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# DED-COMPONENT DESIGN, MANUFACTURING AND PERFORMANCE AS PART OF STRUCTURE

DED-komponentin suunnittelu, valmistus ja suorituskyky  
liitettynä levyrakenteeseen

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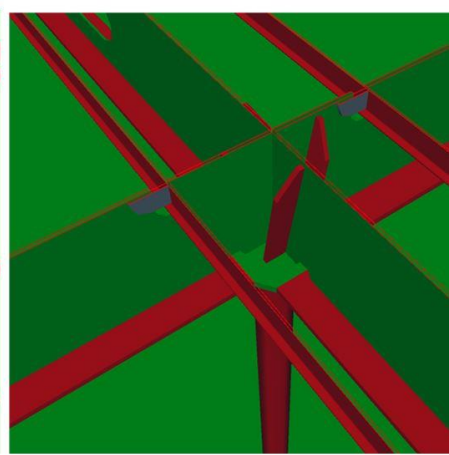
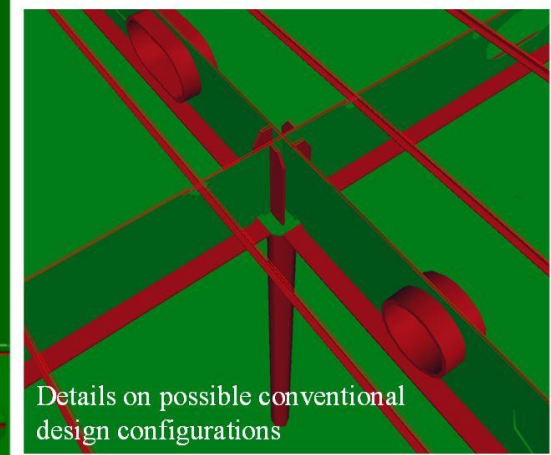
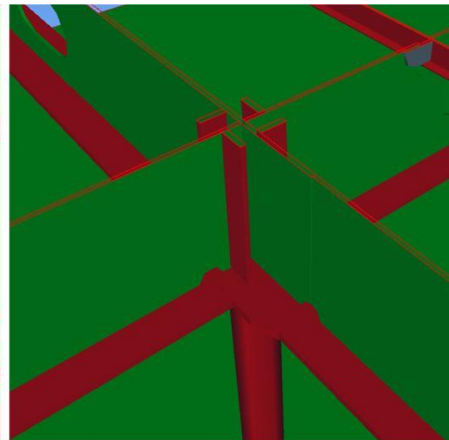
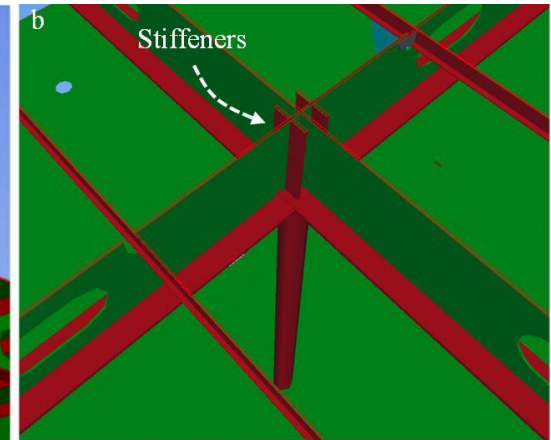
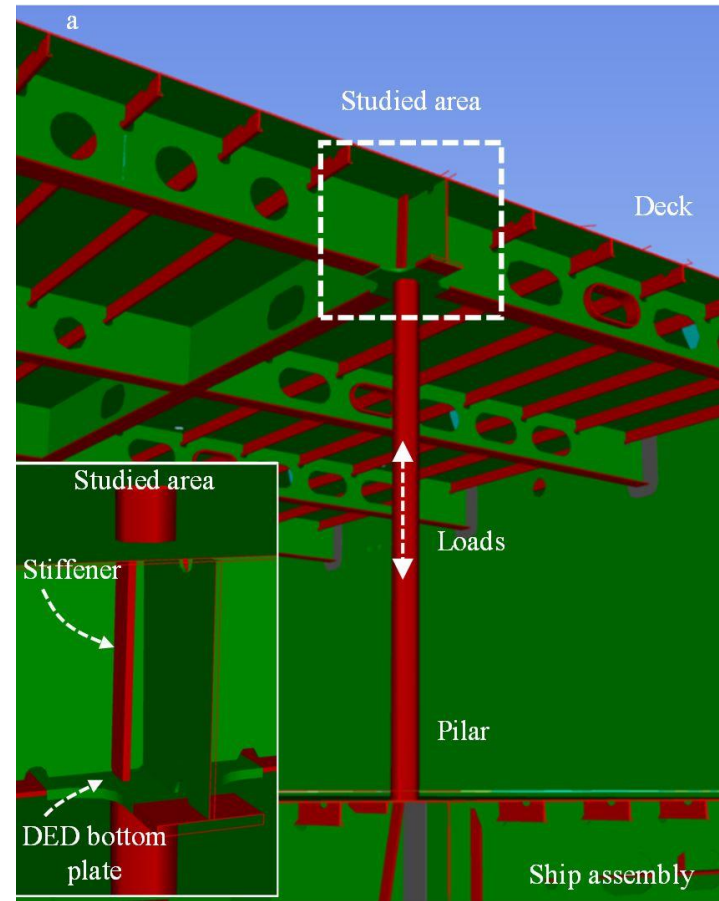
Kalle Lipiäinen

