

**ELYFOG –  
development of robust  
electrical connections,  
pole shoes and busbars  
for EV**

**Presentation 260422**

**Jan Skogsmo  
RISE Research Institutes of Sweden AB**



# Testing and development of long-term reliable electrical contacts (ELYFOG)

**Project content and scope**

- The project focuses on bolted joints and mechanical joining for connectors and connections for electric vehicles. This applies mainly to demountable fixed joints, but not switches.
- Goal is to develop relevant testing methods and solutions for electrical contacts in electric vehicles. That includes testing under combined loading, new surface treatment solutions, optimized assembly parameters fulfilling requirement specifications for electrical contacts.

**Project deliverables**

- Analysis of application scenarios and relevant requirement specifications.
- Testing methods for combined loading and measurement of electrical contacts.
- Evaluated concepts for materials and surface treatment solutions for reliable contacts.
- Guidelines for fasteners, assembly, safety,...

**Project partners**

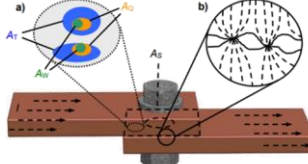
- RISE, Scania CV, Volvo AB, Volvo Cars, Northvolt, Micropowers, Provexa, Husqvarna, Stanley, Atlas Copco, Bulten, Harting, Elpress

**Needed competences:**

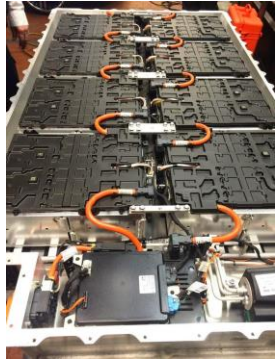
- Mechanical joining, electrical engineering, mechanical and environmental durability, material and surface treatment for electrical applications, education and information, standardization

**Project details**

- Apply for FFI Circularity ([28 March 2023](#)). Project start: Q3 2023. Project duration: 3 years. Project budget: >10 MSEK (50% in-kind)



Source: [1]



**Potential applications**

- Busbar contacts
- Grounding contacts

**Potential accelerated testing**

- Mechanical loads
- Environmental loads
  - Thermal loads
- Sequential vs. combined

**Potential evaluation**

- Contact resistance
- Oxidation and deformation
  - Clamping force
- Surface degeneration

**WP1  
Concepts, specimens and requirement specifications**

- Definition of application cases
- Definition of requirement specification for selected cases

**WP2  
Testing methodologies**

- Measurement methods
- Development of test methods for combined loading
- Comparison with existing testing methods
- Validation of testing concept with field tests

**WP3  
Evaluation of selected concepts**

- Testing of selected assembly parameters, surface treatments, conductor materials
- Testing in standardized tests and new combined test method
- Evaluation and ranking according to requirement specification and expected lifetime

**WP4  
Guidelines**

- Writing of documents for internal and external education
- Instructions for assembly of electrical contacts
- Derivation of best practices

**WP5  
Project management**

- Organise meetings and workshops
- Distribute results
- Report to VINNOVA
- Keep track of project budget
- WP leader: RISE



# Sometimes the knowledge is lacking



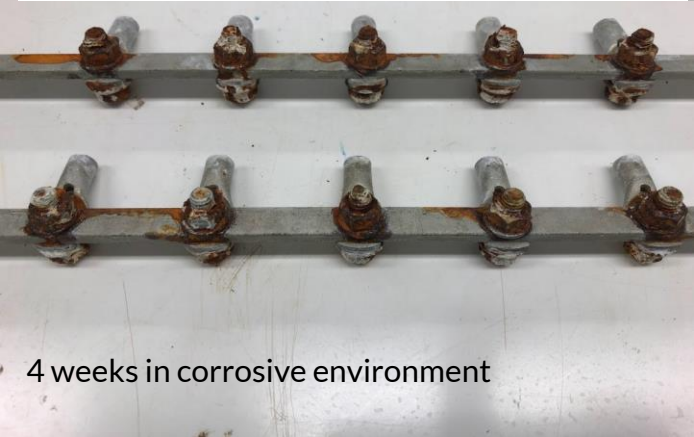
Automotive conditions can be very varying and demanding



A2M Tech



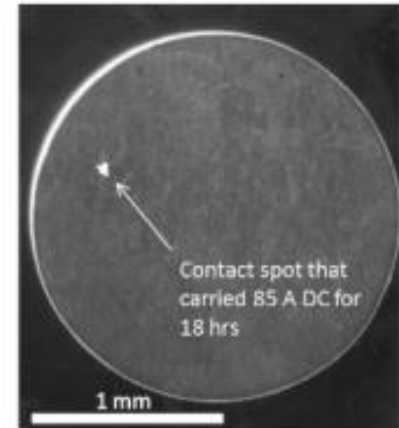
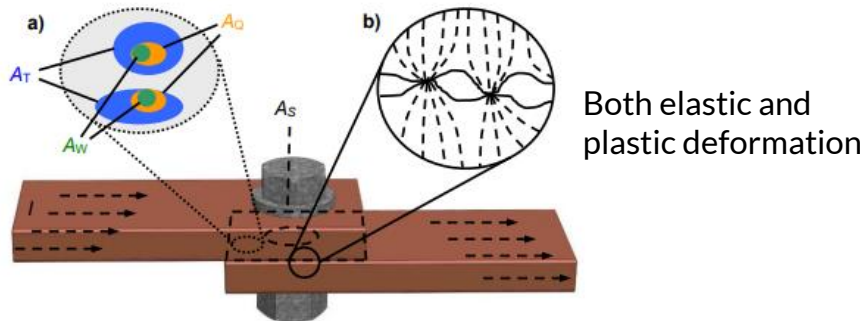
One winter in Norway



