

## Accurate bi-wave ultrasonic stress measurements in already installed bolts in subsea structures

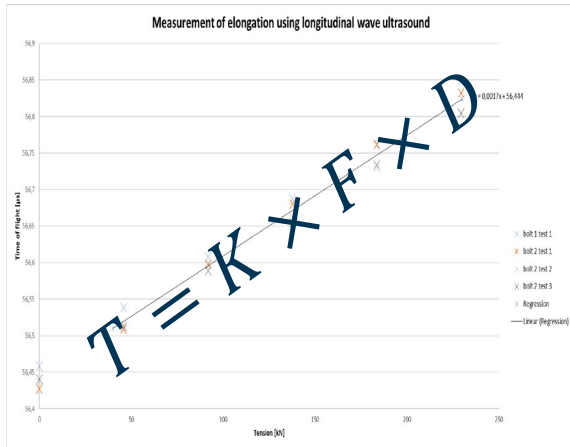
AkerBP and FORCE Technology

# Background

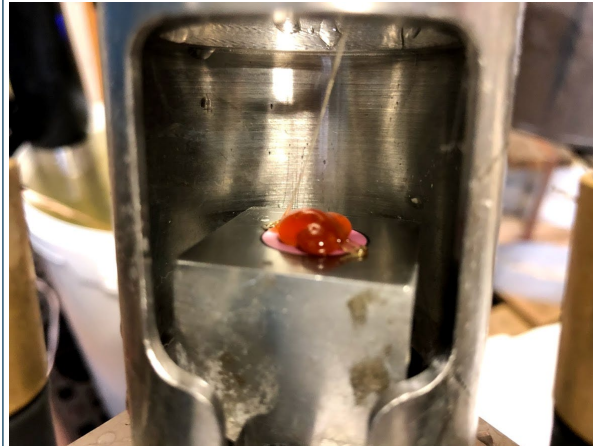


**Measure tension in already installed bolts subsea?**

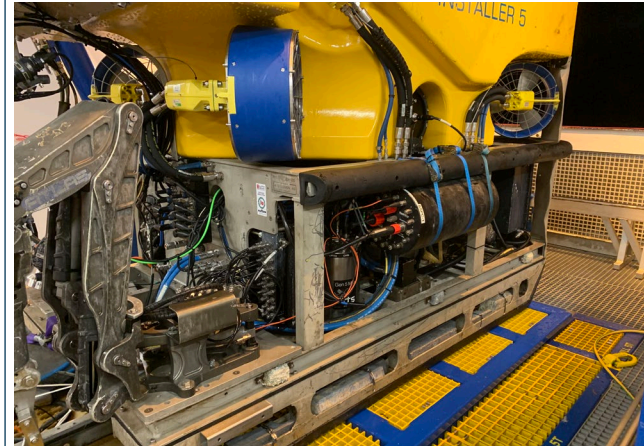
# Theory



# Development



# Current



# Limitation of Torque

$$T = K \times F \times D$$

T = Input torque

F = Tension in bolt

D = Nominal diameter of the bolt

K = Constant called "Nut Factor"

## Variables that affect the Nut Factor:

Lubrication

Debris

Chips

Surface finish

Corrosion

Deformation

Friction

Geometry

Coating

Contact radii

Thread pitch

Perpendicularity

Tool Accuracy

Operator skill

Part Quality

... (and more)



