FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT EA08
RESEARCH GROUP LABORATORY SOETE

HYDROGEN EMBRITTLEMENT IN PIPELINE GIRTH WELDS

EXPERIMENTS AT DIFFERENT LENGTH SCALES

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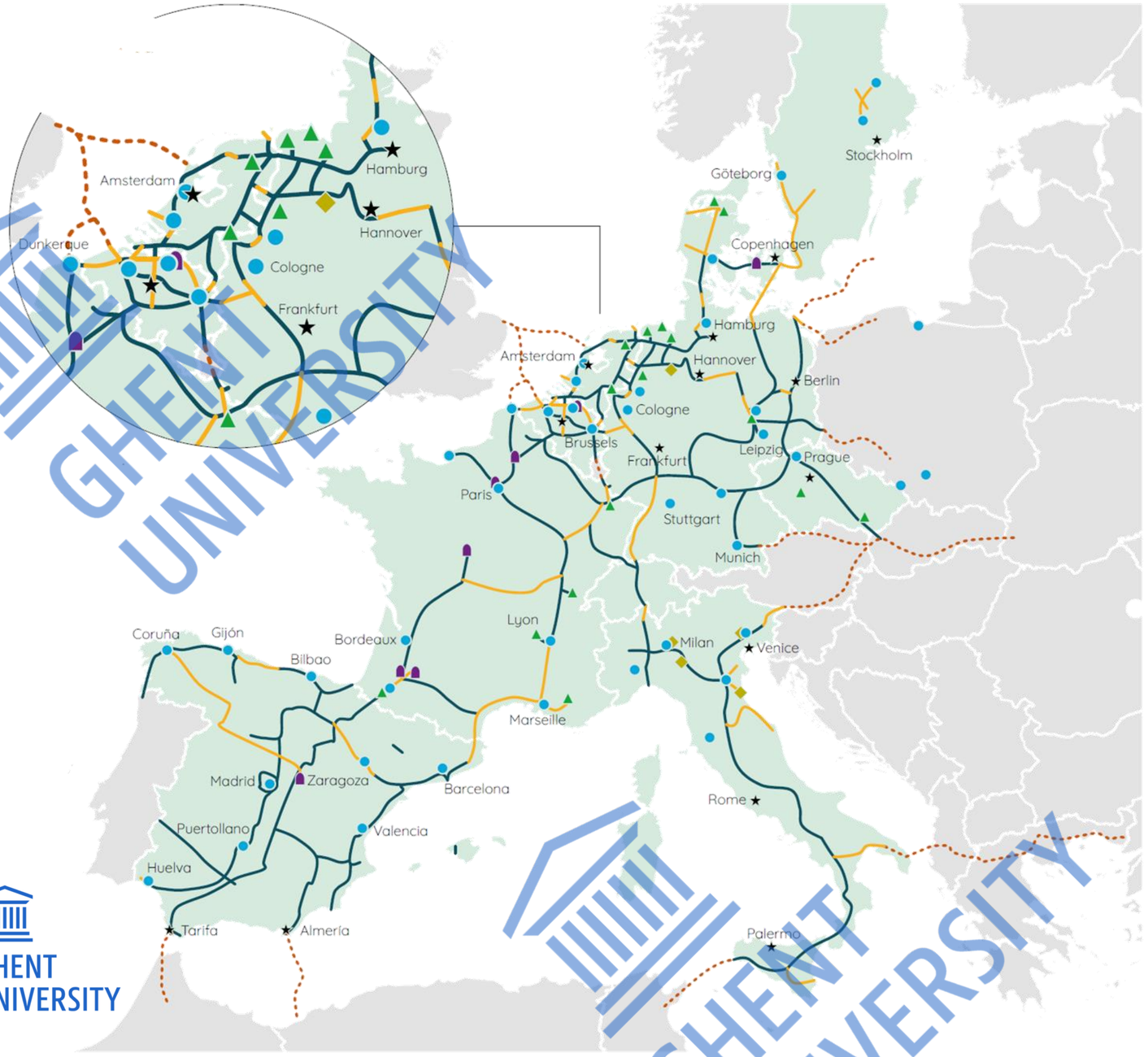
SMS SUSTAINABLE MATERIALS SCIENCE

Research funded by

economie fluxys

Plans for European hydrogen pipeline network by 2040



- H_2 pipelines by conversion of existing natural gas pipelines
- Newly constructed H_2 pipelines
- Possible additional routes
- Countries within scope of study
- Countries beyond scope of study
- Potential H_2 storage: existing / new salt cavern
- Potential H_2 storage: Aquifer
- Potential H_2 storage: Depleted field
- Industrial cluster
- City, for orientation purposes (if not indicated as cluster already)

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Can the existing pipelines be reused for hydrogen purposes?

Mechanical behaviour

Guidelines, standards and regulation

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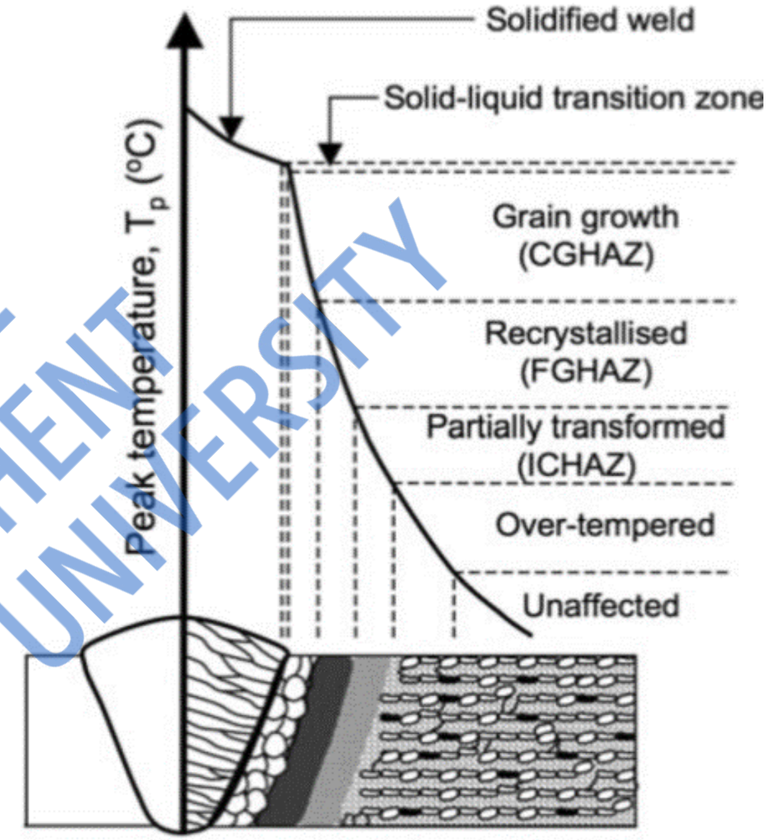
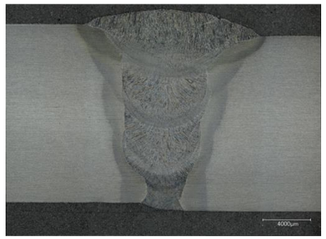
HAZ: a fragile zone in the pipeline grid with its challenges