4 weeks in corrosive environment

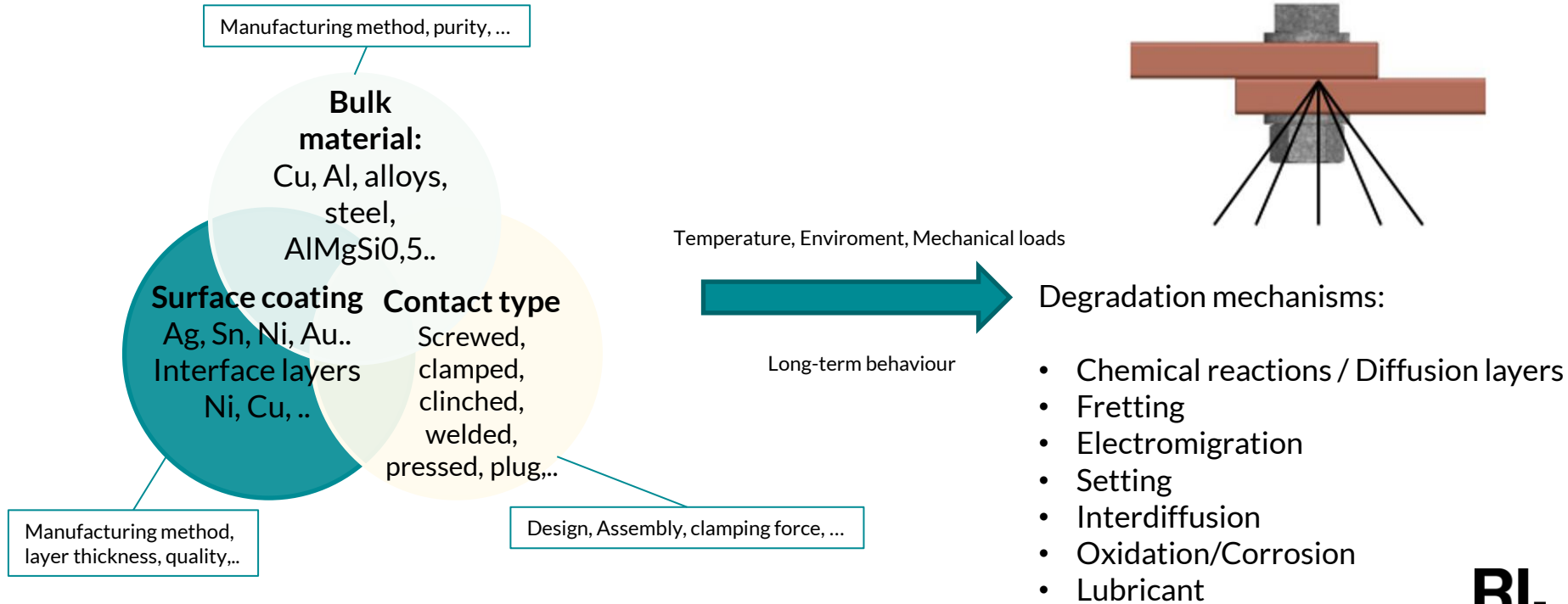
# Basics, electrical screw joints

- Metal to metal contact
- Micro roughness in contact area
- Nominal contact area > Load bearing area > Electrical contact area
- Only small spots "a-spots" carries the current



Polished aluminium  
DOI: [10.1109/HOLM.2019.8923842](https://doi.org/10.1109/HOLM.2019.8923842)

# Long-term stability of a contact



# Resistance measurement on conductive coatings

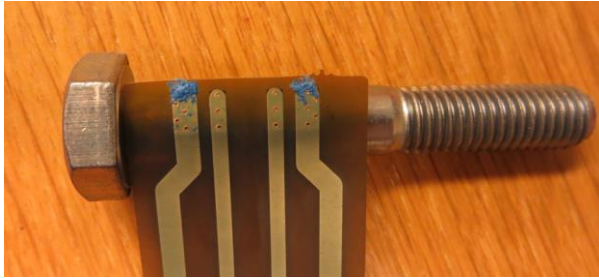
- Multimeter is not possible to use: the probes contact resistance will drown the results
- 4-point measurement with a relatively high current can measure down to  $\mu\Omega$



Megger mikroohm measurement unit with 2 voltage probes and 2 current probes

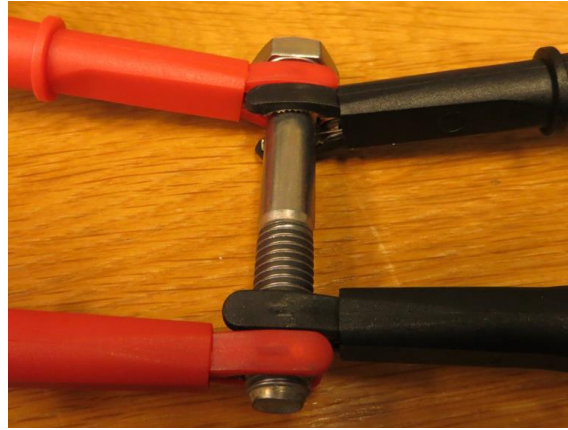
# Resistance measurement of coated parts

