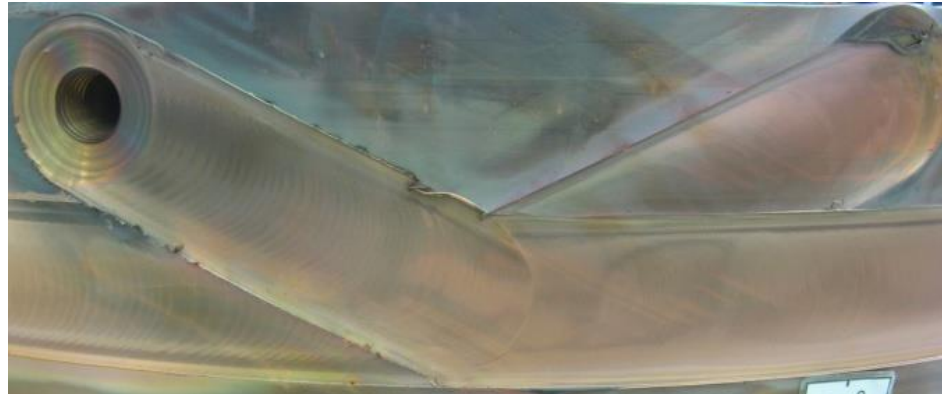


Verification of SKB's depth controller

Lars Cederqvist¹, Olof Garpinger², Isak Nielsen³

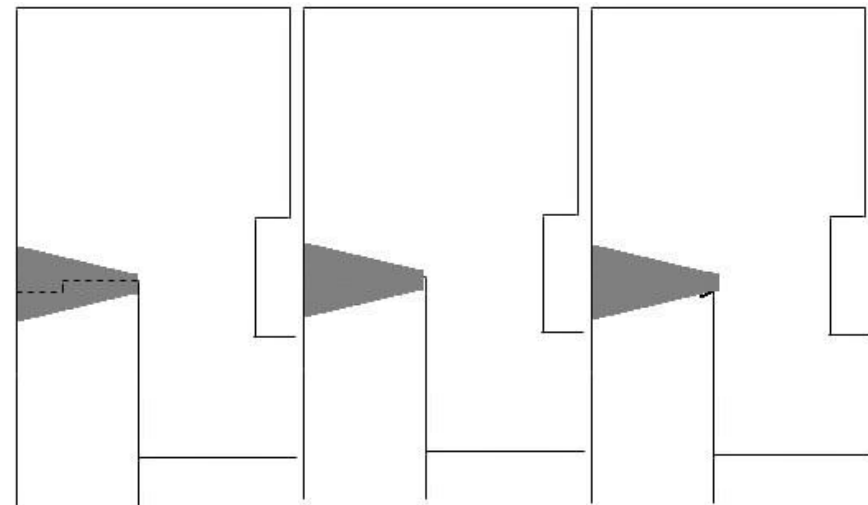
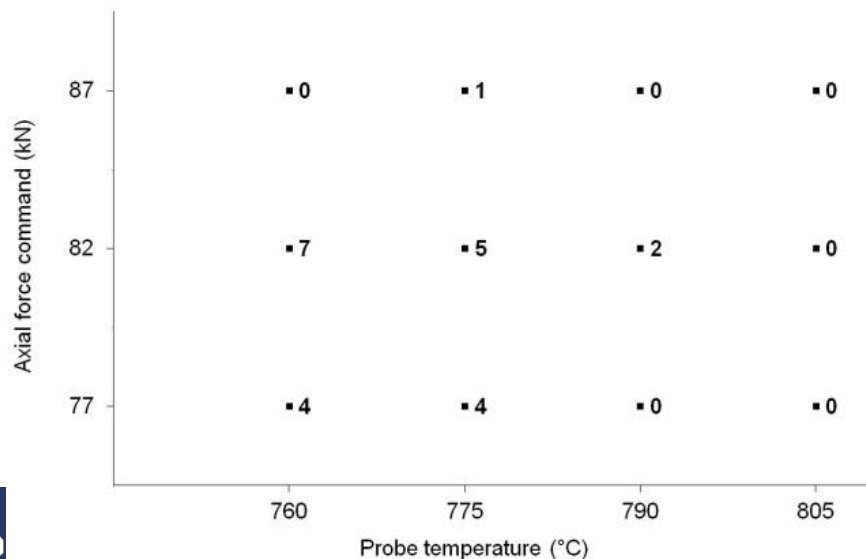
¹Swedish Nuclear Fuel and Waste Management Company (SKB)

²ALTEN, ³IAN Consulting



Why depth control?

