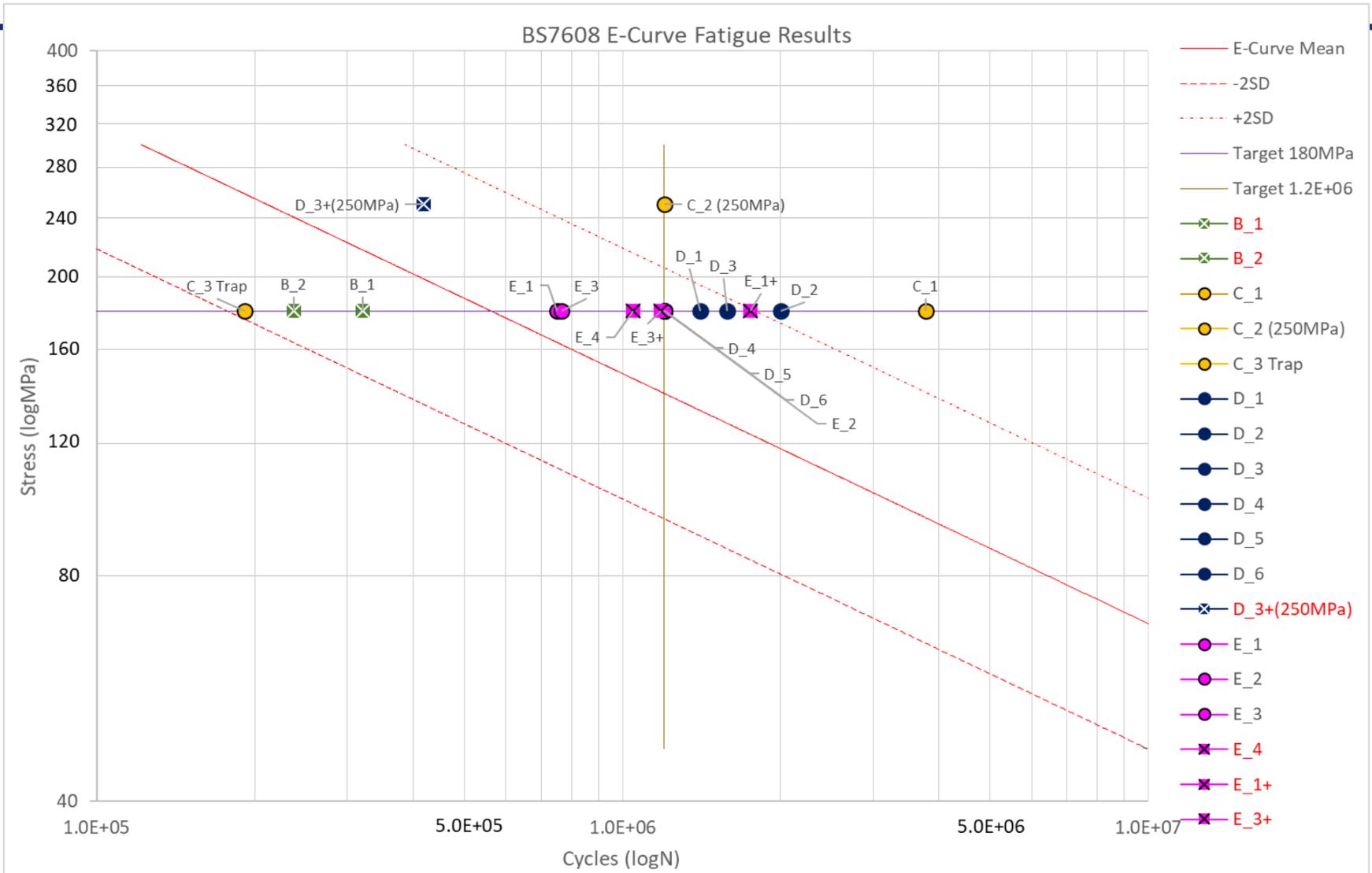
Results: Defect-Sample Comparison

External Defects	Sample												C_1	C_2	C_3		
	D_2	D_1	D_3	D_4	D_5	D_6	B_2	B_1	E_4	E_3	E_2	E_1					
Lap																	
LOP (mm)			9.60			20.60	24.00	24.00	22.40					24.00	24.00	24.00	
SB																	
RU																	
CU																	
Off (mm)							1.45	1.69	1.00								
MV (mm)									0.04	0.92	1.74	1.19					
PCP																	
ExC (% Ex)			26%	31%					34%								
Exp																	
BT (mm)								12.17									
Spa																	
PSS (mm)								11.35									
ICF																	
Internal Defects	All Measurements Approximated																
Por (No.)							3	1	10				3				
CPo																	
IFu (mm)			1.00	5.00									1+3.3				
CrL (mm)		4.00		2.00			3.00		8.00								
CrT (mm)							1.55		11.00	1.54							
Wor (mm)				4.00				1.00					3.00				
Inc																	
Total Defects	3	2	7	5	2	3	7	6	11	4	4	5	1	1	1		
Fracture Order at 180MPa							1st	2nd	3rd	4th		5th					
Final Cycle Count (100k)	20	14	15	12	12	12	2	3	10	12	12	18	12	37	2		

Discussion

- Conservative measures taken included:
 - Stress range from liquid pipeline
 - Hoop stress applied axially
 - Focus on largest defects
 - Surge pressures tested
 - Dwell fatigue conducted
 - Analysis of results using BS7608 E-Curve