15mm

Presence of imperfections

Small zone

Different materials and microstructures

→ mechanical characteristics

→ hydrogen concentration

→ hydrogen sensitivity

→ …

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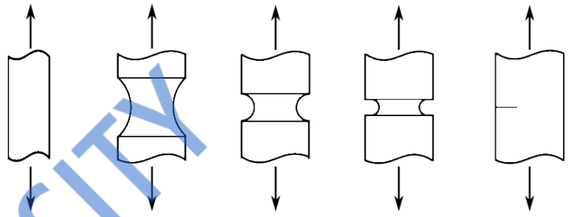
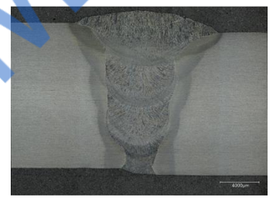
Strategy combining experimental & numerical research

Mechanical testing

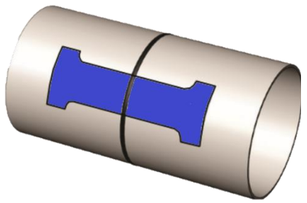
Tensile and toughness



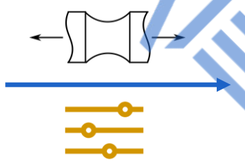
Welds

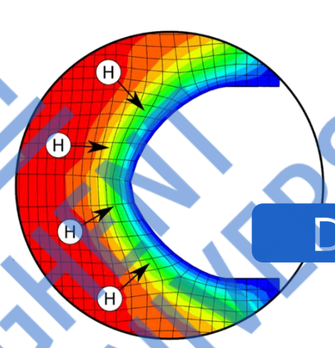


Scale effects

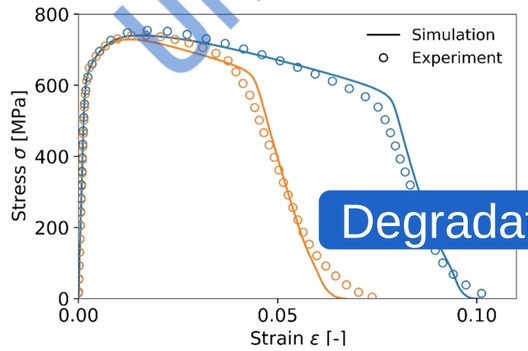


Numerical simulation

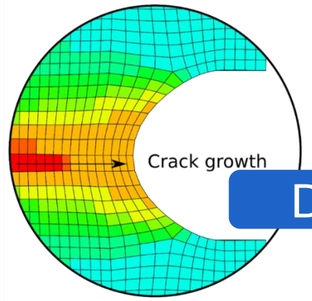




Diffusion



Degradation



Damage

Prediction for fitness-for-service

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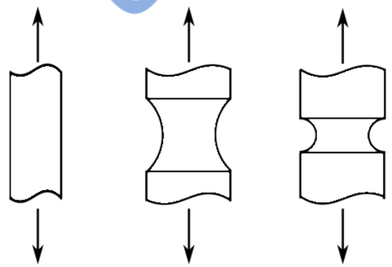
Tensile tests for calibration of mechanical parameters