LUT Steel Structures

# BRACKGROUND

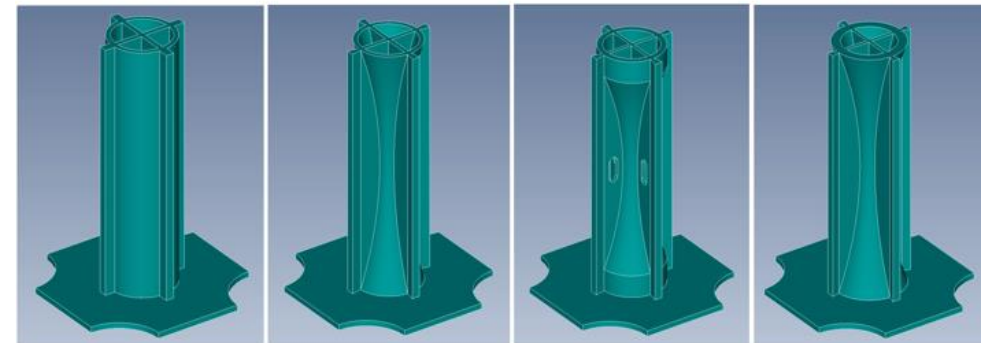
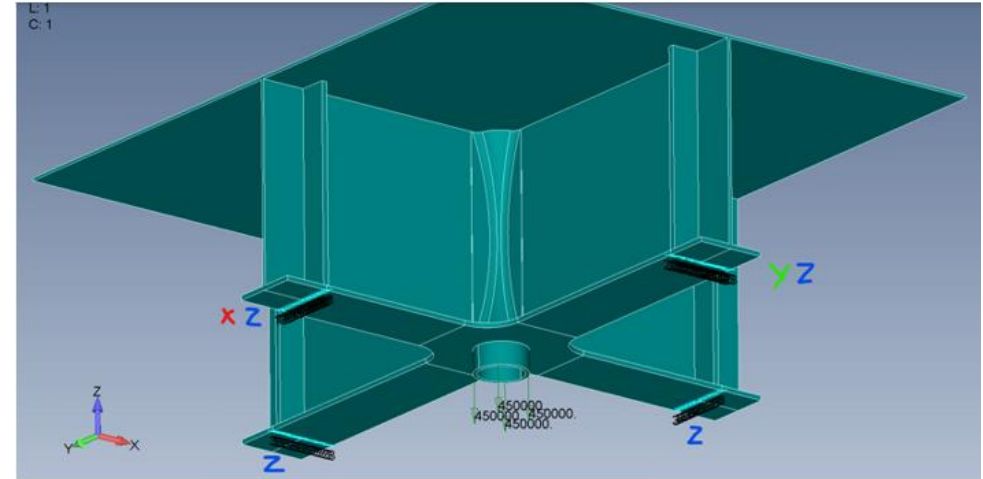


- **Aim**
- Case-study to identify AM feasibility and potential in shipbuilding
  
- **Present study**
- Joining part for construction
- Multiple variations in current design



# DEVELOPING IDEAS

- Directed energy deposition (DED) was selected due to cost efficiency potential
- DED-Arc-wire method specifically – Also known as WAAM
  
- Finite element analysis (FEA) for initial screening for optimal weight and design
- Manufacturability considerations during design