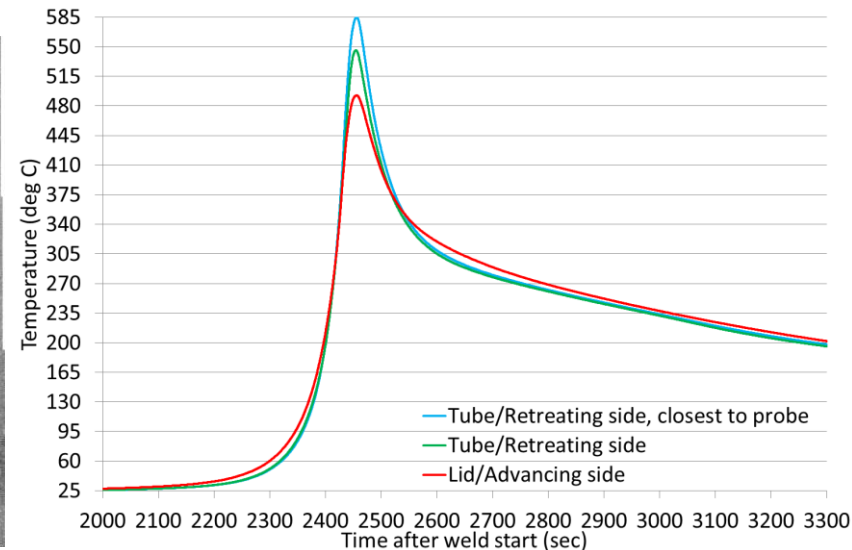
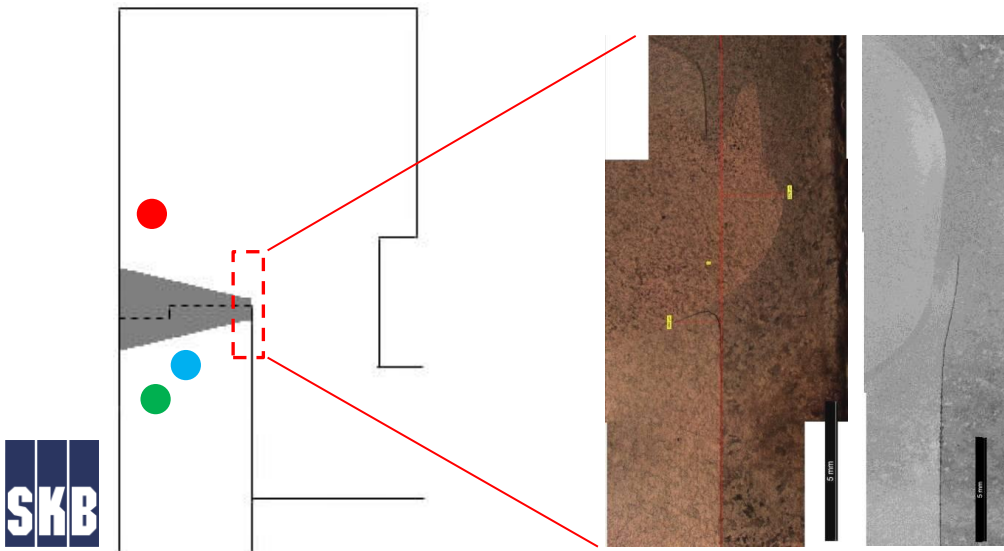
- Objective: Achieve set depth throughout weld cycles
 - Control of joint line hooking / remain
 - Flash induces torque disturbances (during overlap)
- Hypothesis: Reduced axial force will cause wormhole to be produced at higher probe temperature; i.e. controller needs lower axial force limit