Specimens

Materials

- Base materials (L485MB)
- Seam and girth welds
- HAZ of welds

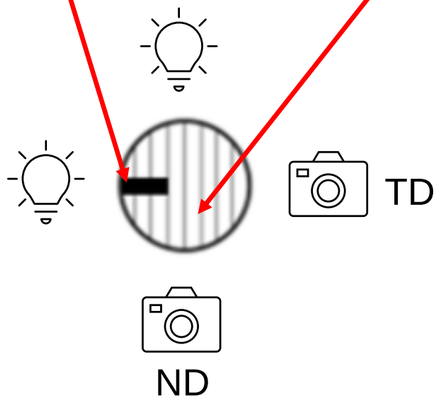
Range of stress triaxialities



Set-up and test

Mark of direction

Test specimen



Ex-situ

Electrochemical charging

18h in 0,5M H_2SO_4 incl. 1 g/l thiourea

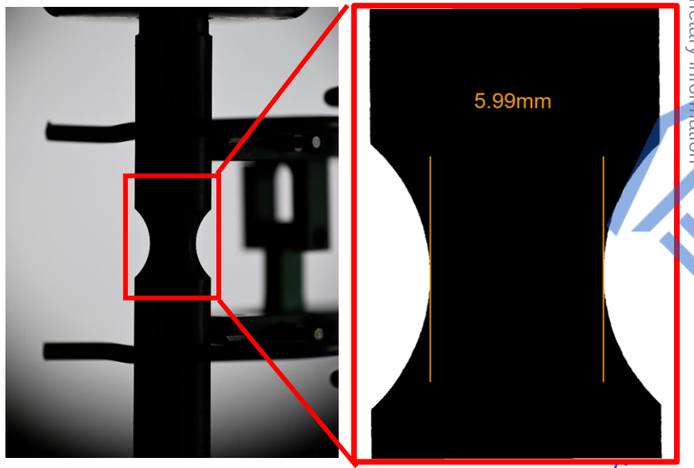
at 0,8mA/cm²

Strain rate = $2,5*10^{-4}$ /s

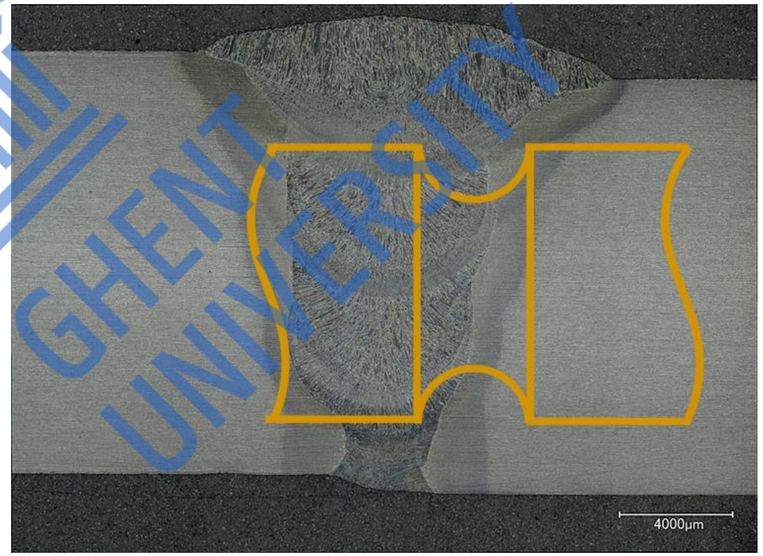
Data acquisition

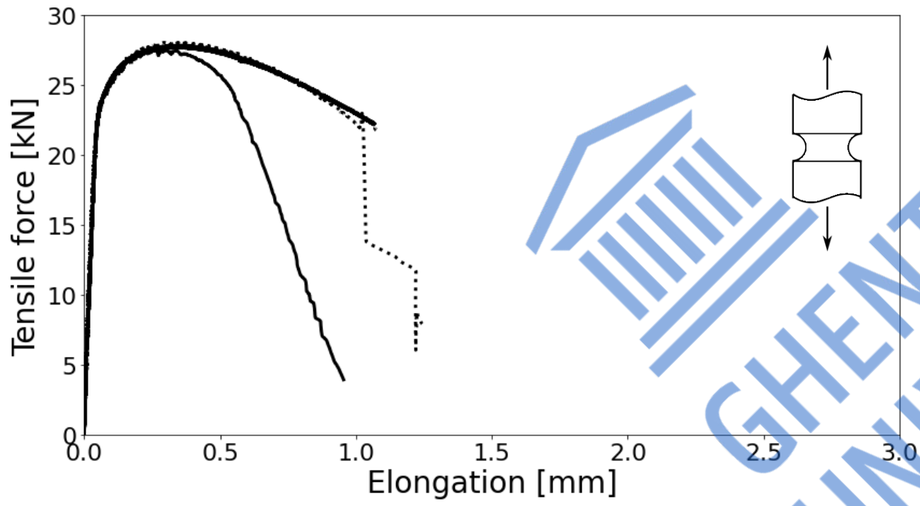
Elongation

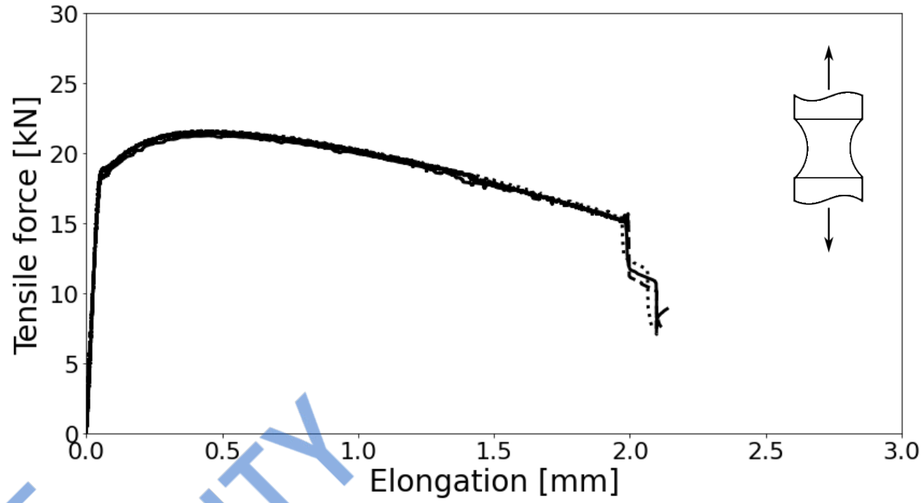
Optical Diameter Reduction



Option 1: Position notch in the HAZ







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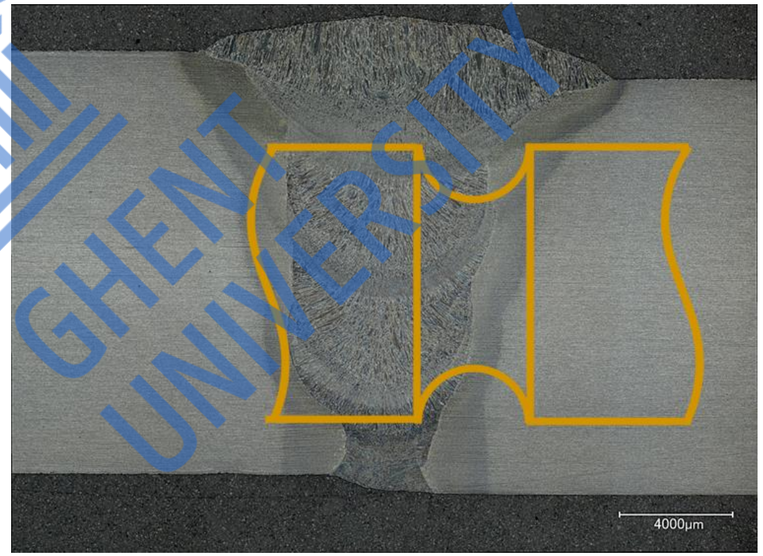