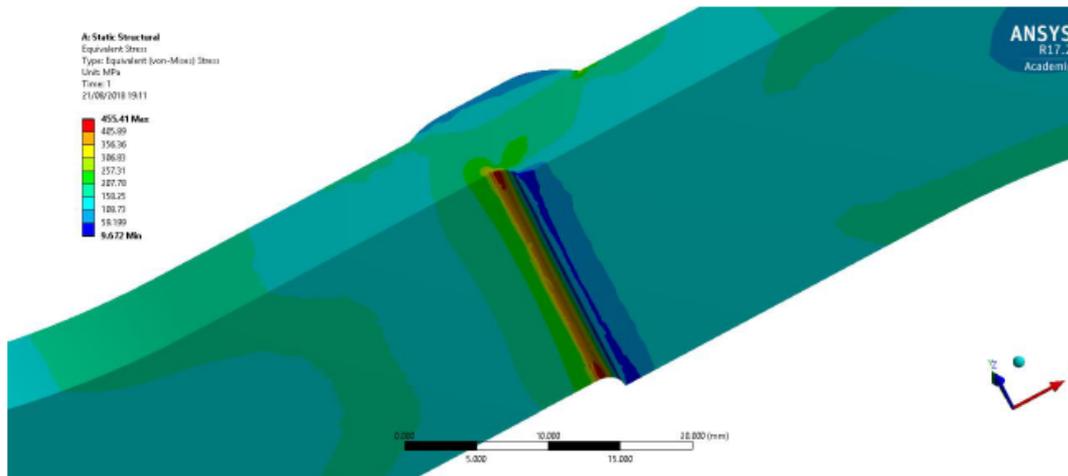
Results: Fatigue



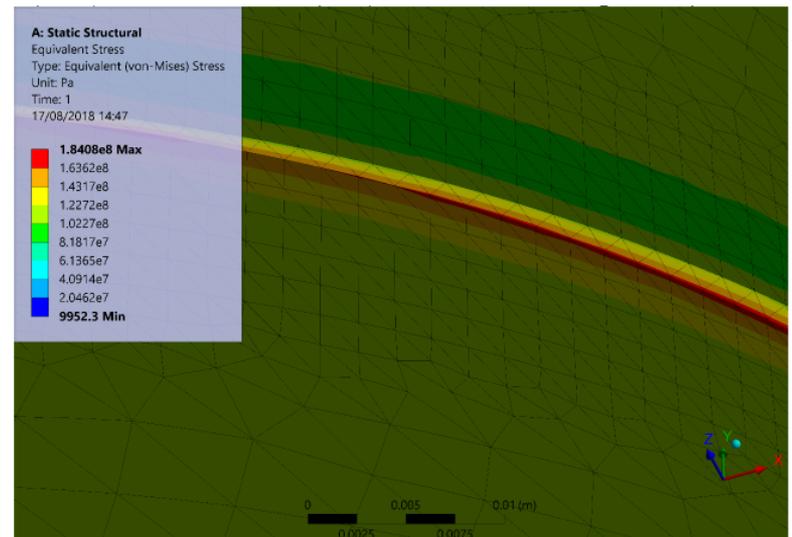
Discussion

- All fatigue results above -2SD 'design' curve
- Only two results fractured below the mean curve; the order of fracture was surprising
- Main defects present in fractured specimens:
 - Misalignment
 - Lack of penetration
- Misalignment produced artificially high stress

Results: FEA



kk) FEA, Stress Concentration (MPa) in Off/LOP Welded Dog-Bone Specimen