Effects of reversed welding direction

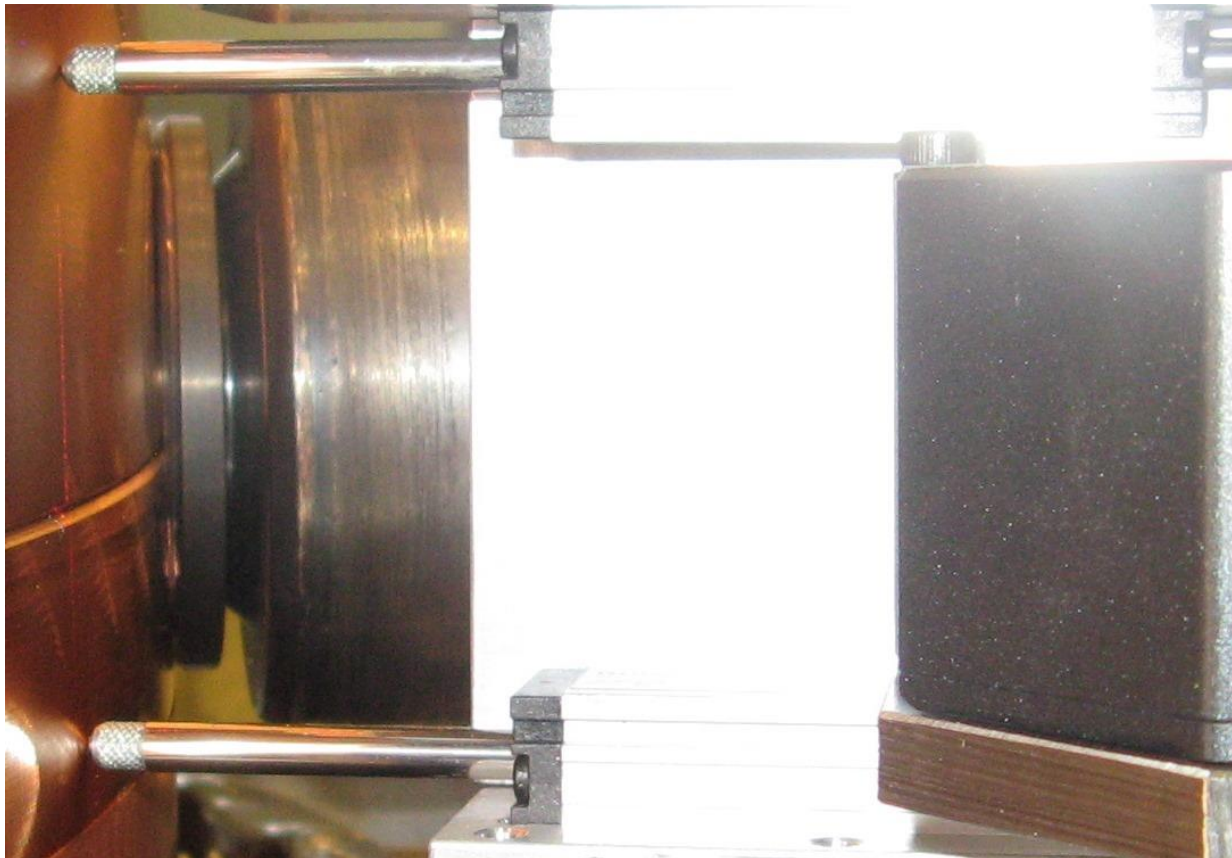
- No joint line hooking (like retreating side in lap joints)
- 1st test: 54°C colder lid/advancing vs. tube/retreating
- 2nd test, normal welding direction:
lid/retreating 31°C colder than tube/advancing side,
reverse: lid/advancing 4°C colder than tube/retreating