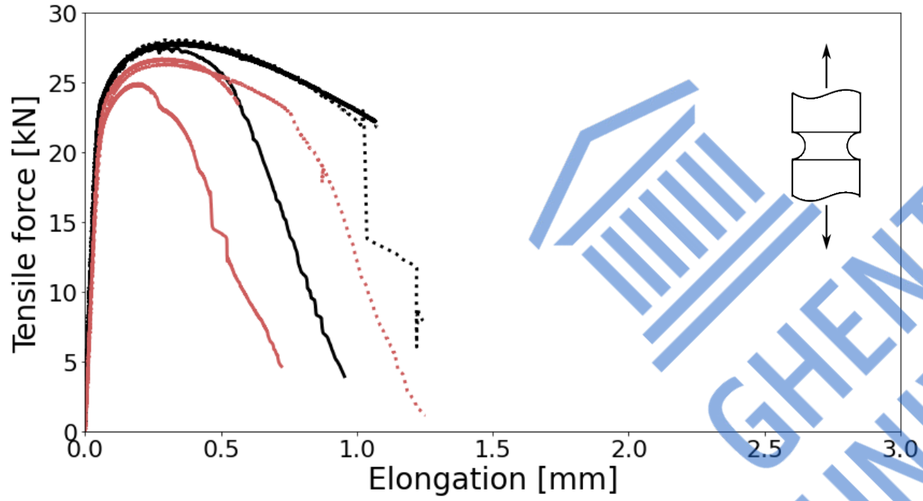

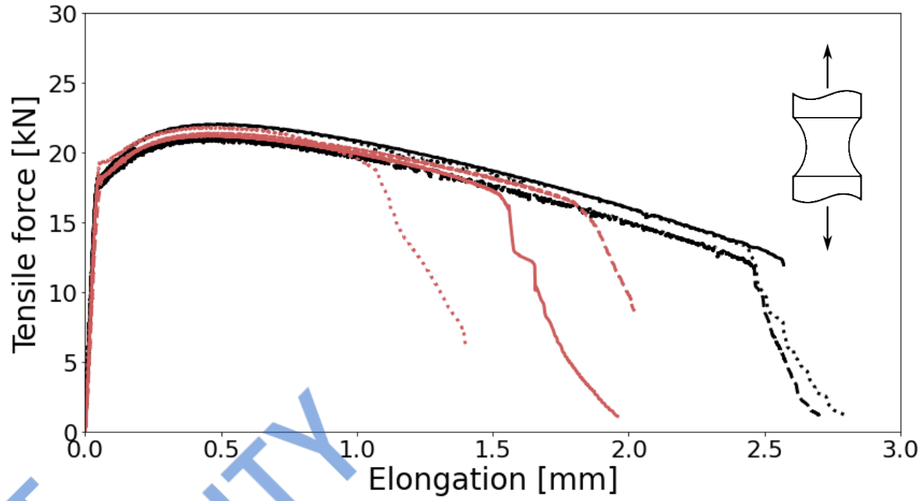

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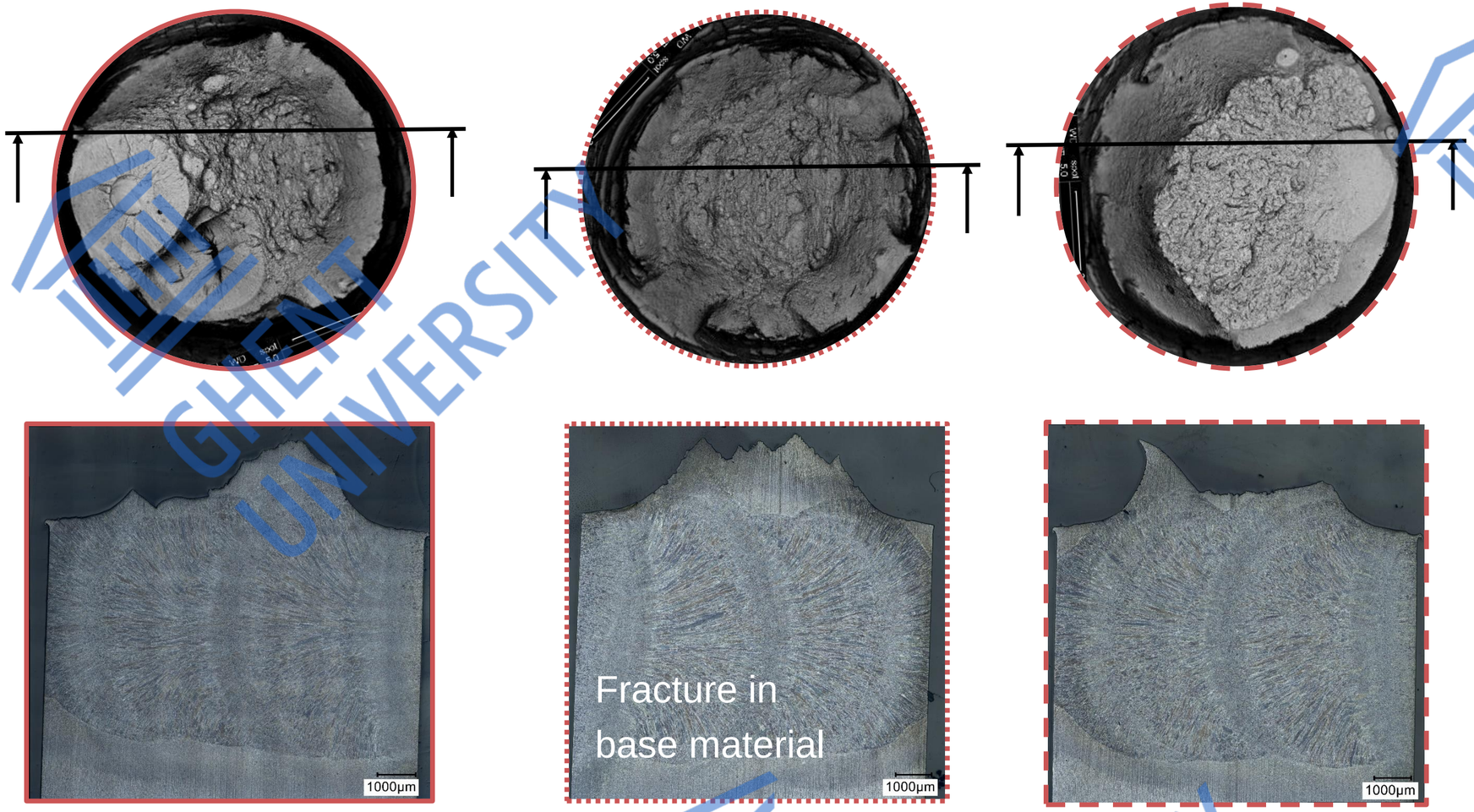
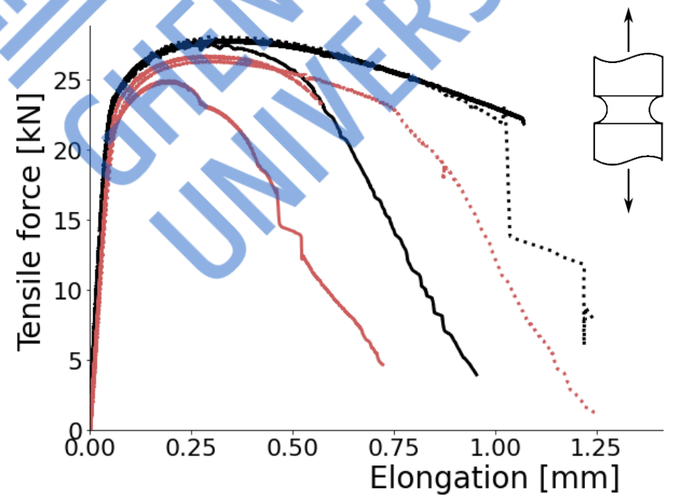
Crack does not follow one single microstructure