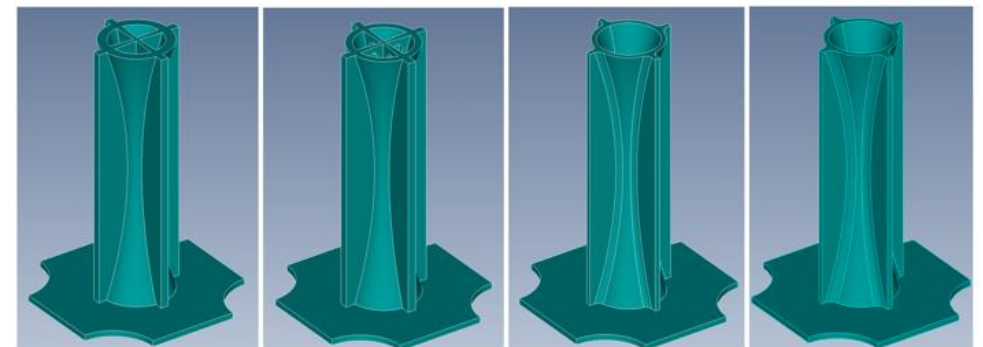


(a) Weight  $\approx$  17,91 kg

(b) Weight  $\approx$  12,08kg

(c) Weight  $\approx$  12,66 kg

(d) Weight  $\approx$  13,03 kg



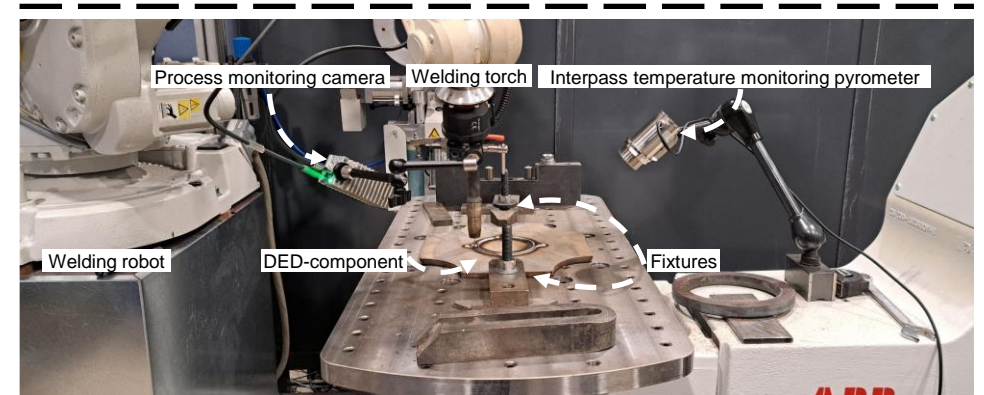
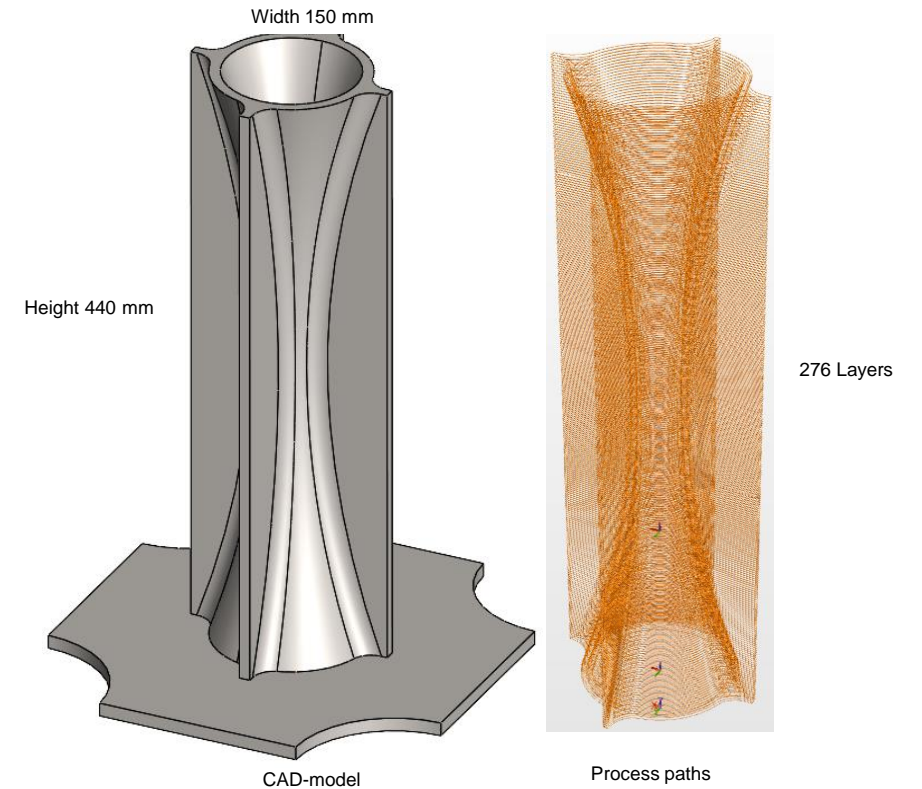
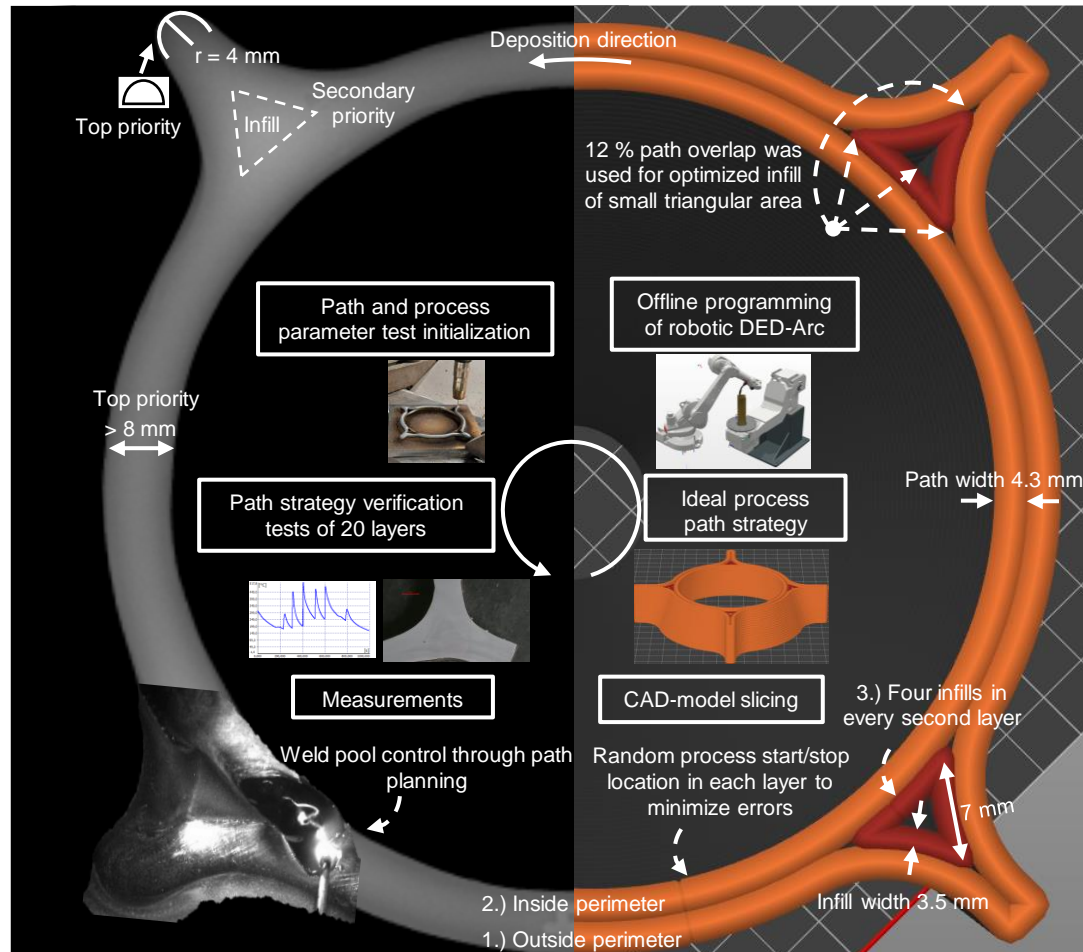
(e) Weight  $\approx$  15,80 kg