ll) FEA, Stress Concentration (Pa) in Off/LOP Welded Pipeline Specimen

Discussion: Fracture Surface

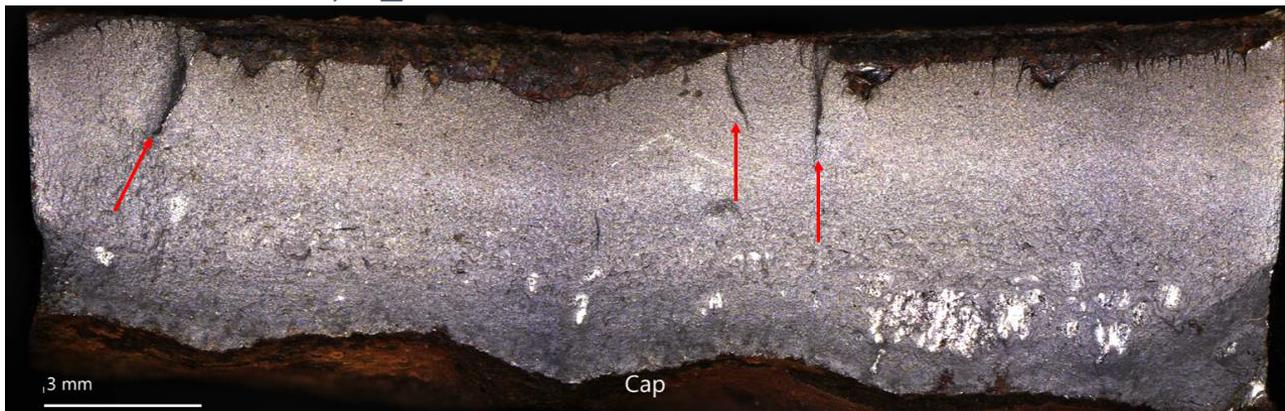
- Ratchet marks indicated that none of the initiations occurred internally or artificially
- Internal defects contained expected elements
- Specimen which fractured above mean stress curve, had multiple pores on fracture surface
- The two below-mean fractures had no signs of internal defects on the crack propagation path