Air

Hydrogen

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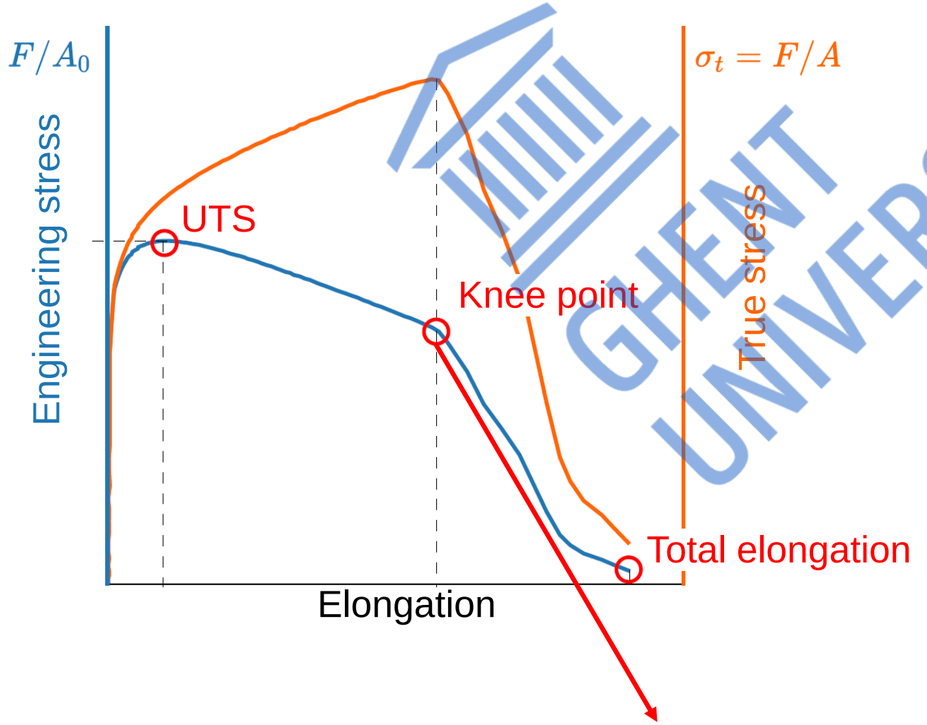
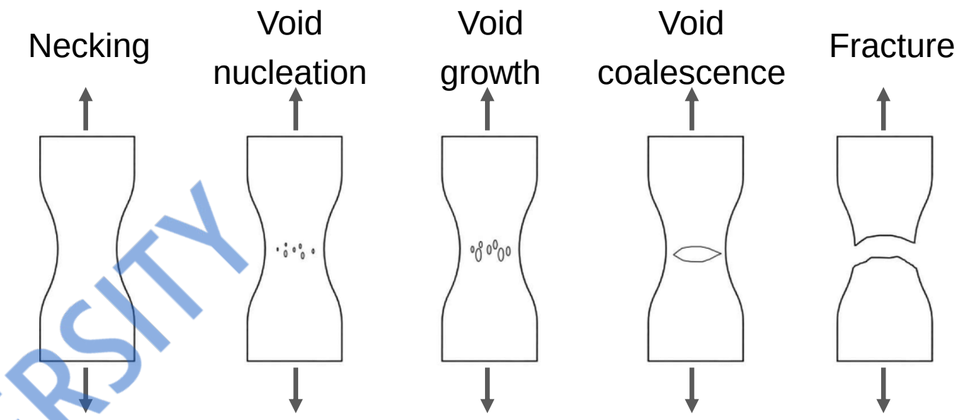
Compare behaviour by embrittlement indices at differents points of ductile failure

Hydrogen embrittlement index

$$EI = 100\%(1 - \frac{X_{hydrogen}}{X_{air}})$$





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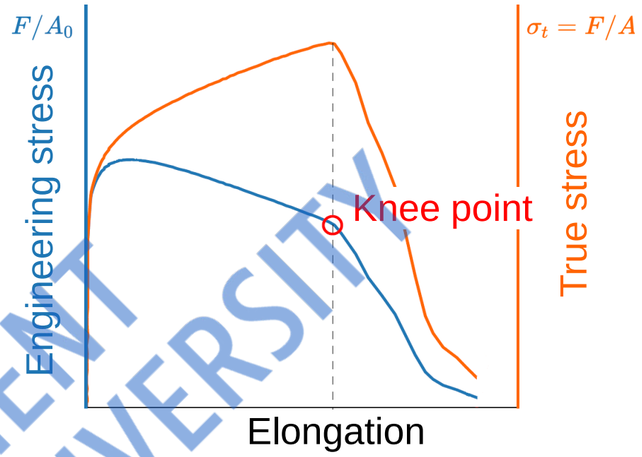
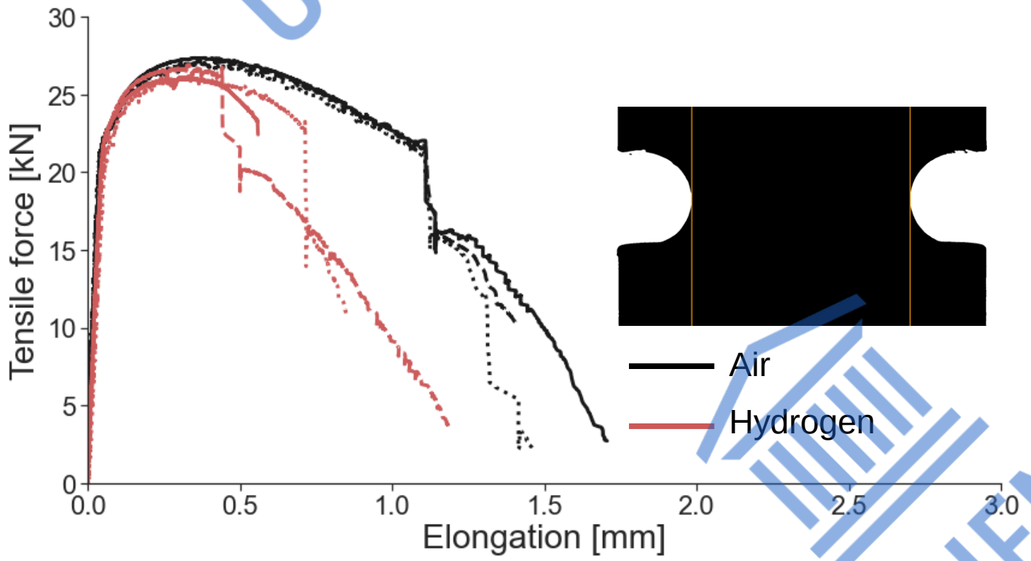
Importance of EI at the knee point