(f) Weight  $\approx$  13,63 kg

(g) Weight  $\approx$  9,94 kg

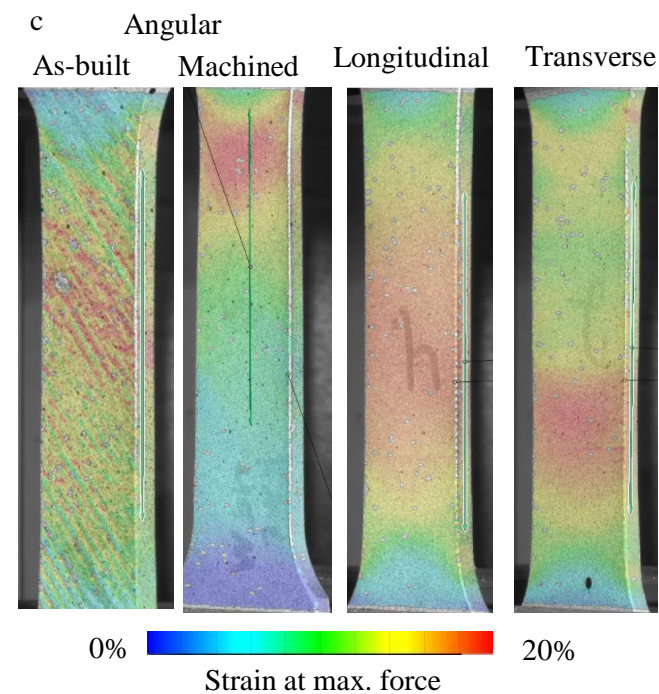
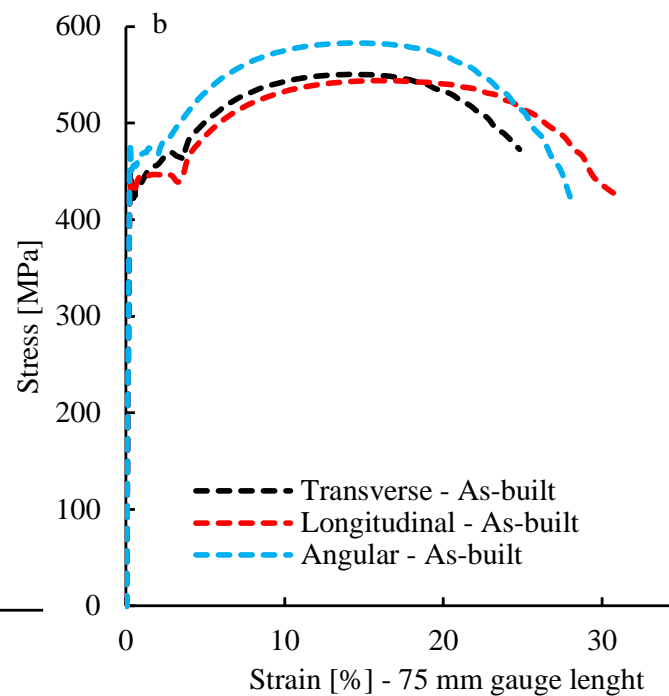
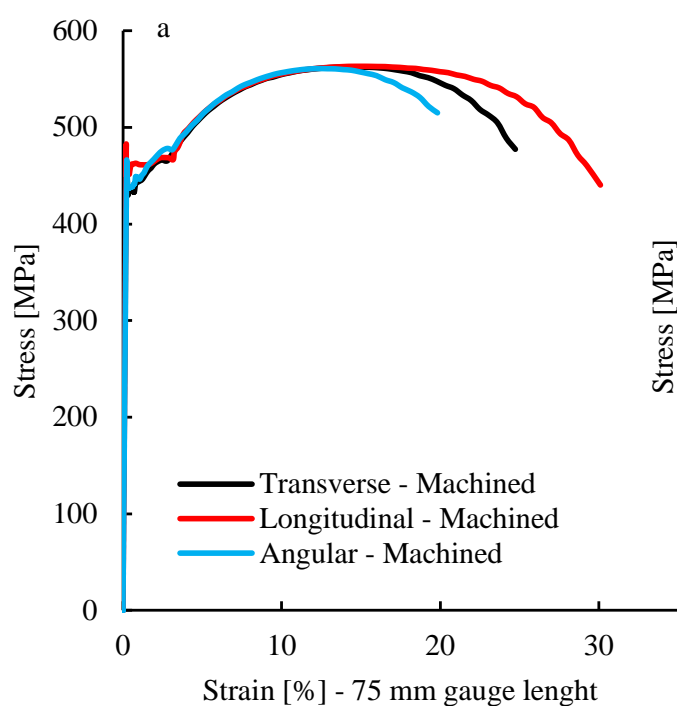
(h) Weight  $\approx$  10,23 kg

# MANUFACTURING



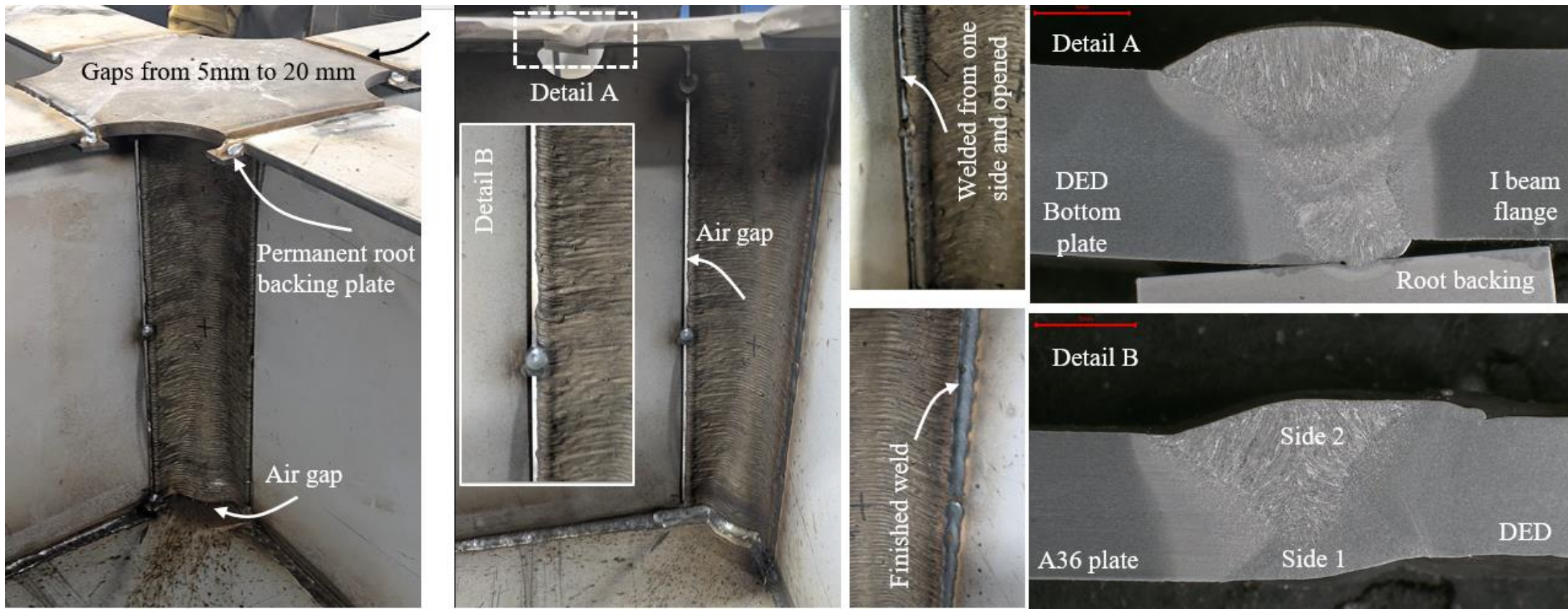
# TENSILE STRENGTH

- Low strength filler wire (Elga Elgamic 100) used
- Low cost (3-4e/kg) and matches to rest of ship structure