- Wormholes easily mistaken for pores

Results: Microscopy Ratchet Marks

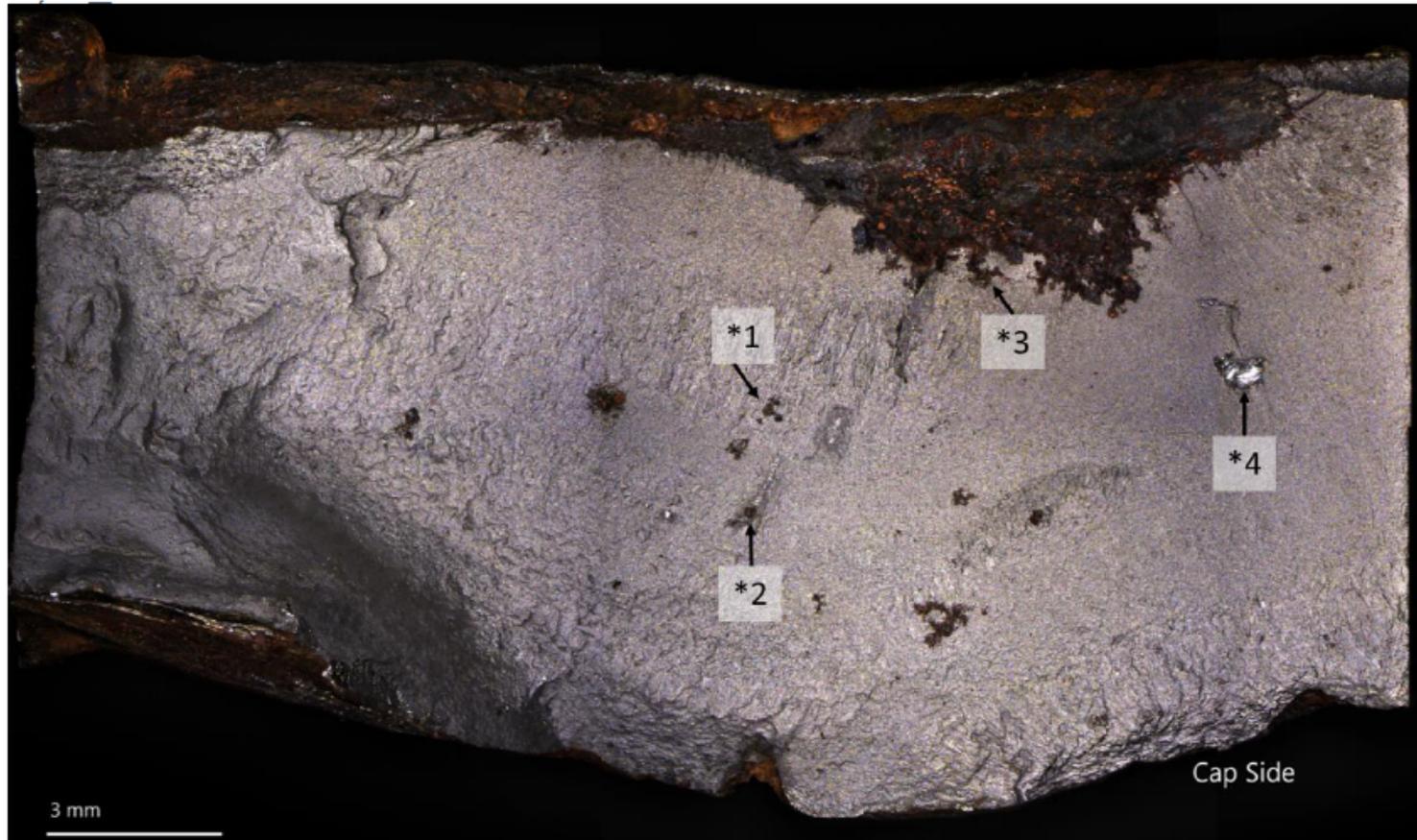