# Advantage of Ultrasonic measurements

Direct measurements of tension in the bolt,  
independent of Nut Factor

## Mono-wave measurements

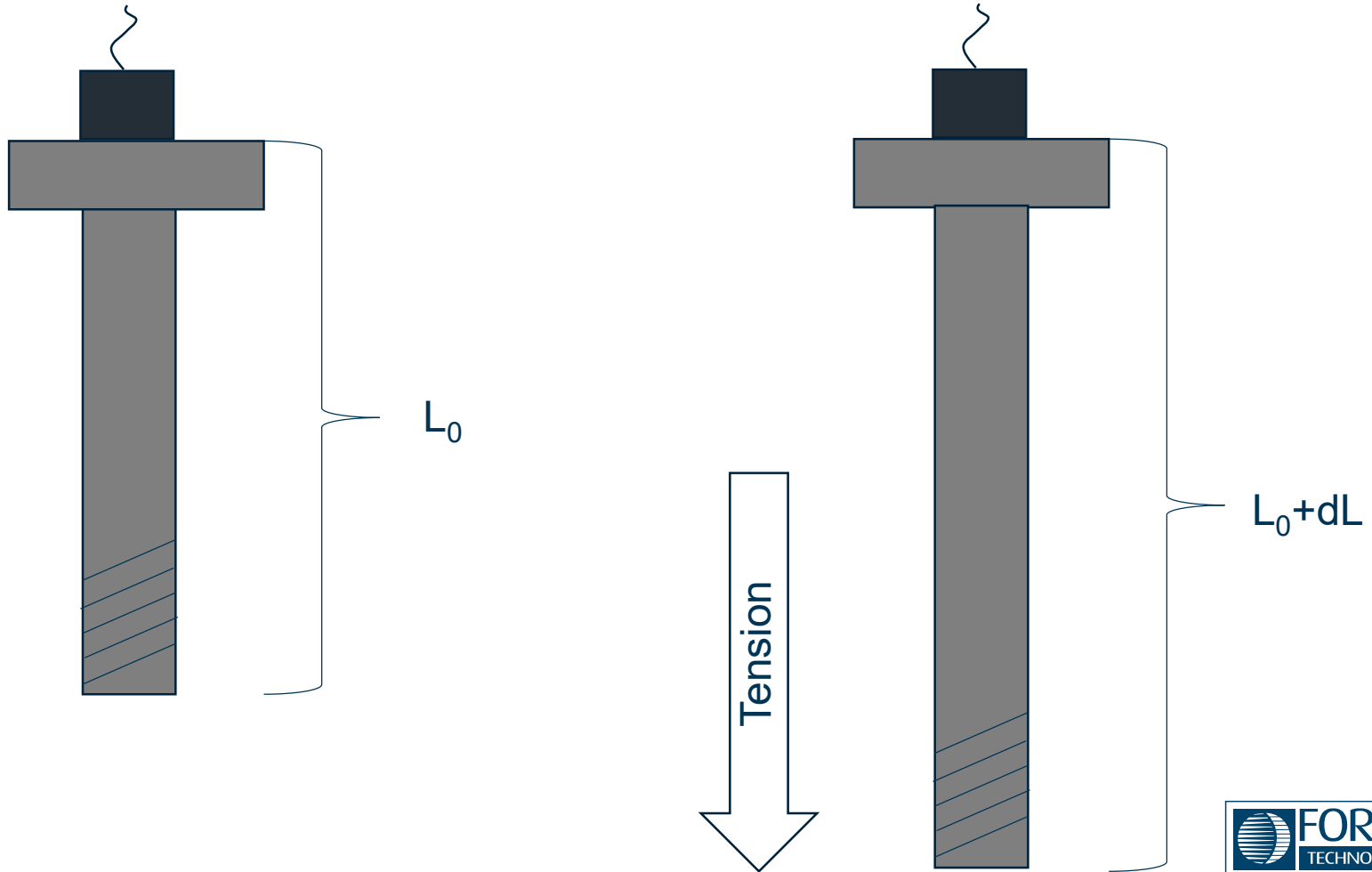
Compression

## Bi-wave measurements

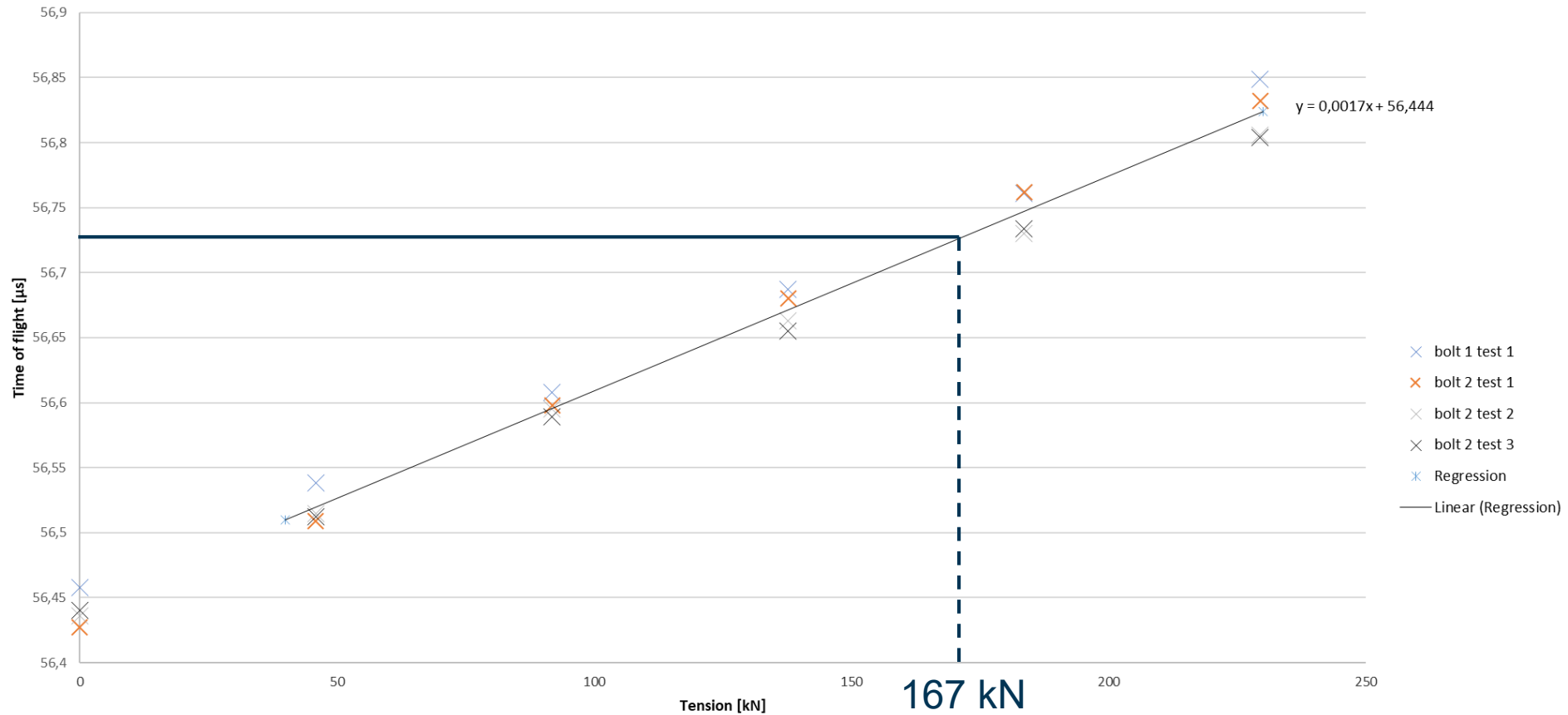
Compression and Shear



# Mono-wave measurements



## Measurement of elongation using longitudinal wave ultrasound



# Mono-wave measurements

Pro:

Easy to use

Commercially available probes

Cons:

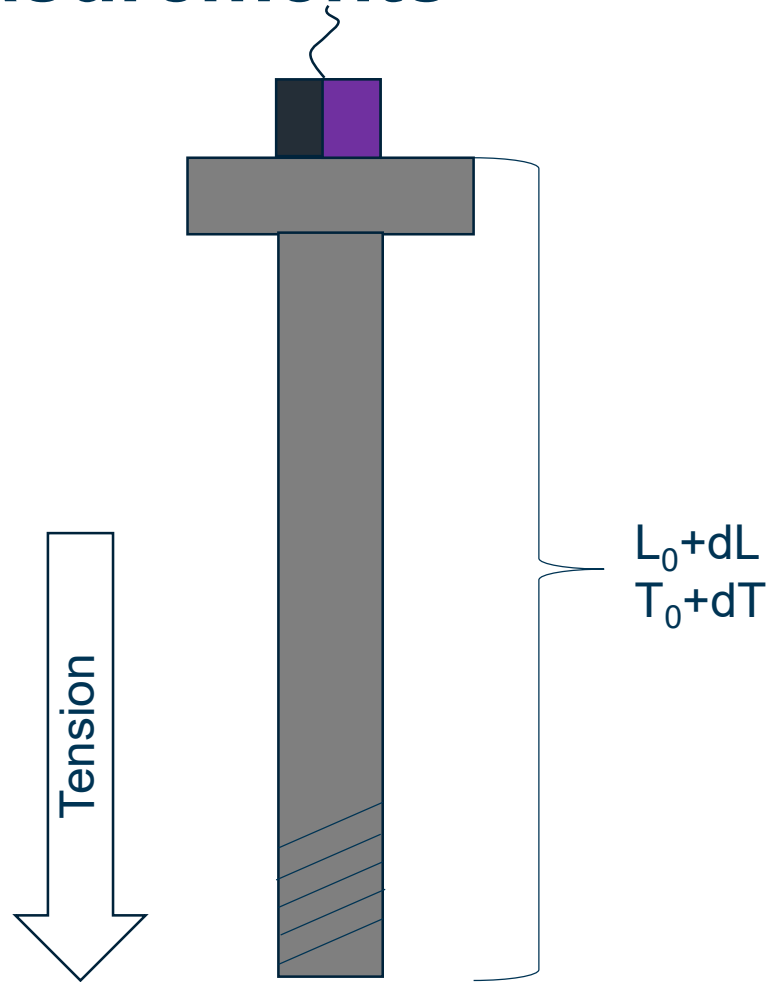
**Requires baseline measurement**

Requires flat ends

(Temperature dependent)