# ASSEMBLY

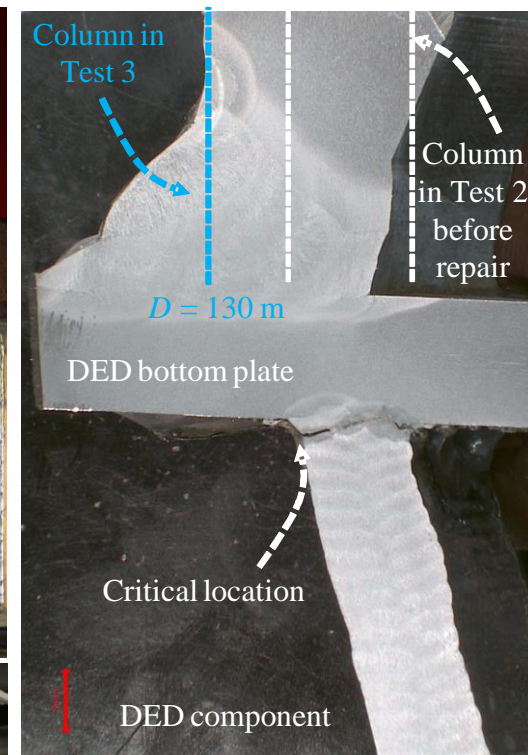
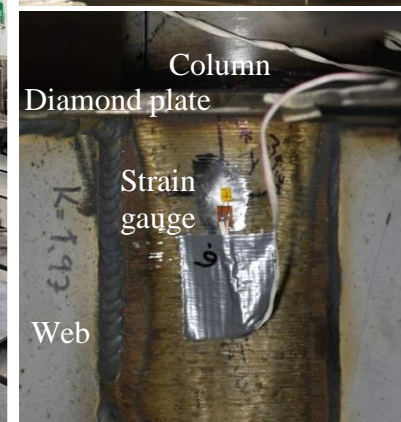
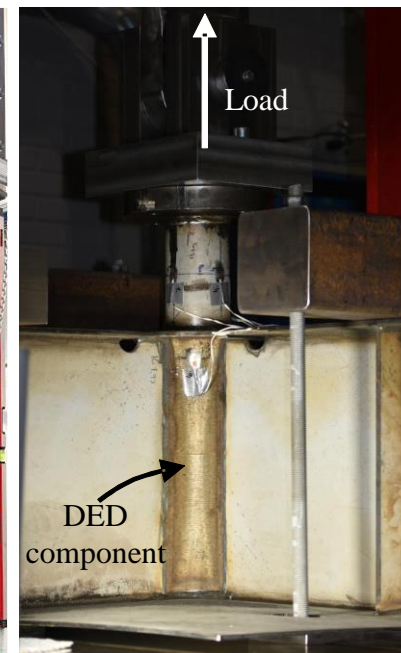
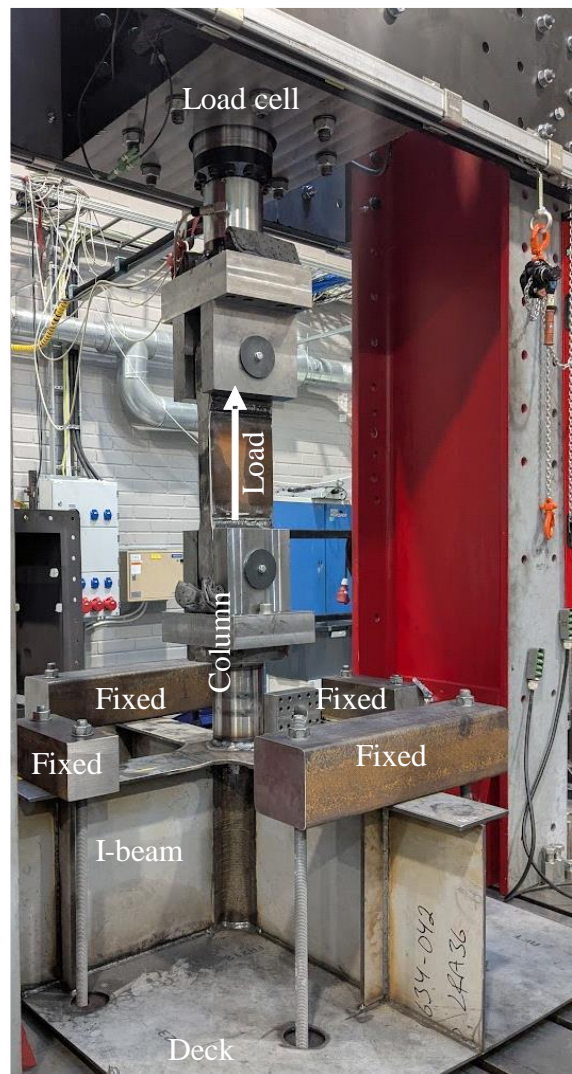
- Assembly in realistic position (as photographed) with GMAW – Tolerance handling important