Welding dir.	Lid, avg. Tmax	Tube, avg. Tmax
Normal	633	664
Reverse	648	652



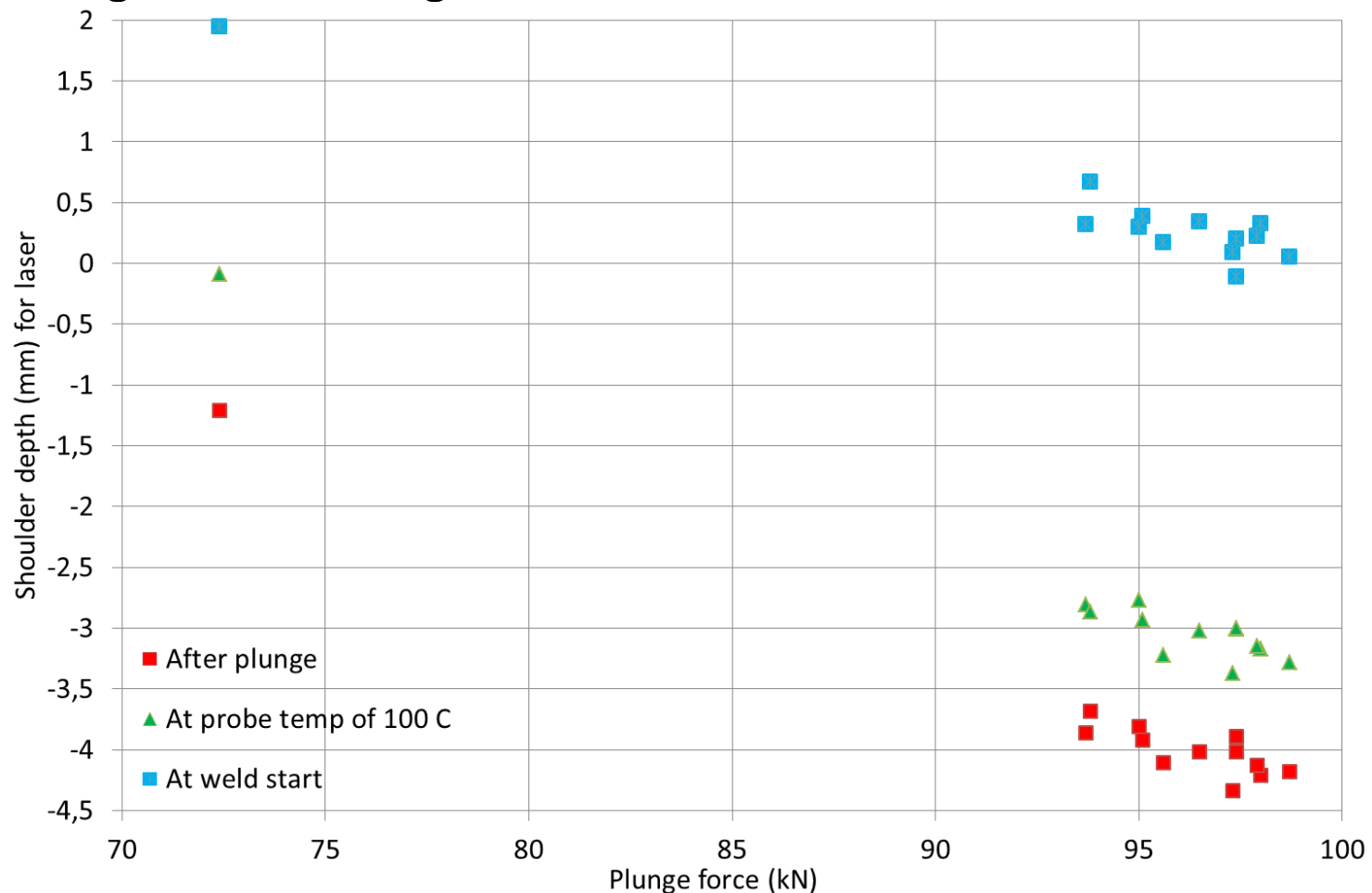
Depth controller(s)

- Spindle influenced by expansion, eccentricity & defl.
- Installed laser and 2 LVDT's in front of tool
 - Laser uses average along red line
 - Lower LVDT will register thermal expansion of tube