4-point square resistance



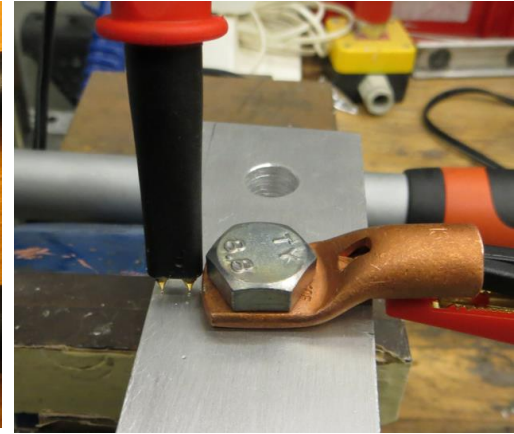
Soft contact probes  
No penetration of soft coatings,  
like passivation layers or oxides

4-point sharp probes



Probes penetrating to metal

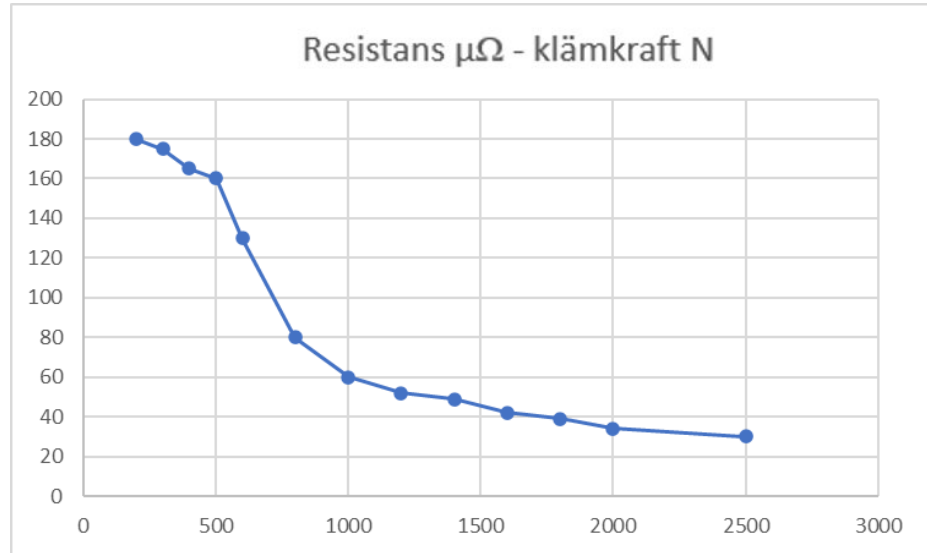
4-point sharp probes  
clamped contact surfaces



Probes penetrating to metal  
but clamped contact surfaces  
have intact coatings or oxide  
layers