- Root backing used for diamond plate to handle 5-20 mm gaps





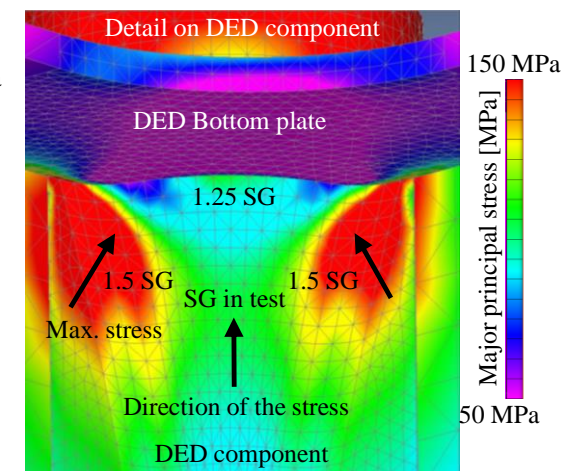
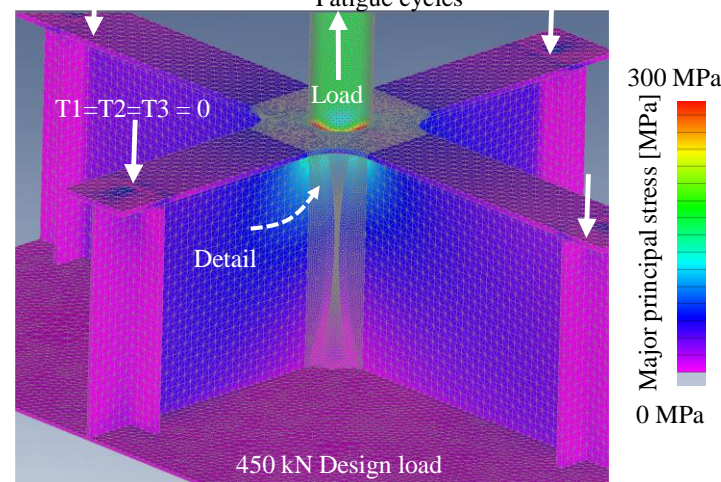
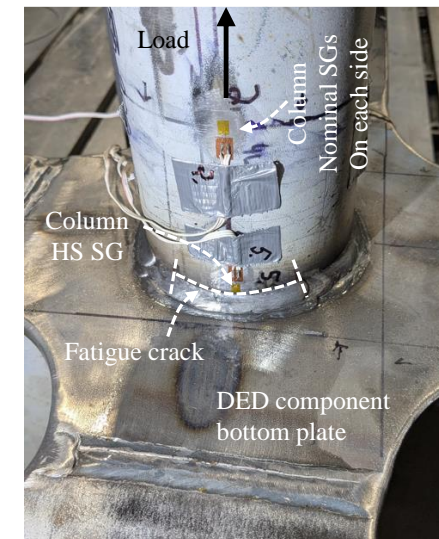
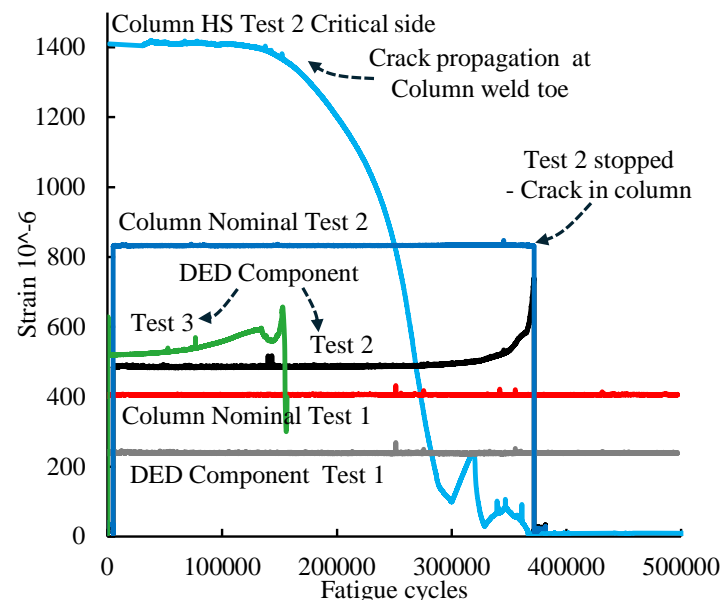
# FATIGUE TESTING