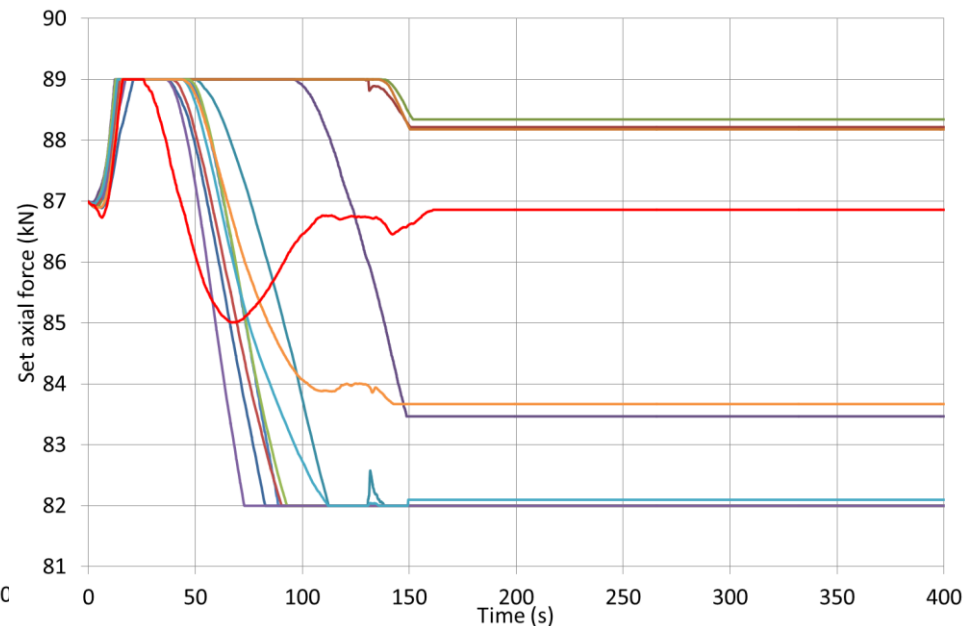
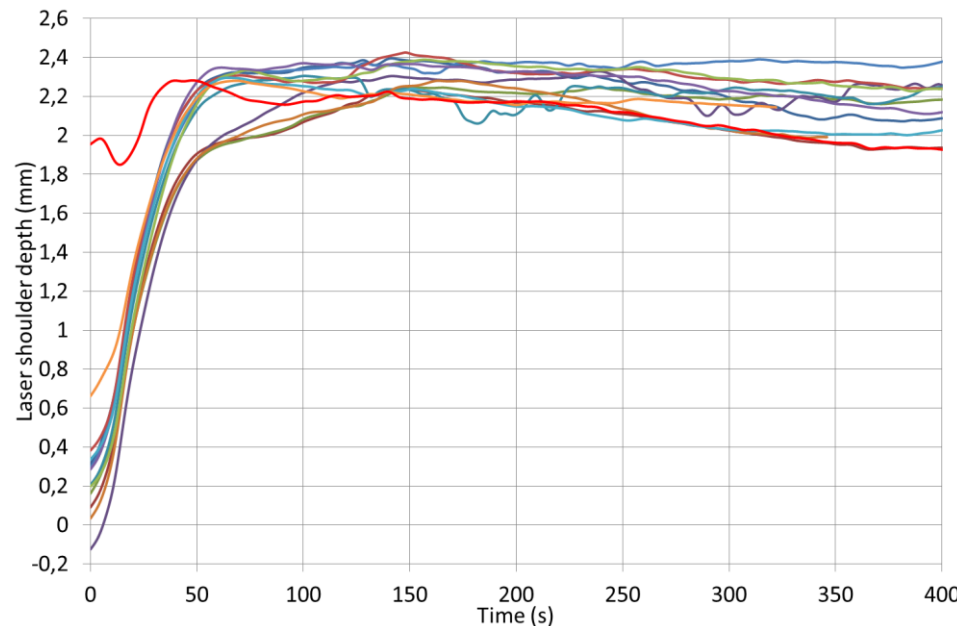
Depth controller(s), Results

- Verified during 13 welds in 3 different lids/tubes
 - Different manufacturing techniques and heat treatments
 - Plunge force range: 72-99 kN