# Measurements –

tinplated copper contact pressed by M10 screw against nickelplated copper bar



# Measurement of resistance under compressive force

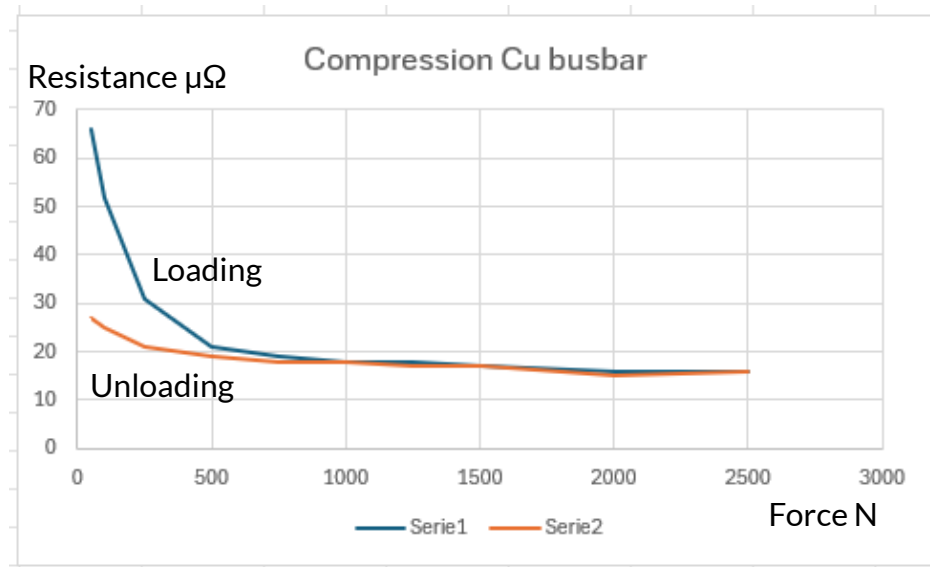
## In tensile testing machine



## By applying torque



# Compression Cu busbar

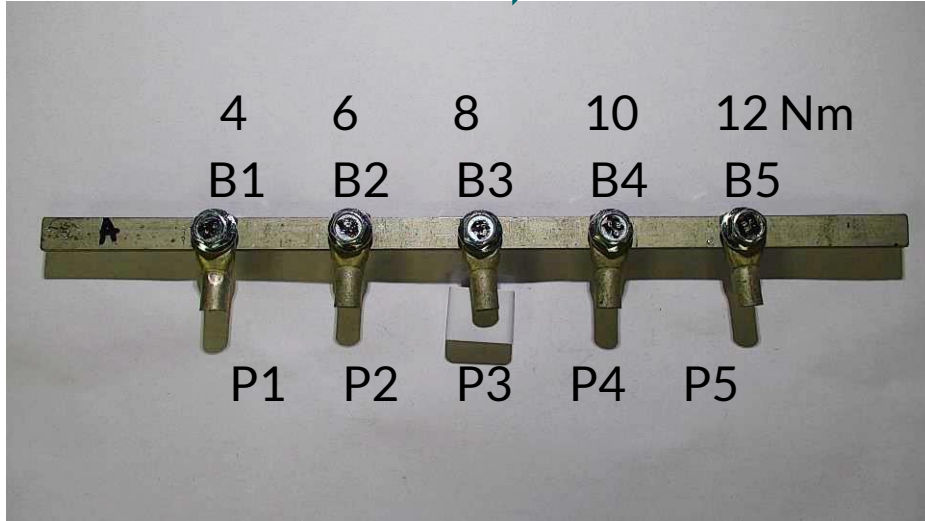


Torque Nm	Resistance $\mu\Omega$
0	70
2	15
4	13
6	12
8	13
10	13
12	12
14	13
15,5	12