- Full-scale test to study performance
- $R = 0$  stress ratio loading
- Multiple test and repair after Test 2
- Total >1 000 000 cycles
- Test 2 was found to start crack propagation in DED component
- Test 3 after column repair for fatigue crack propagation in DED component



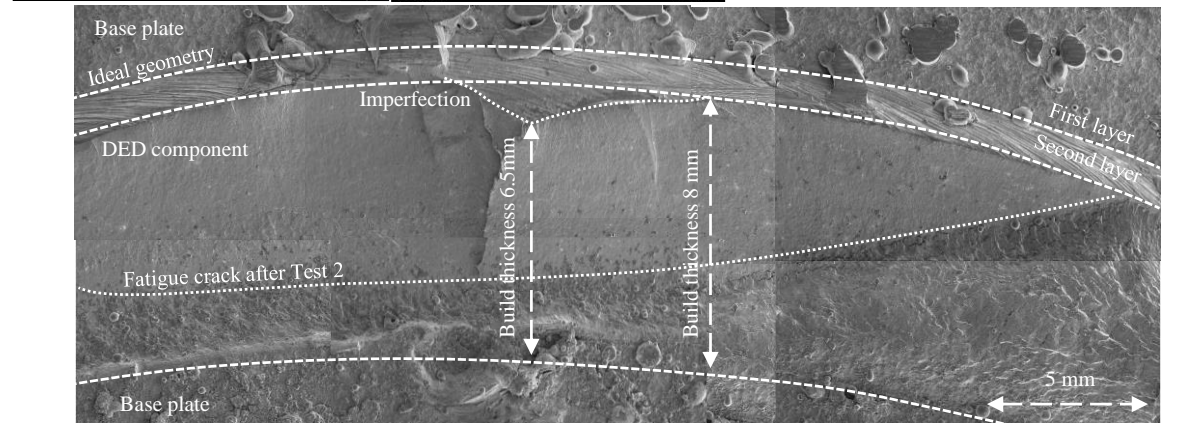
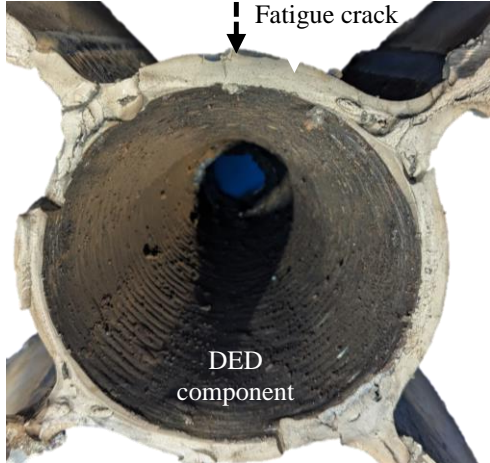
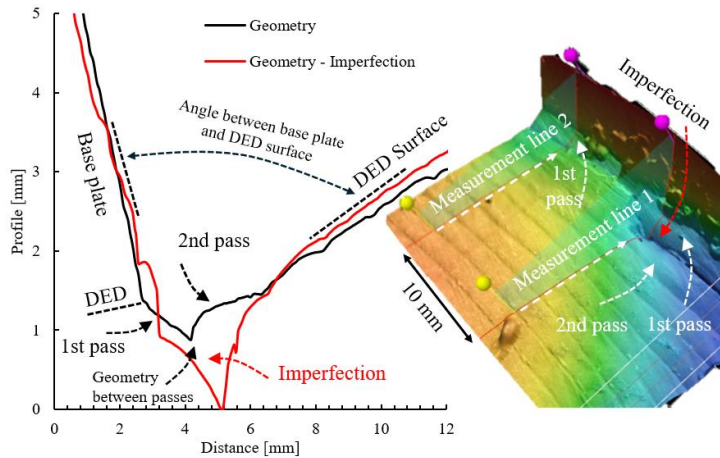
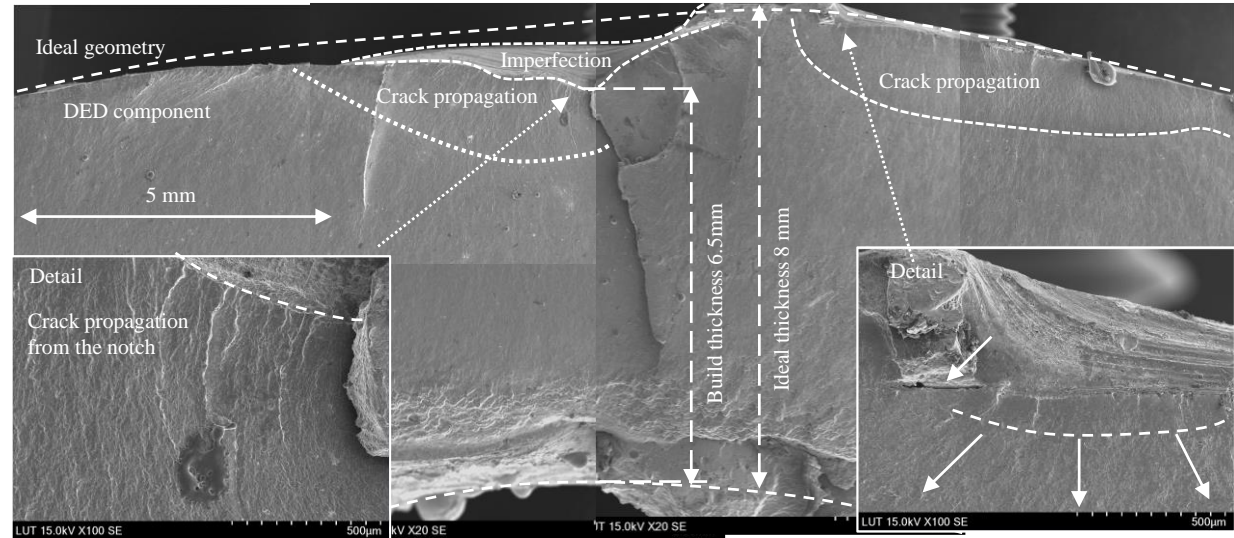
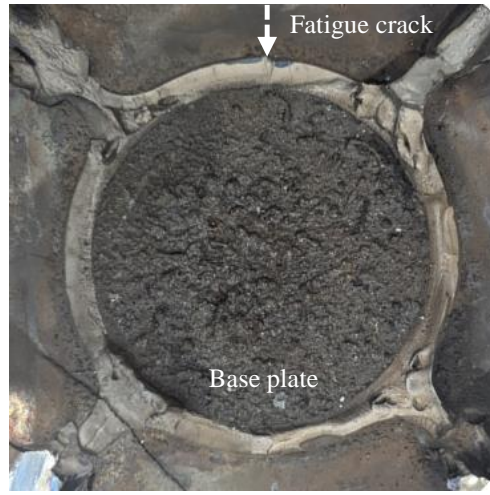
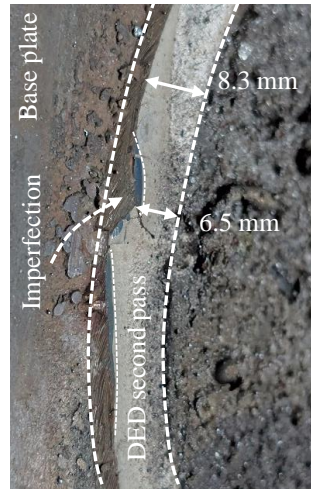
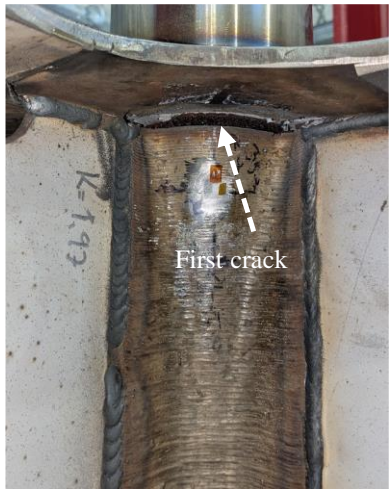
# STRESSES IN FATIGUE TEST