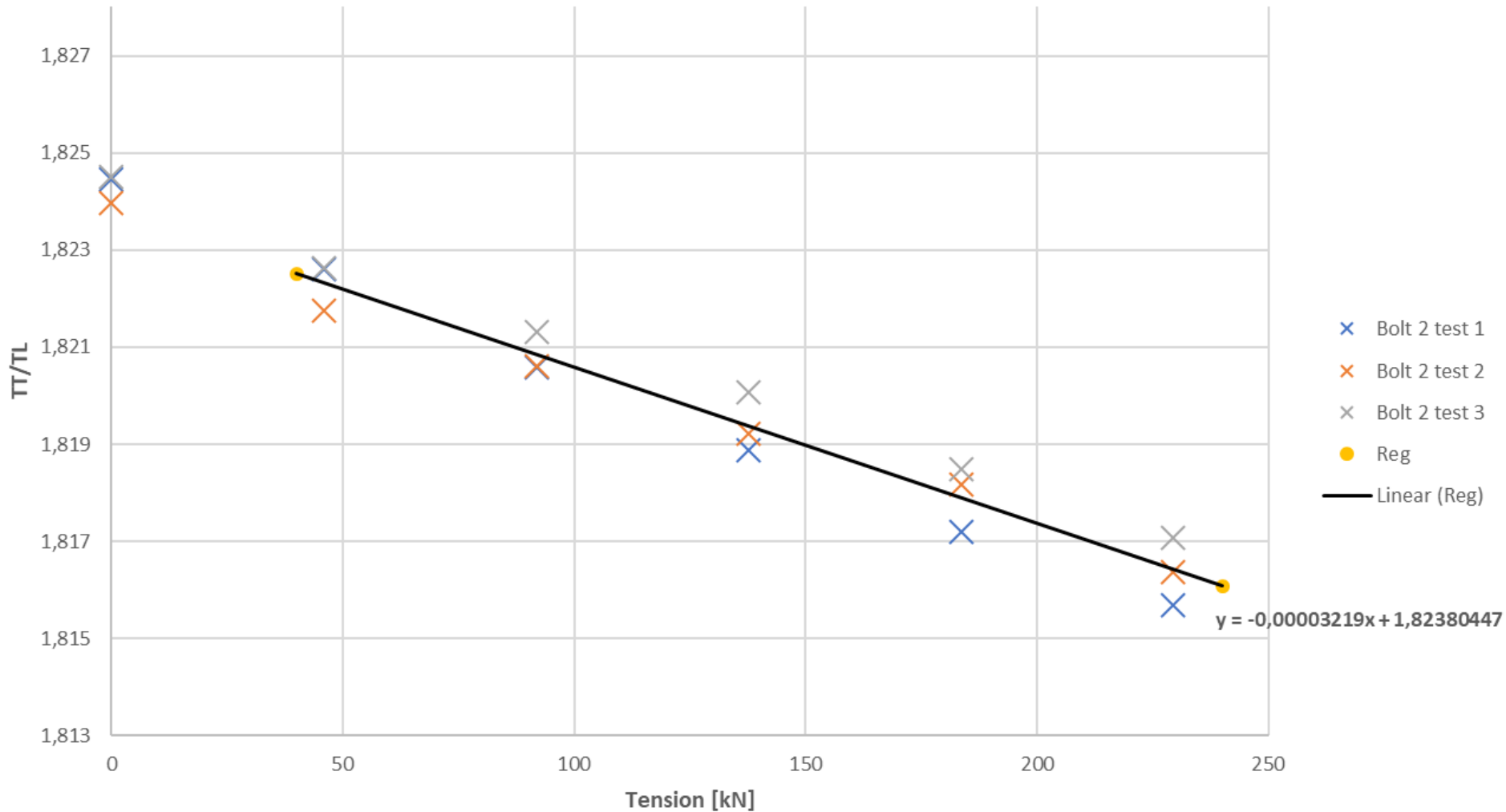


# Bi-wave measurements



Based on work done by Henri Walaszek, CETIM.

## Bi-wave measurement of tension



Valid for all bolts of the same batch!  
Ratio is independent of length

# Bi-wave measurements

Pro:

**Does not require known baseline**

Easy to calibrate to new batch

Cons:

Two probes

Shear wave do not propagate in liquids

Sensitive to heat treatment

Requires flat and clean

(Temperature dependent)

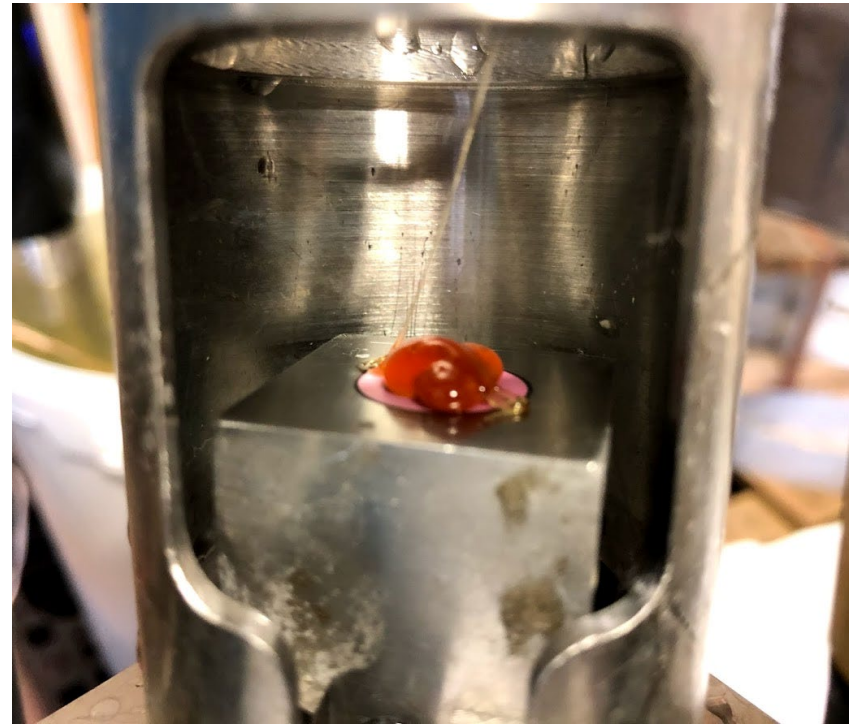
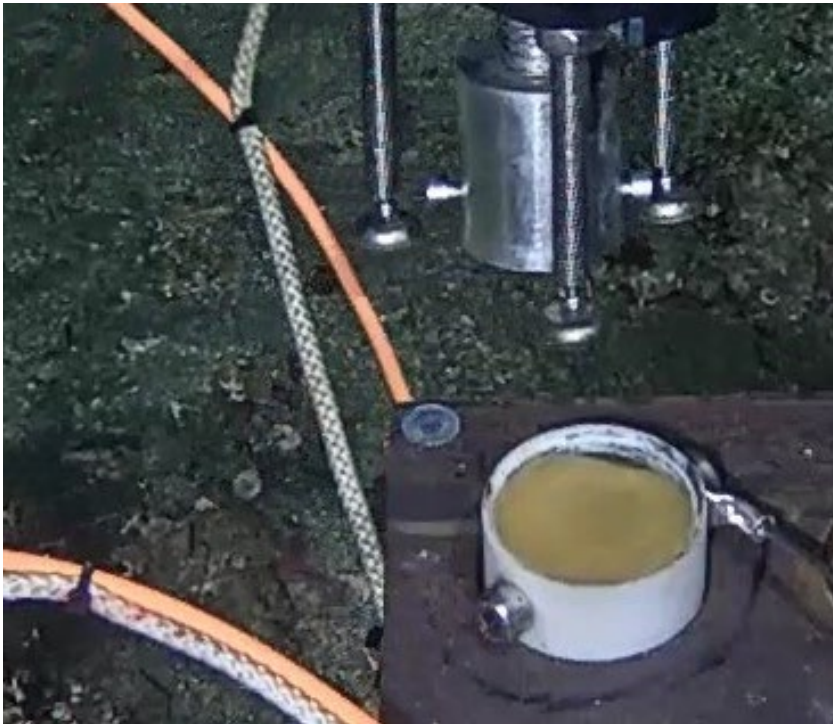
# Development