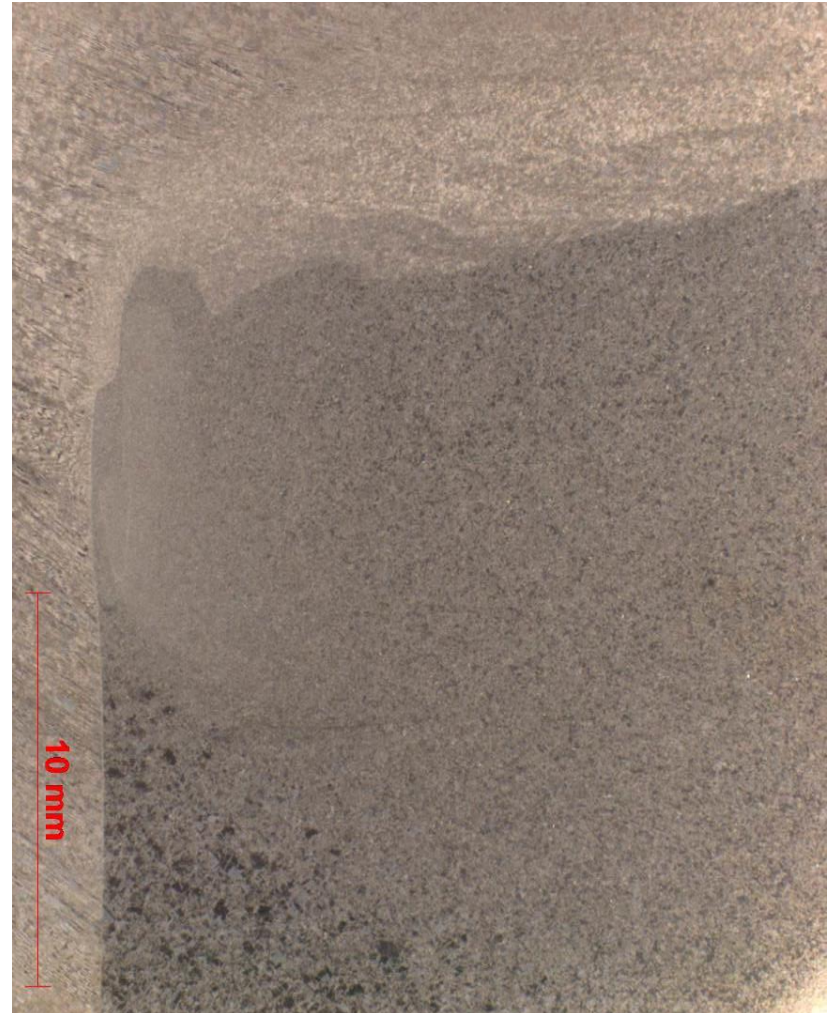
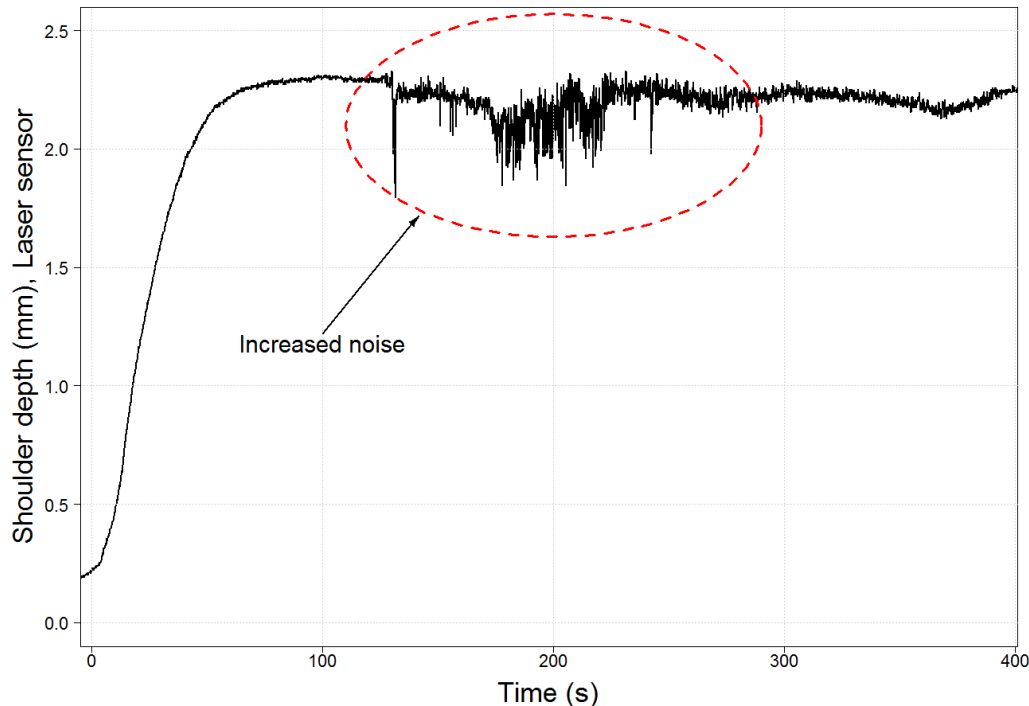
Depth controller(s), Results cont.