Did not reach 16 Nm, plastic deformation

# Contact pressure (tightening torque) vs. Contact resistance

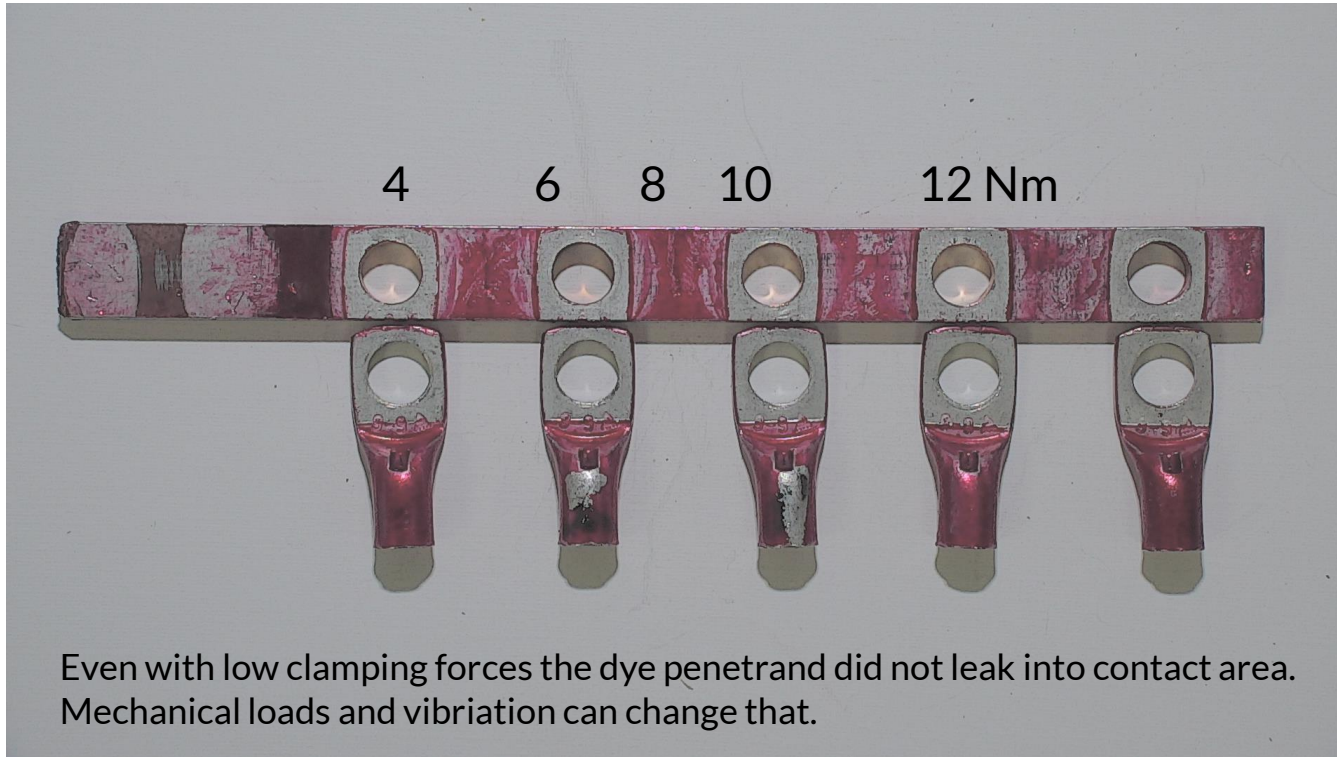
Increased tightening torque



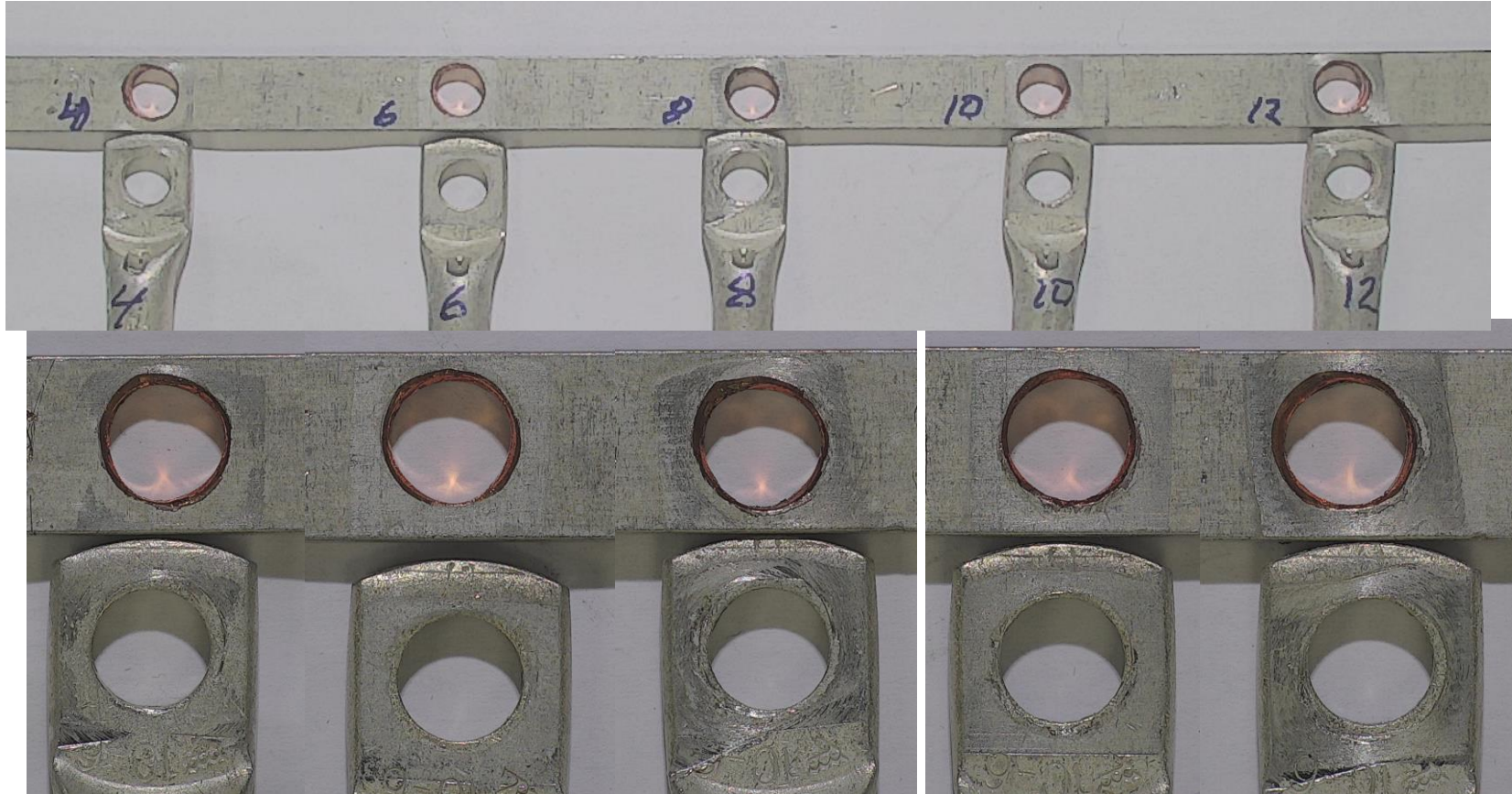
Red = Current Black = Voltage



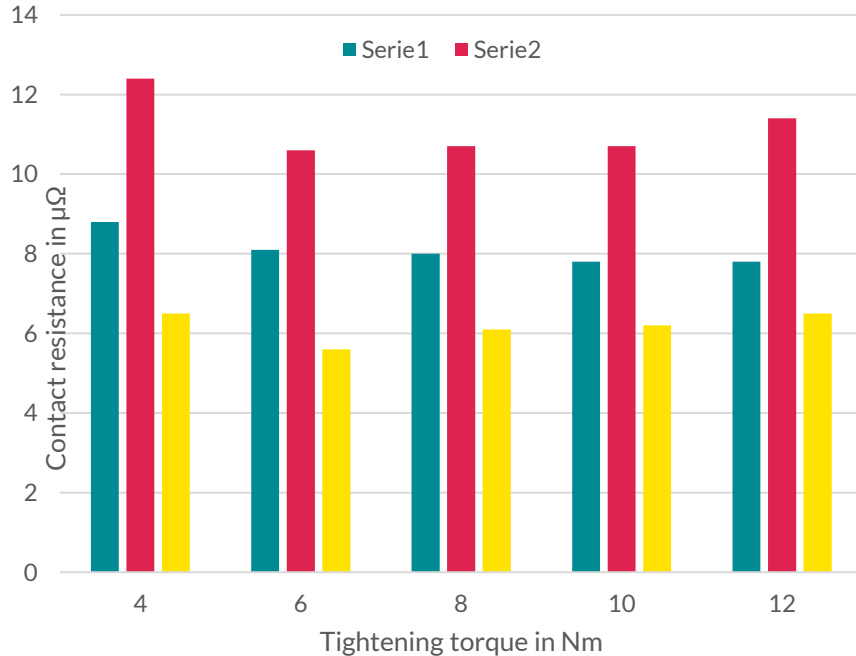
# Penetrant test, Sn-Cu – M6



# Bar A - after Climate test



# Contact resistance vs. Climate

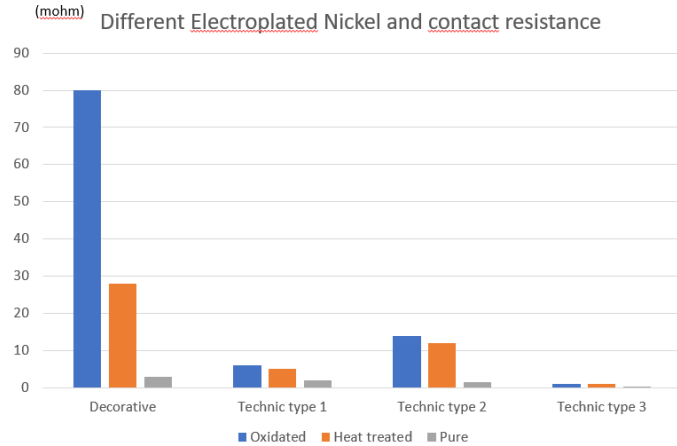


- Serie 1: busbar-cable lug
- Serie 2: after busbar-cable lug after 2 weeks climate chamber
- Serie 3: busbar-screw head after 2 weeks climate chamber

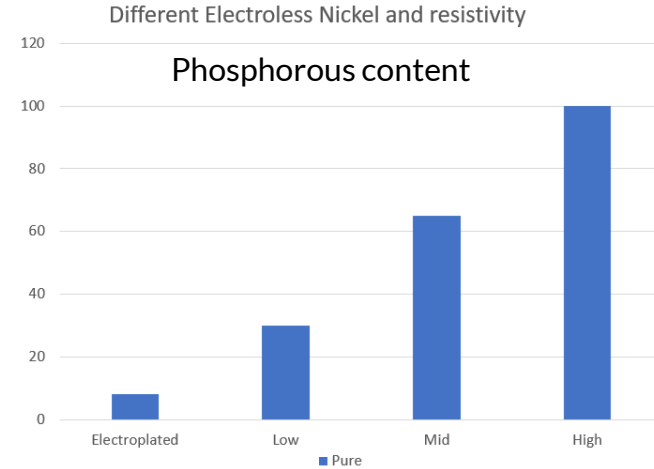
# Surface treatment for electrical contacts

See below list for different nickel platings and their electrical resistivity.