t) B_1 Fracture Ratchet-Mark Locations



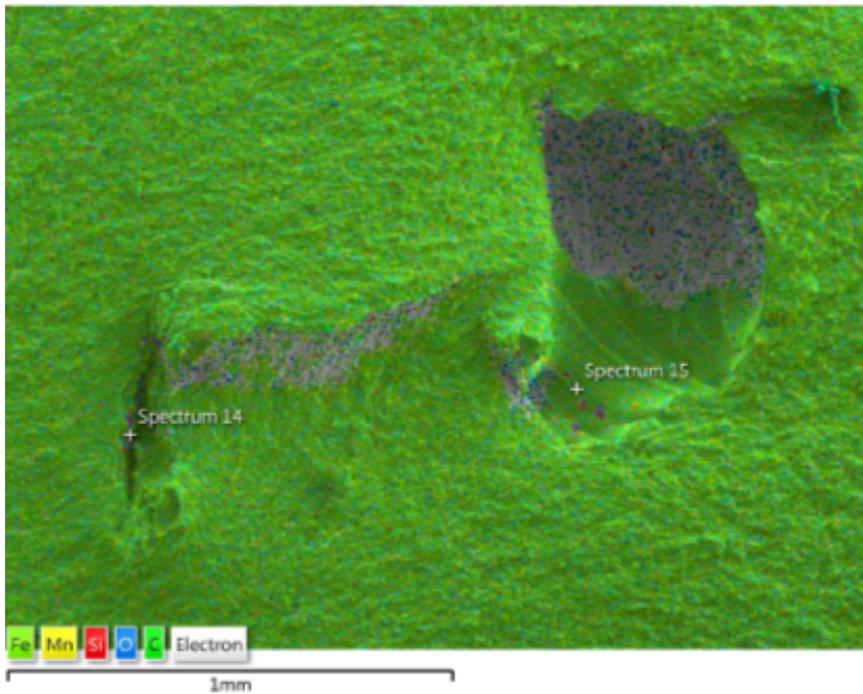
u) B_2 Fracture Ratchet-Mark Locations

Results: SEM/EDS Internal Defects