- ▶▶ Hot spot (HS) stress evaluation in case of column weld toe fatigue crack (Test 1 and 2)
- ▶▶  $\Delta\sigma_{c,50\%} = 152 \text{ MPa}$  ( $m = 3$ ) for weld toe
  - ▶▶ Reference value 137 MPa – Inline with IIW recommendations
- ▶▶ Stress in DED component monitored by strain gauges and FEA



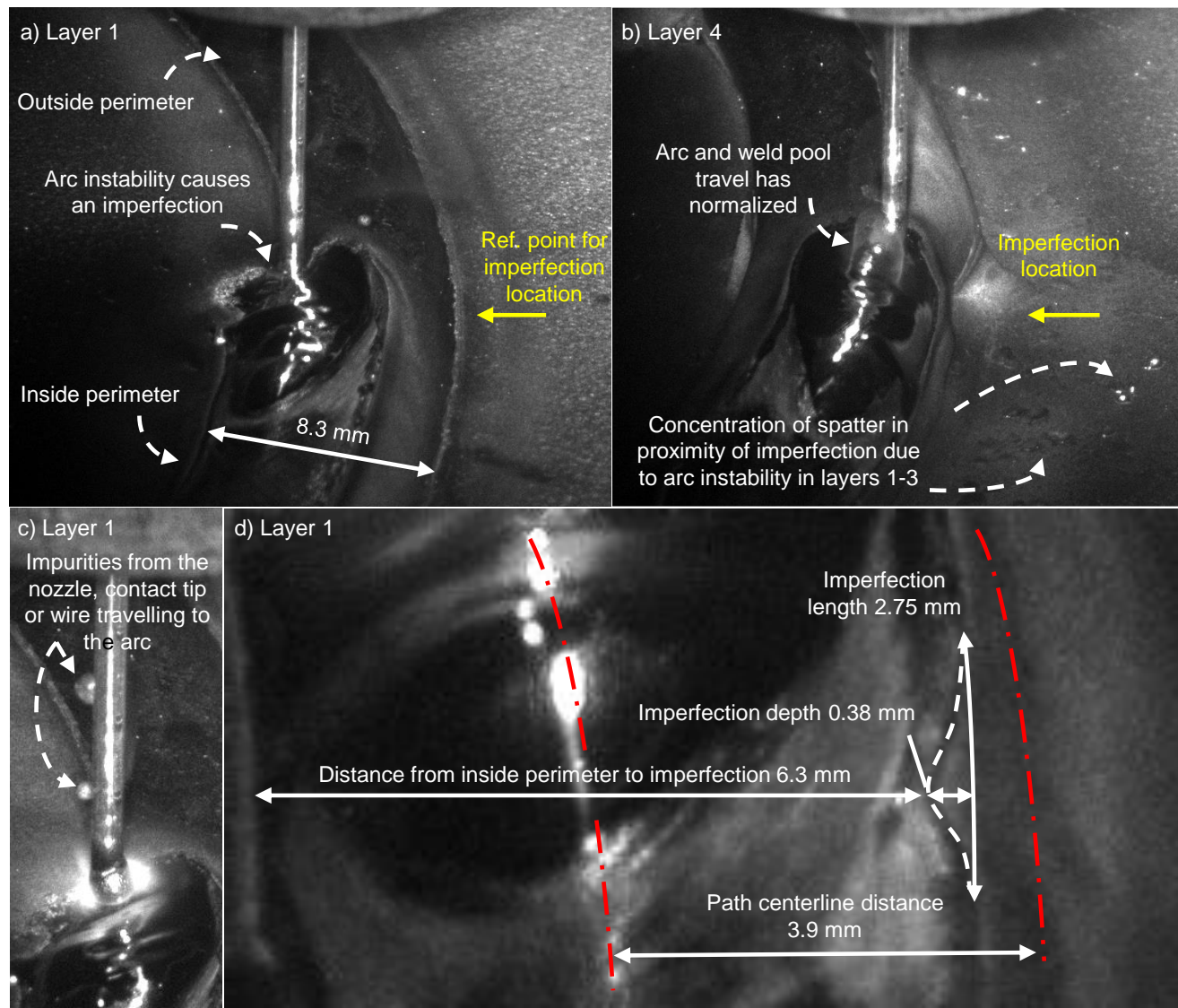
# FAILURE ANALYSIS

➤ Visual and SEM combined – Imperfection caused increase in local stress



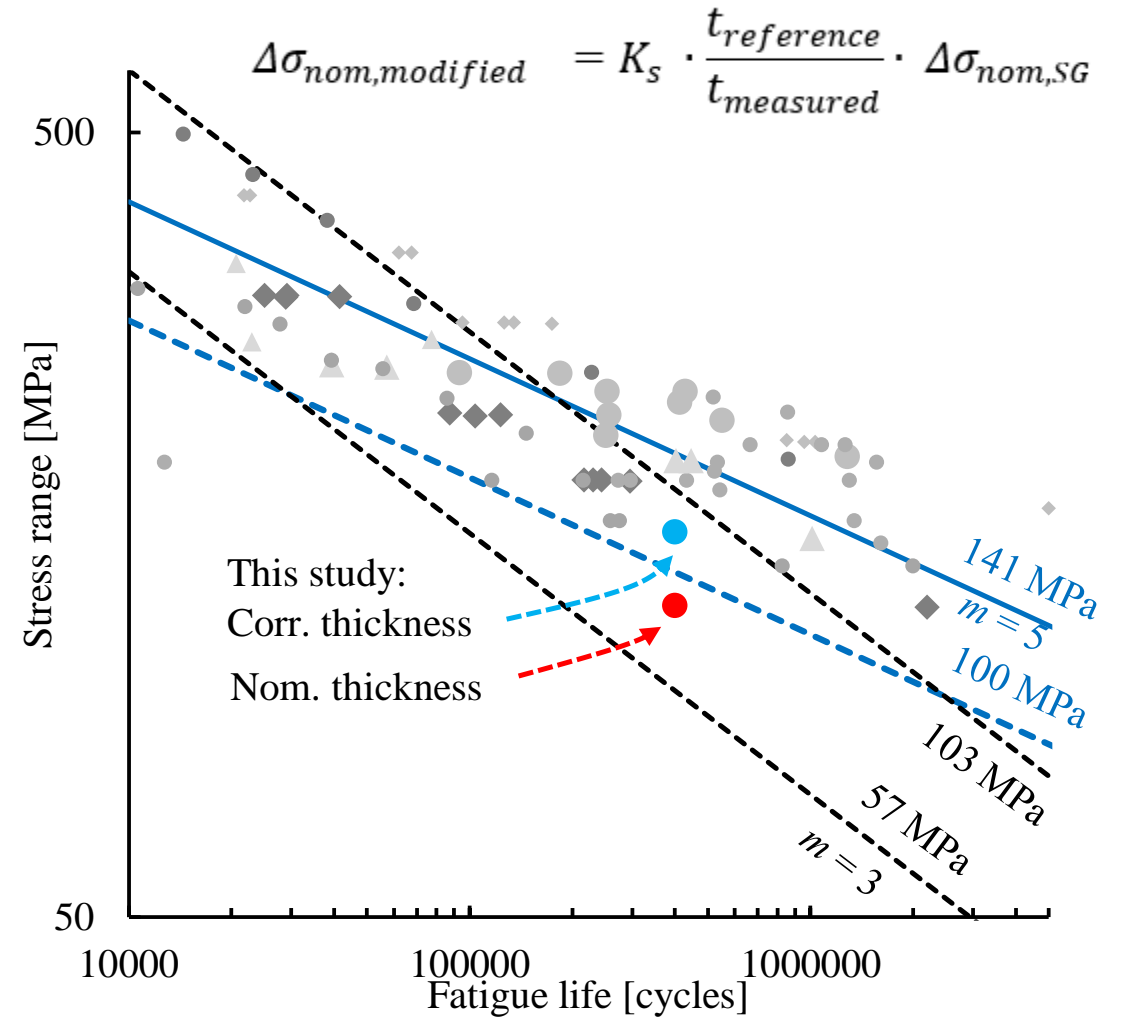
# QUALITY OF MANUFACTURING – CAVITAR VIDEO

- ▶▶ Recording process with Cavitar-branded camera system
- ▶▶ Analysing the video when imperfection location was observed in SEM
- ▶▶ Imperfection clearly visible
- ▶▶ Impurities in wire also visible
- ▶▶ Adaption and repair could have been performed as FEA indicated critical area



# DED FATIGUE STRENGTH ANALYSIS

- The strength after considering local thickness decrease inline with our previous study findings
- Fatigue performance based on FEA and SGs exceeding FAT 100 MPa  $m = 3$
- Imperfections and especially thickness reduction important to control or use more conservative fatigue strength assesment



# CONCLUSIONS

- Structure re-design for DED enables benefits and considering DED technique characteristics in initial design phase results optimal outcome
- Critical areas for quality control should be specified In DED production to meet designed fatigue strength
- Geometric tolerances on DED components should be specified according to surrounding structure and used joining methods
- Fatigue strength of DED components could be higher than with conventional manufacturing in structural applications





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**THANK YOU**

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