Materia	Electrical resistivity microhm-cm
Nickel as pur metal	6,85
Bright nickel	10
Mattnickel	8,6
Sulfamatenickel	7,76
EN low phosphorus	30
EN mid phosphorus	65
EN High phosphorus	100



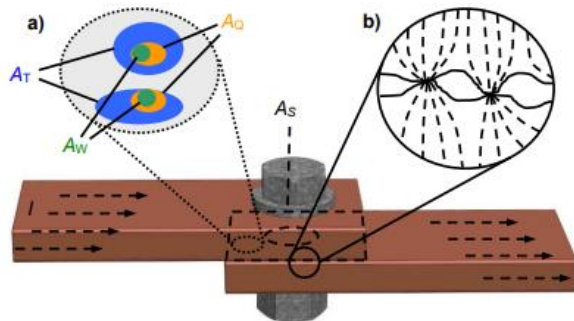
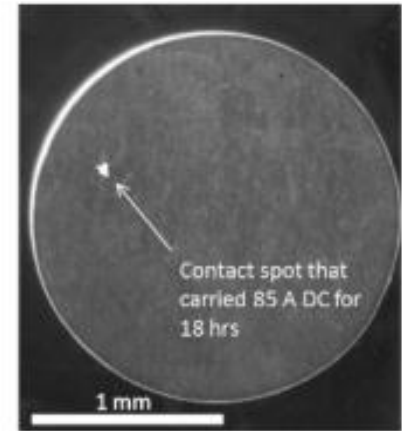
**PROVEXA**  
Surface Technology



**PROVEXA**  
Surface Technology

# Basics, electrical screw joints

- Metal to metal contact
- Micro roughness in contact area
- Nominal contact area > Load bearing area > Electrical contact area
- Only small spots "a-spots" carries the current



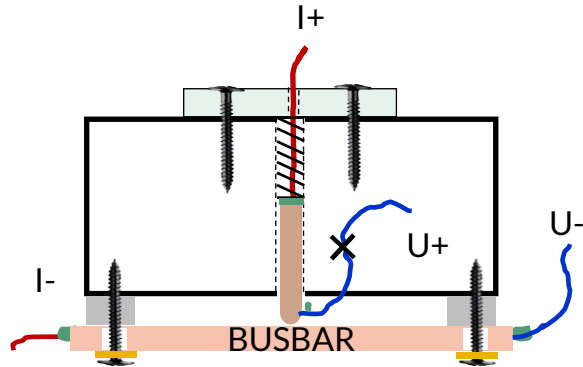
Both elastic and plastic deformation

Polished aluminium  
DOI: [10.1109/HOLM.2019.8923842](https://doi.org/10.1109/HOLM.2019.8923842)