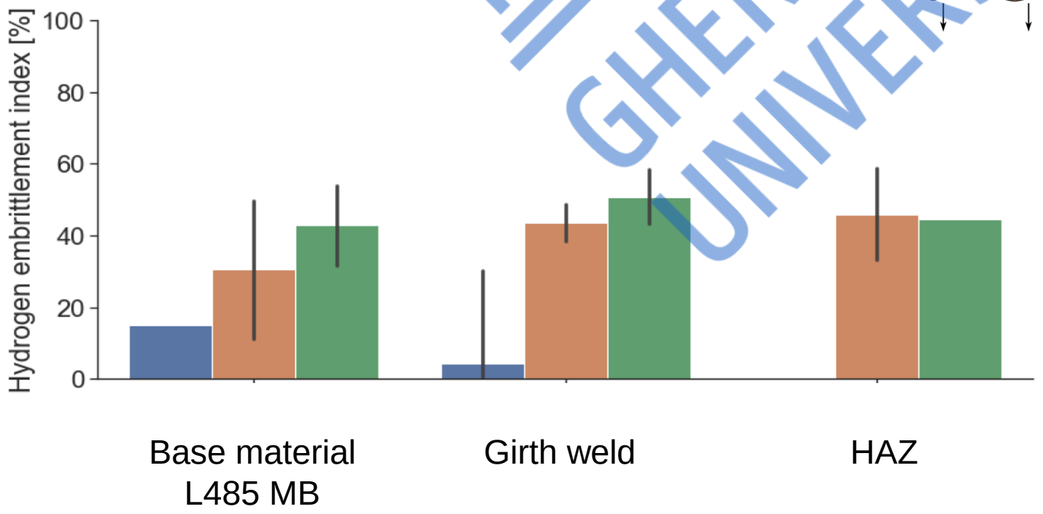
Indication of void **coalescence**



Delaminations in specimens

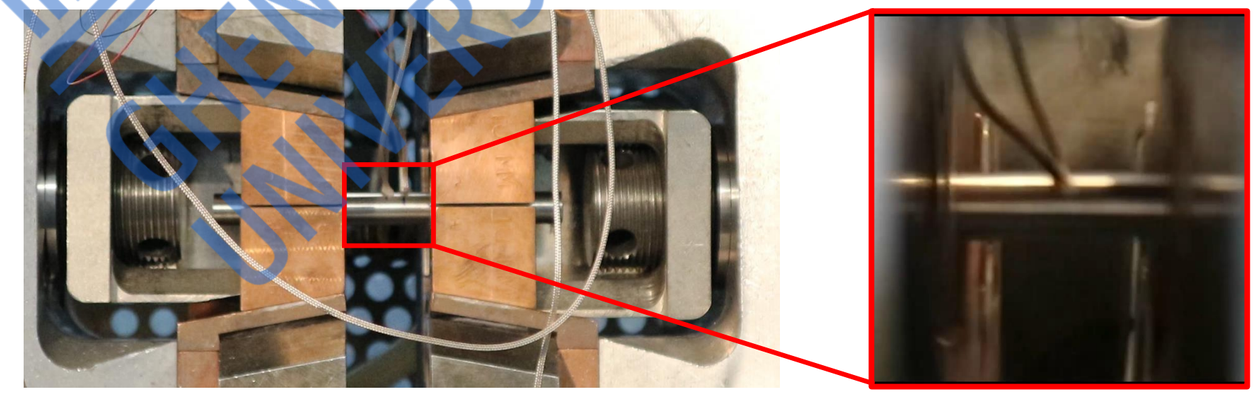


EI of elongation at knee point

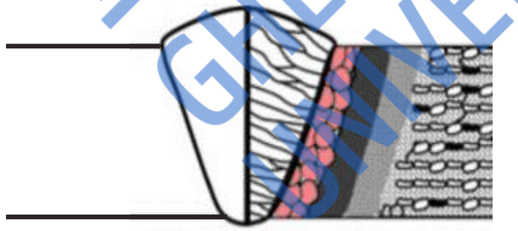


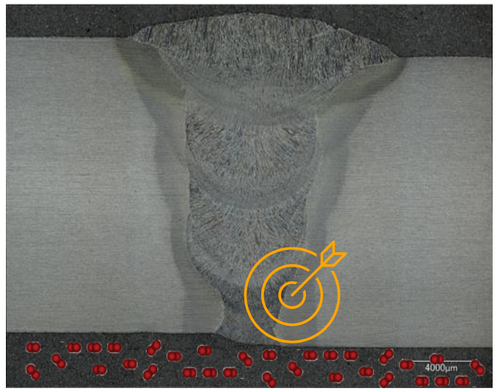
Option 2: Recreate a homogeneous microstructure