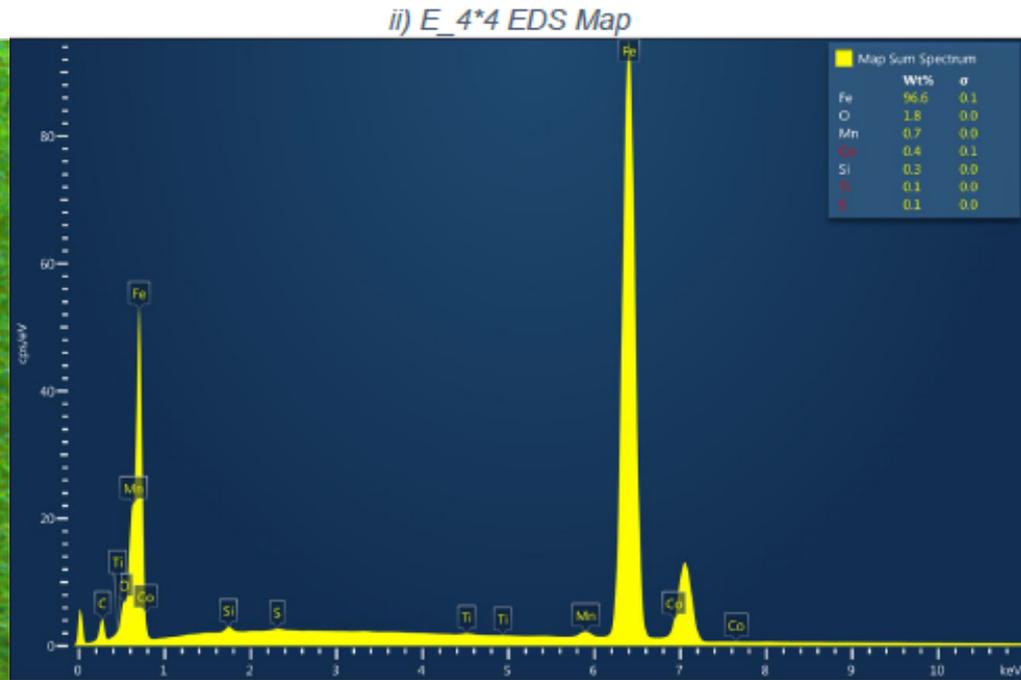


x) E_4 Fracture Internal Defect EDS Locations

Results: SEM/EDS



ii) E_4*4 EDS Map