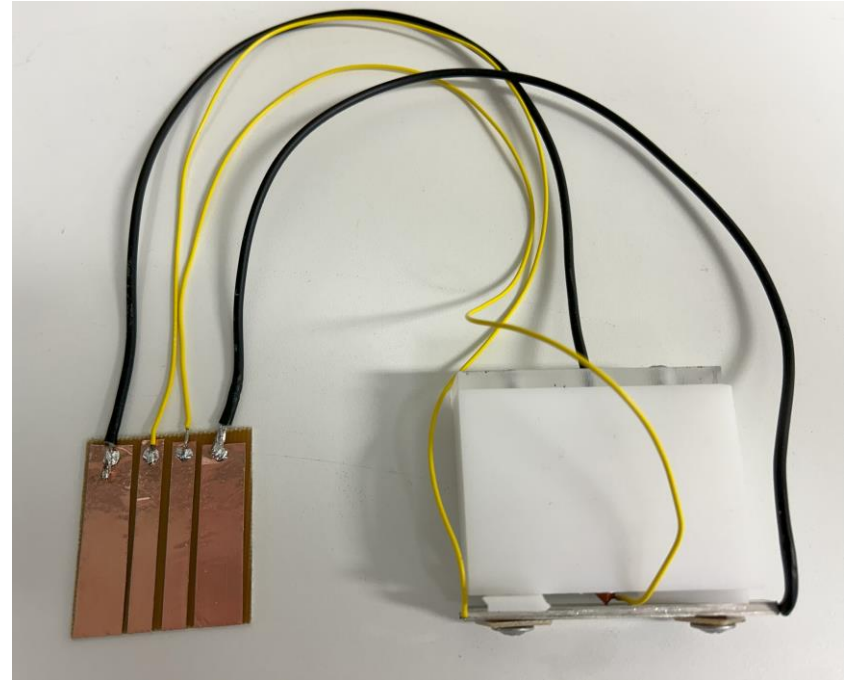
Cu => Al

# WP2, Method development

- Improve understanding and screening of parameters

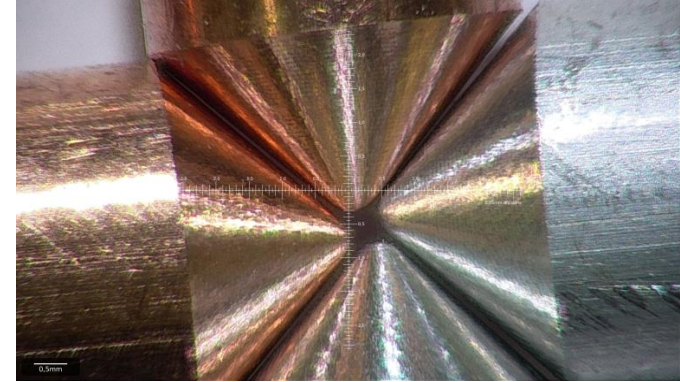
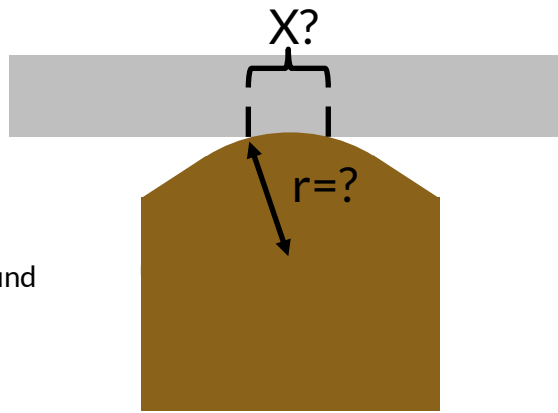


- Defined contact point for analysis
- Constant force
- Different exposures
- Four-point resistance measurements