Controlled heat treatment
on base material



Coarse grain heat affected zone of girth weld
Between root pass and hot pass





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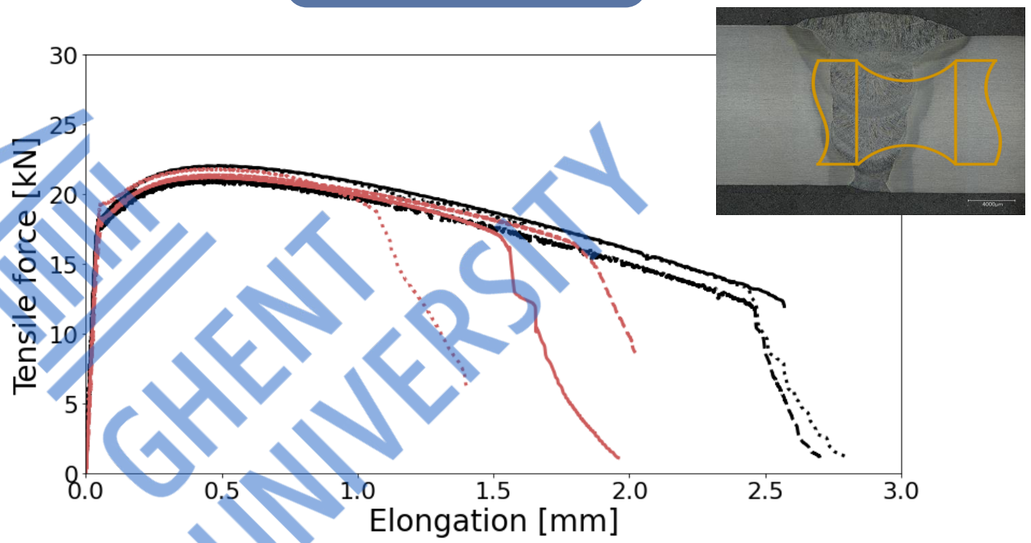
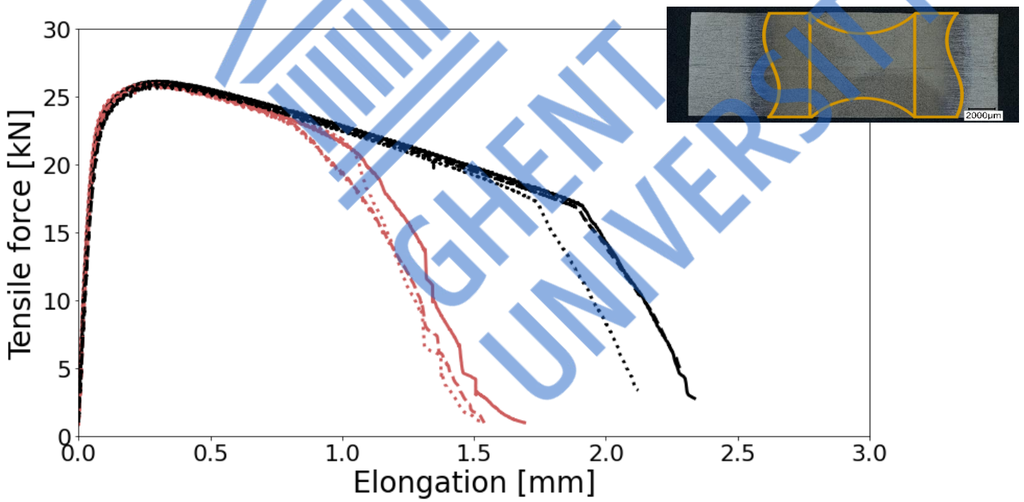
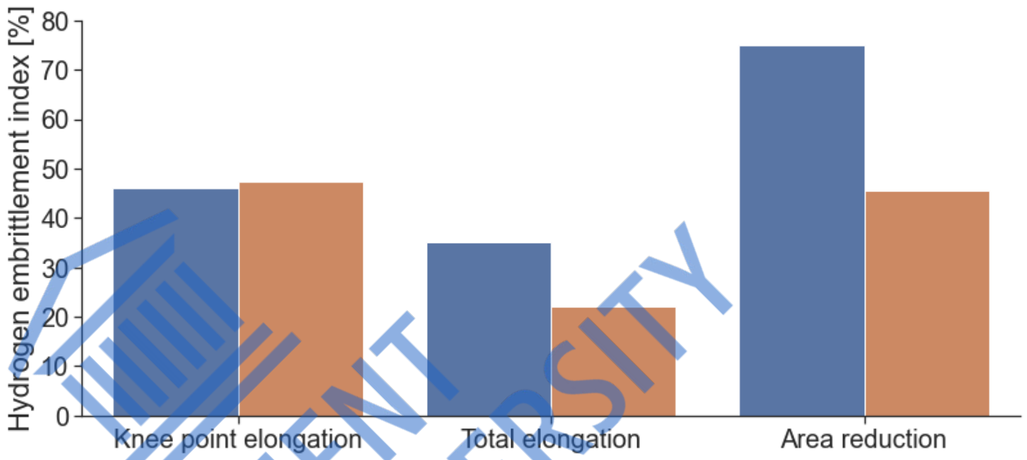
Comparison of the two options

1. Real HAZ



2. Recreated HAZ





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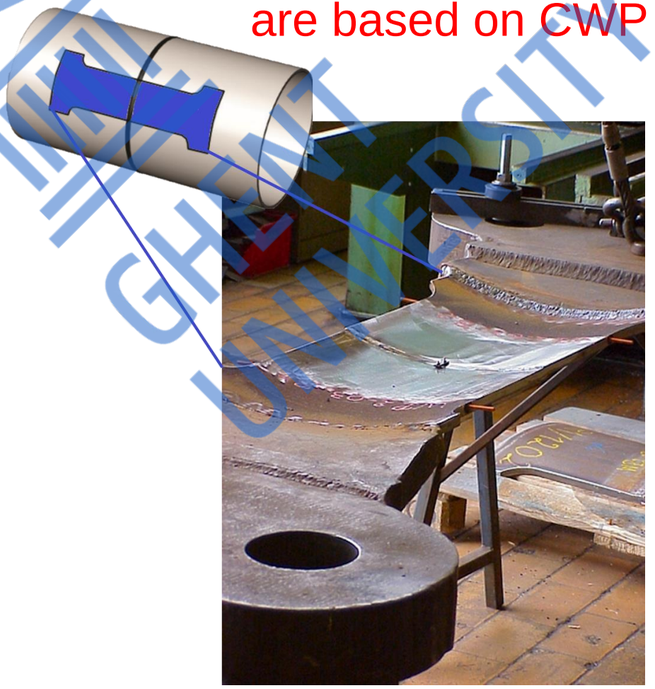
Flaw assessment guidelines need an update for hydrogen use