# Couplant

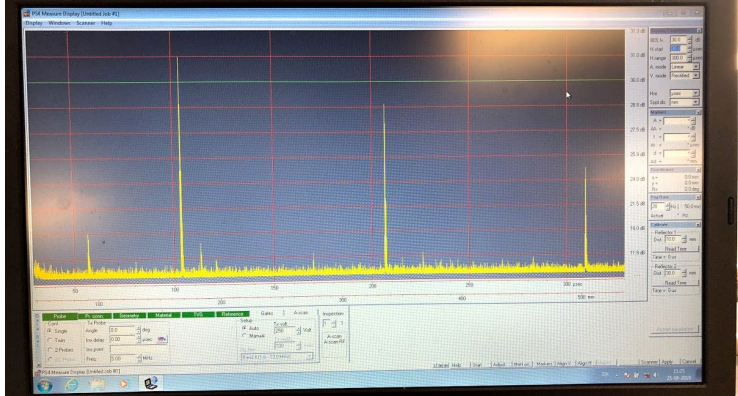


# Probeholders

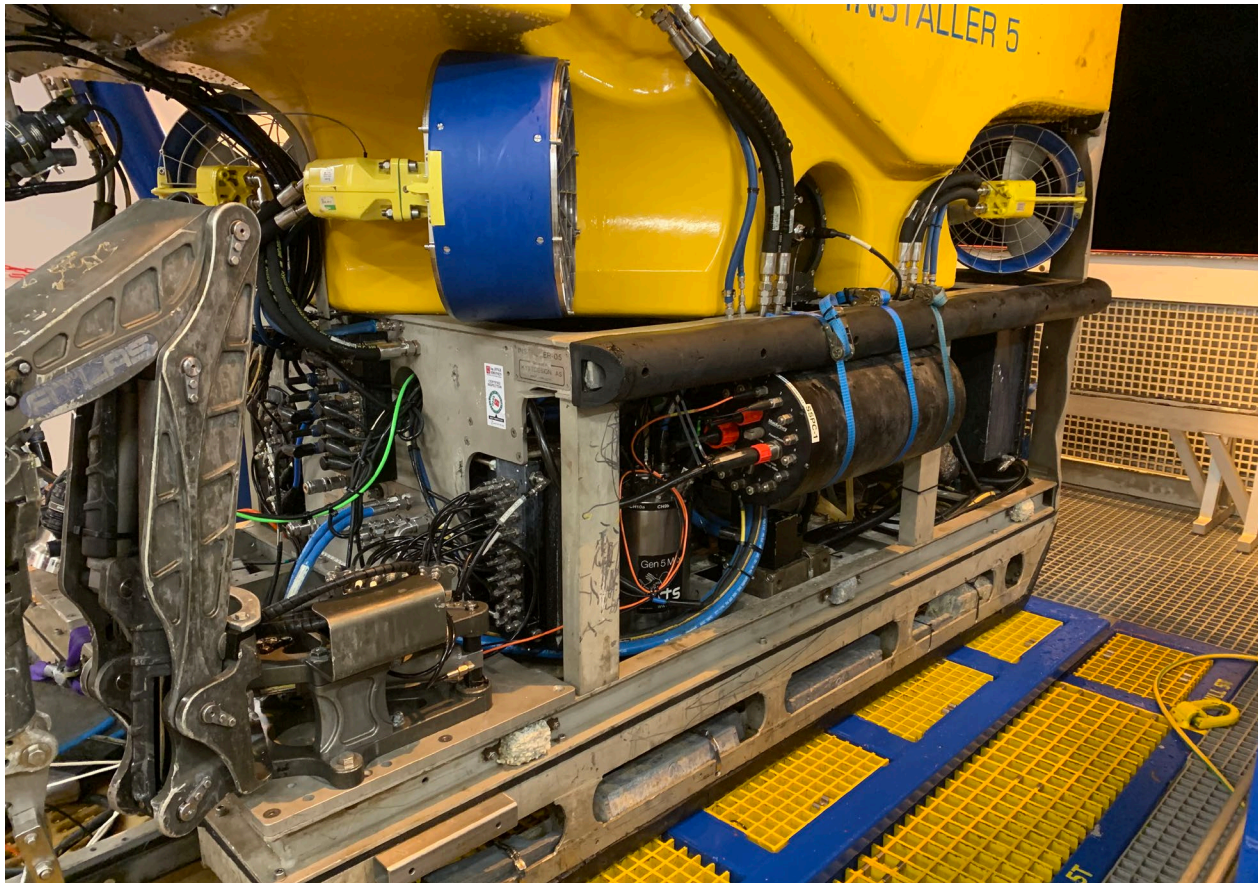




# Calibration curves

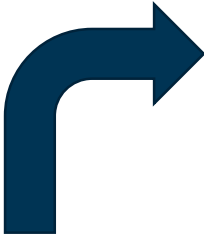


# Current

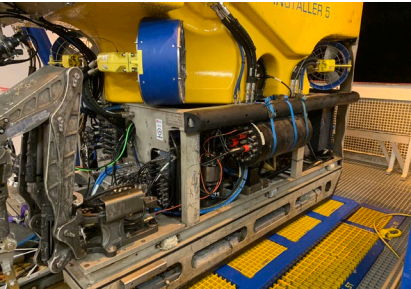
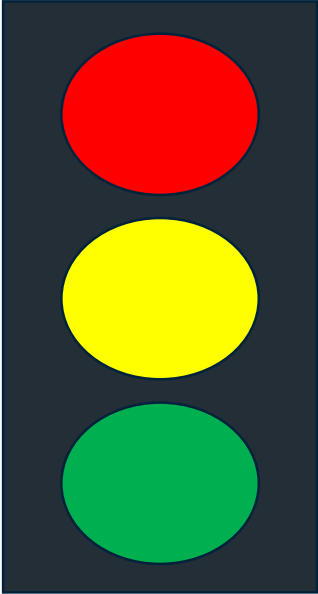
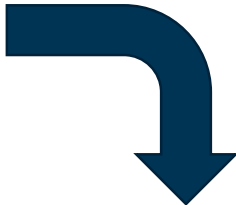