- Depth controller (and convex scroll shoulder) used to achieve set shoulder depth of 2.2 mm
- Shoulder depth above 3.0 mm and 10 mm flash achieved in former welds without active depth control



Depth controller(s), Results cont.

- Laser and LVDT_{upper} correlate best with actual shoulder depth (by measuring shoulder footprint)
- Lower robustness for laser
- No hook defect noted



Nordic Friction Stir Welding Centre

Established 2016 by
Swedish Nuclear Fuel and Waste Management Company (SKB)

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Nordic Friction Stir Welding Centre

- Aims to be a strategic Nordic resource for FSW research and development
- Main objective is to assist the industry to implement FSW in new applications
- SKB has developed unique FSW competence, both to produce welds and to locate defects with non-destructive testing (NDT) techniques
 - Correlation between tool temperature and defect formation
 - Cascade temperature controller able to suppress disturbances, and maintain tool temperature within 5°C

$$\Delta\omega_0 = \Delta\omega_1 + a \cdot (T - T_{des})_0 + b \cdot (T - T_{des})_1 + c \cdot (T - T_{des})_2 + d \cdot P_0 + e \cdot P_1 + f \cdot P_2$$

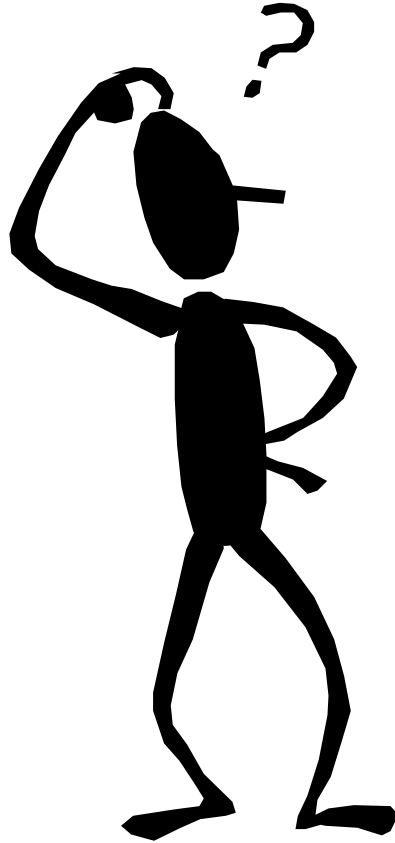
Nordic Friction Stir Welding Centre

Current projects:

- 7XXX/2XXX lap joint, thickness 2.2-3.0 mm
- Super-duplex (austenitic-ferritic) stainless steel butt joint, thickness 2.2 mm



Questions?



Summary

- Depth controller
 - Able to control depth within $\pm 0.X$ mm
 - LVDT_{upper} used due to more robust/reliable measurement
 - To be verified in more welds (different lids & tubes), and evaluate need during overlap sequence to control hook def.