Type of requirement		Tier 1[A]	Tier 2	Tier 3[B]
Geometry	Wall thickness (t)	7 ≤ t ≤ 25.4 mm wall thickness outside this range by agreement	5 ≤ t ≤ 30 mm	7 ≤ t ≤ 25.4 mm
	Defect height	No requirement	Table 2	≤ 3 mm (single weld run)
	Additional remarks	Surface-breaking non-planar defects should be treated as planar defects		
			Only girth welds between pipes of equal thickness	
Toughness	Charpy and CTOD values for the weld at minimum design temperature	CVN - Average ≥ 40 J CVN - Minimum ≥ 30 J	Sub-size specimen have the required impact energy reduced pro rata with their dimensions	
				CTOD - Average ≥ 15mm CTOD - Minimum ≥ 0.10mm
Strength	Cross-weld tensile tests with weld reinforcement removed	Acceptable if the specimen breaks in the base material or when it breaks in the weld metal with a tensile strength ≥ the specified minimum tensile strength (SMTS)		
	Pipe yield strength Specified minimum yield strength in transverse direction (SMYS)	No limit specified	≤ 555 N/	

Acceptable defect length limits are based on CWP



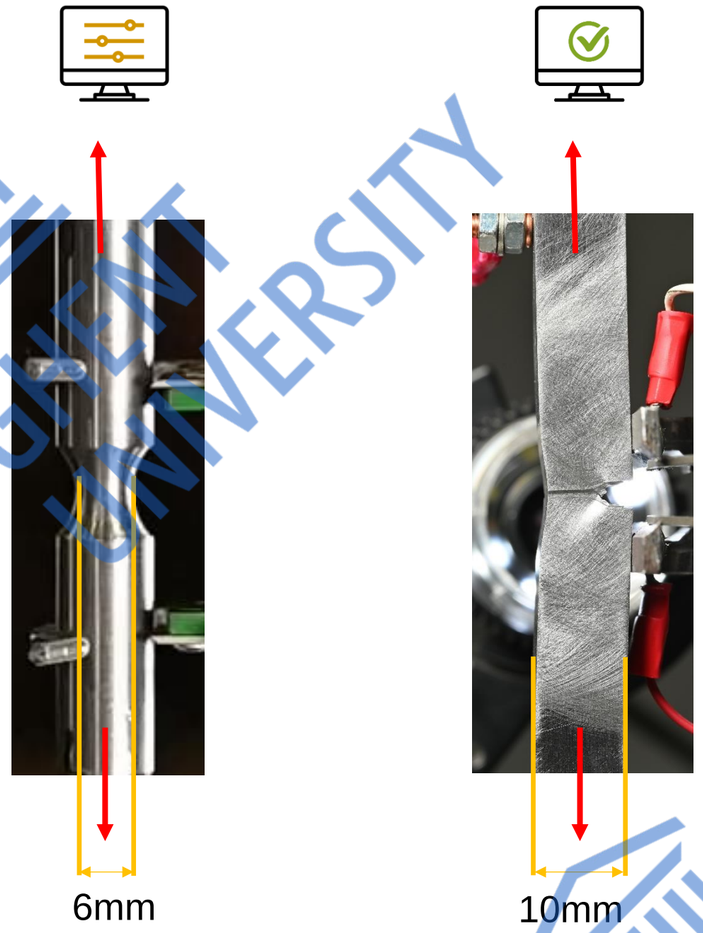
Defect height, h (mm) (with h ≤ 0.5t)	≤ 3	3 < h ≤ 4	4 < h ≤ 5
Allowable defect length limit, l (mm)	≤ 7 t	≤ 5 t	≤ 3 t

Table 2. Allowable defect length limits for single planar defects at Tier 2.

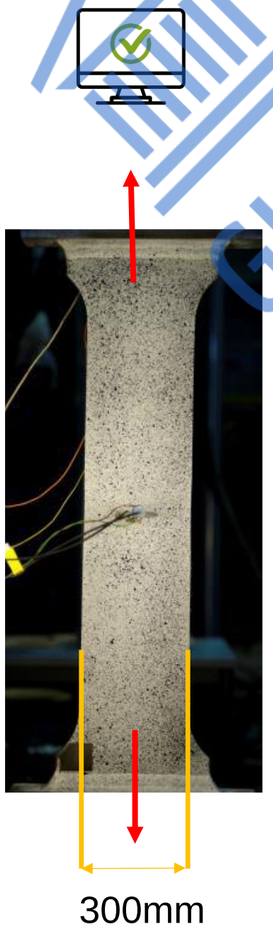
EPRG guidelines on the assessment of defects in transmission pipeline girth welds – Revision 2014

Upscaling of experiments

Small scale



Component scale



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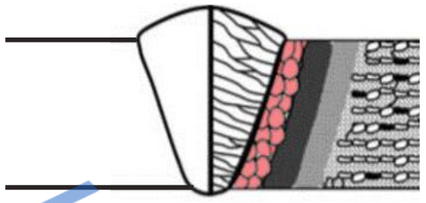
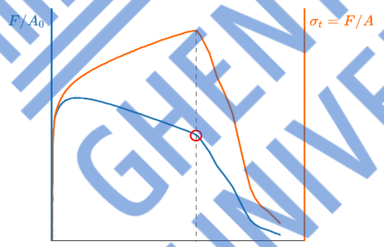
Take-aways

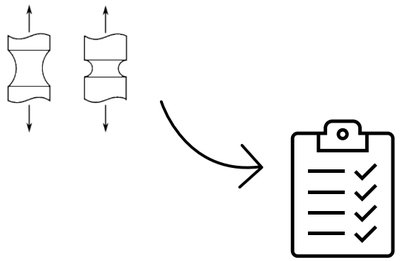


2 ways of investigating the embrittlement of the HAZ

- positioning notch in HAZ
- recreating microstructure of HAZ



Using the knee point to derive embrittlement indices



Experiments → Guidelines

- link with numerical model
- upscaling of experiments

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Ghent University

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