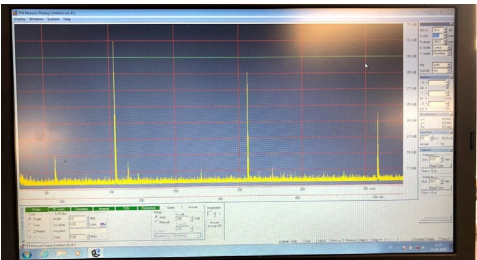
# Precision



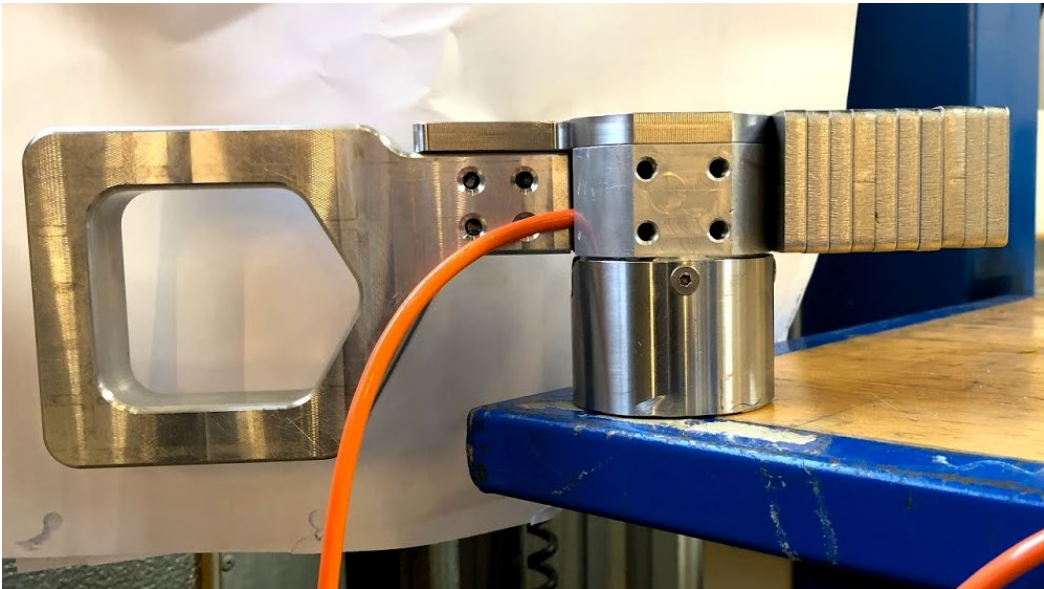
$d \sim 6 \%$



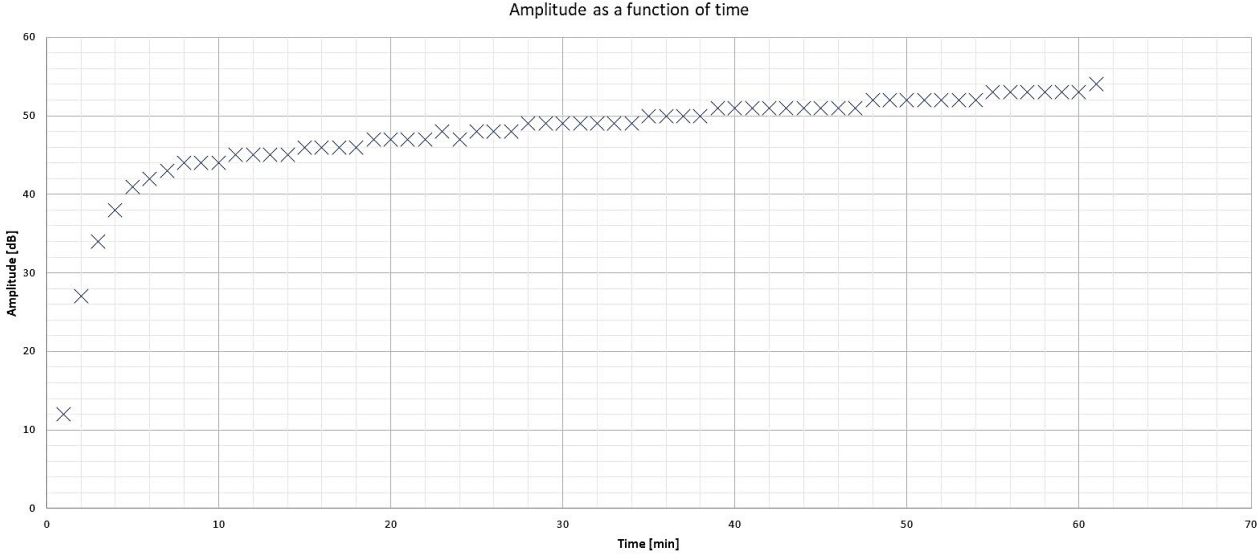
$d > 6 \%$



# Probe holder



# Couplant



# Conclusion

- Torque includes many variables, measure tension instead
- Mono-wave and bi-wave measurements possible
- Successful adaptation from topside to subsea use
- Still at an early stage, further testing necessary

Thank you