jj) E_4*4 EDS Map Spectrum

Results: SEM/EDS

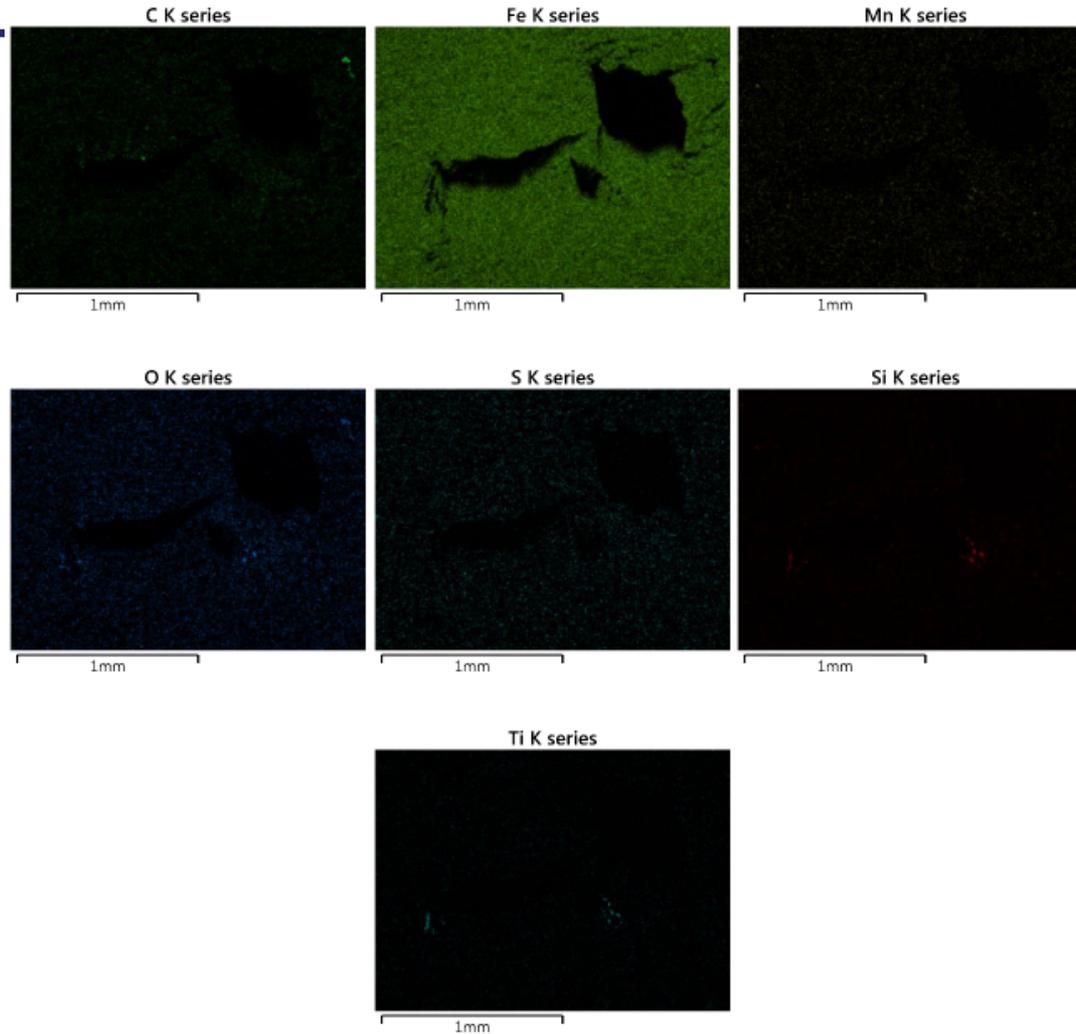
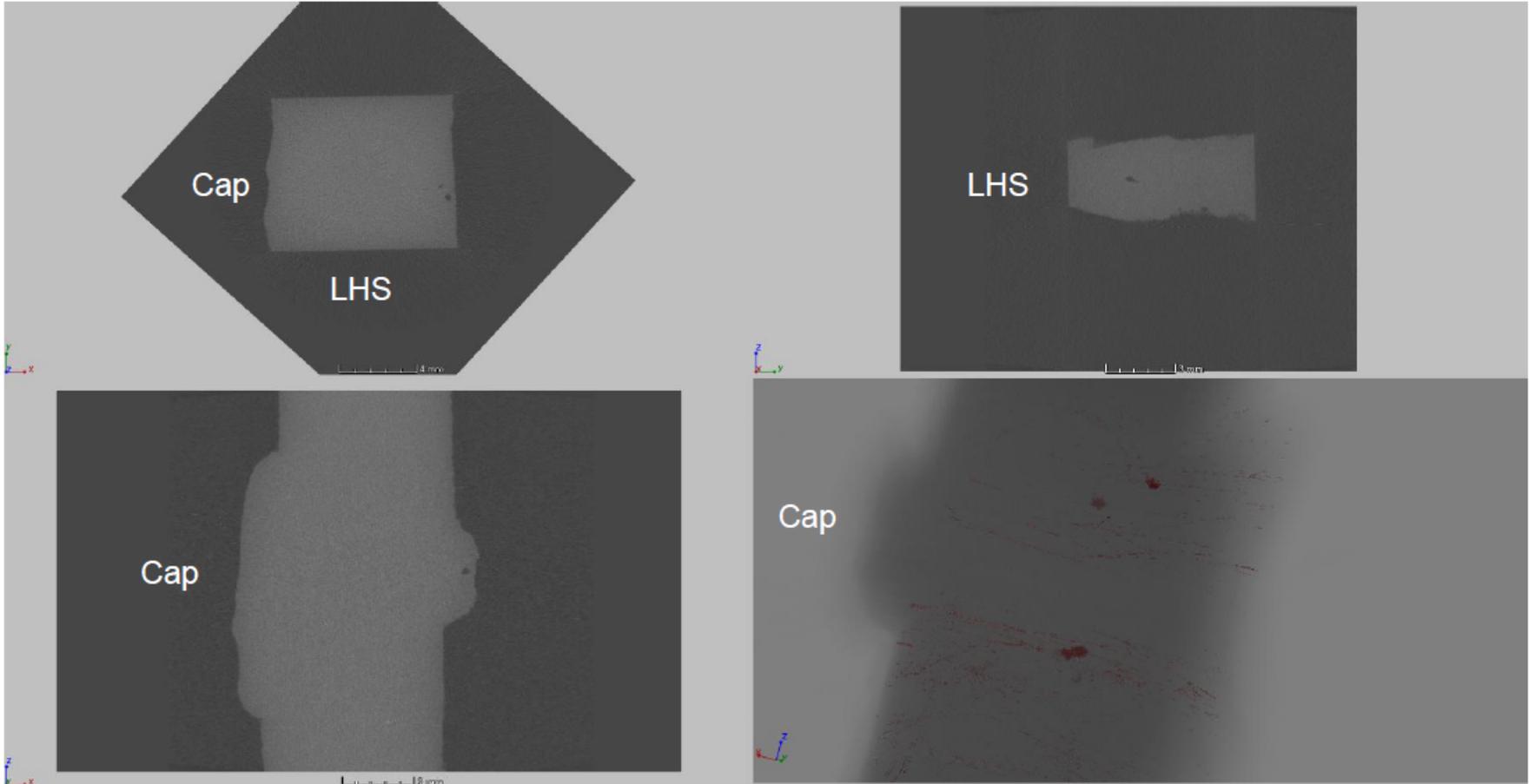


Figure 4.22 EDS map element overlay, specimen E_4, location *4

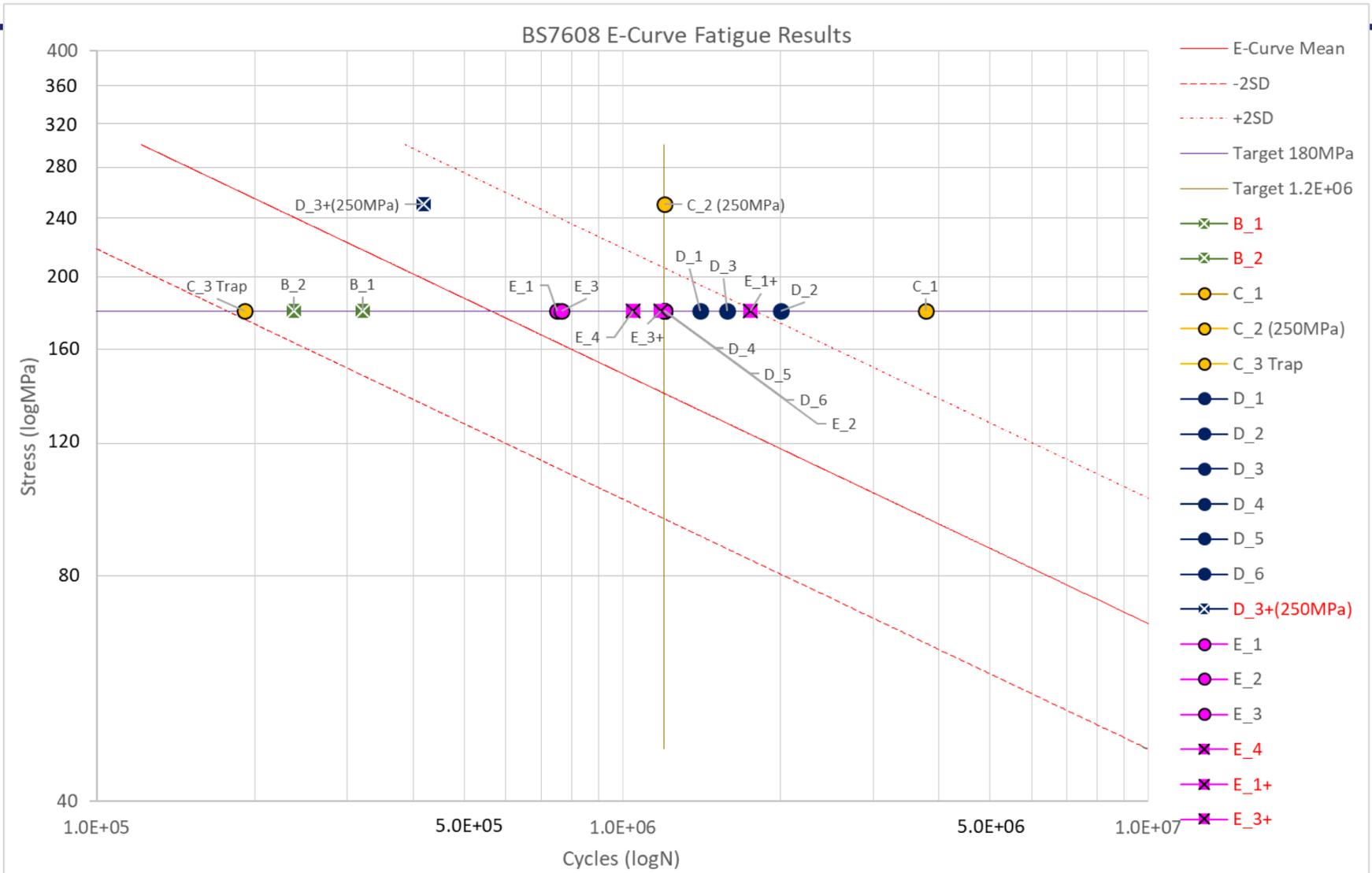
Results: CT-Scanning, Worm Hole



Discussion: Three Extra Tests

- Extra tests:
 - Two to explore milling variation
 - One to consider surge pressures
- All fractured above mean stress curve
- Surge test of approx. +40% stress, conducted on the most defected surviving specimen;
 - Surge fatigue life fractured above mean stress curve
 - Combined with previous tests puts result above +2SD

Results: Fatigue



Conclusions

- One cycle represented approximately one day, therefore with a safety factor of 10 applied:
 - 95% probability that heavily defected X52 pipelines will last at least another 49 years
 - Most results above mean curve ~ 156 years
- Most significant defects are external and visually obvious

Possible Future Work

- Further research into effects of individual and combinations of defects
- Future projects including misalignment should take steps to mitigate excess stress, e.g. rigs that can misalign their grips
- Laser-speckle/digital image correlation tests
- Investigate internal defect interaction:
 - 1Hz. Frequency, for beach mark interaction
 - Use of in-situ tensile/CT-scanning systems
 - Synchrotron Diamond Light Source, for rapid analysis

Thank You For Your Time

Any Questions?