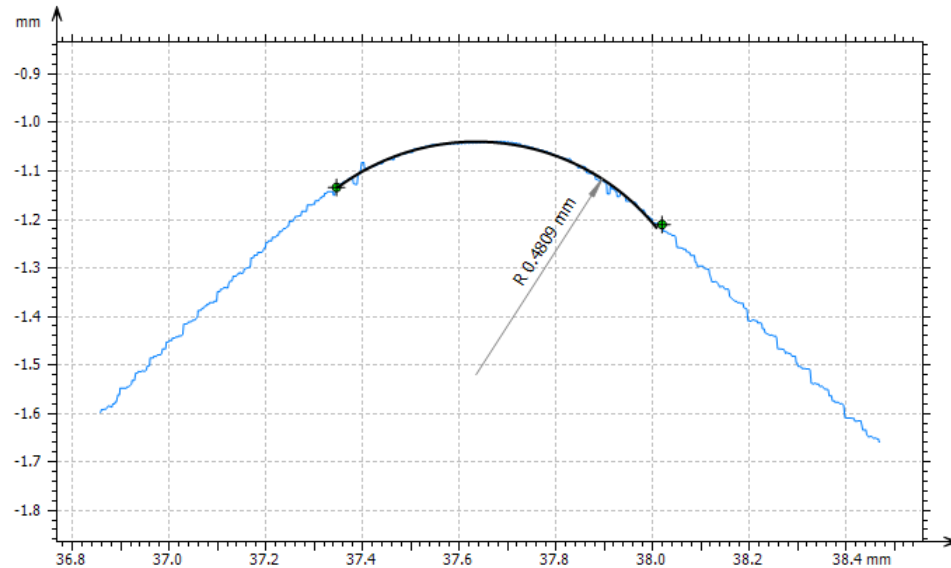
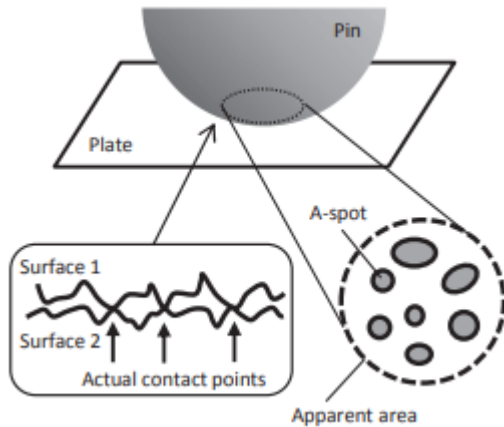


# Contact tip

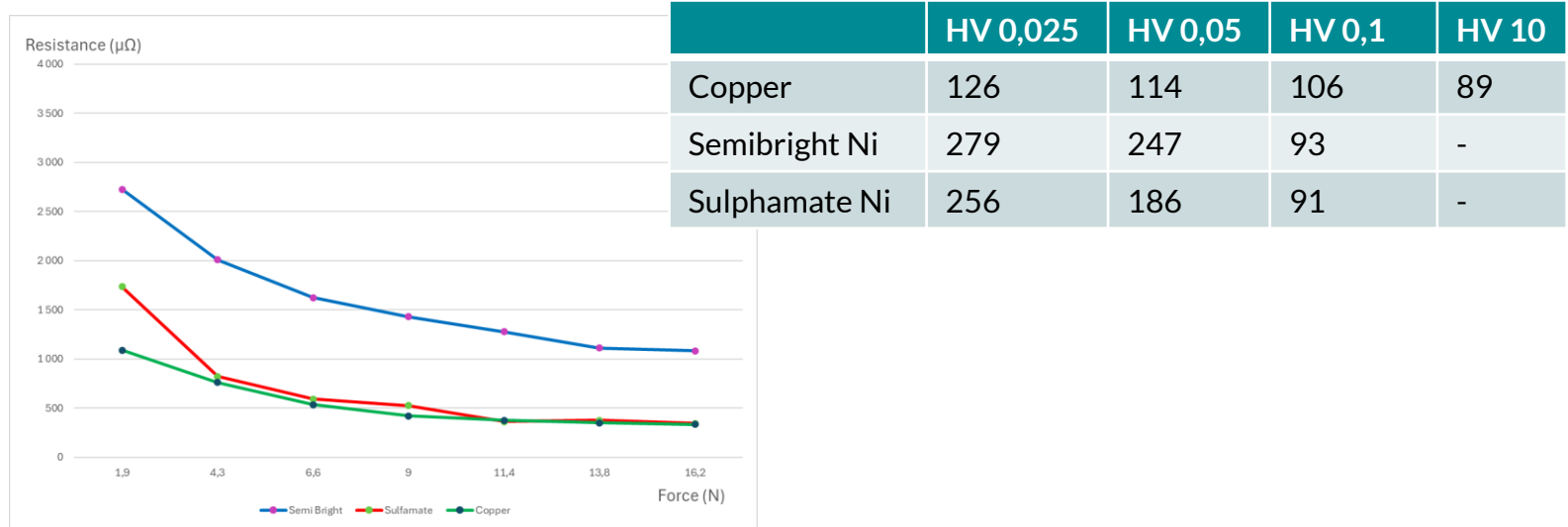
- Aim:
  - Defined indent that can be found
  - Rather flat contact area
  - No interlocking penetration
  - Contact area =  $f(\text{surface roughness})$



CNC machining of 0,5 mm radius tips

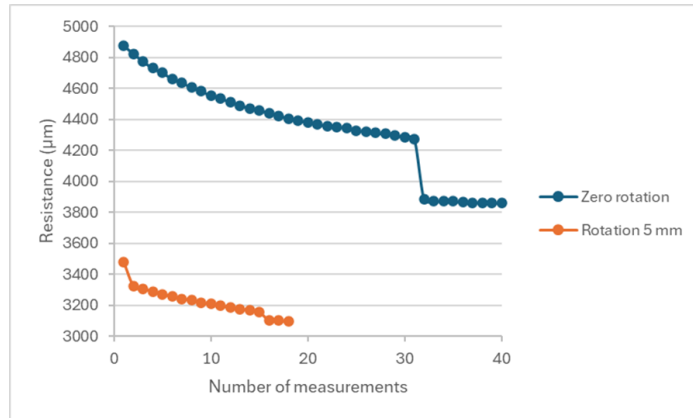


# Contact resistance as function of force with all four curves averaged. Blue curve is semi-bright nickel, red is sulfamate nickel and green is copper.



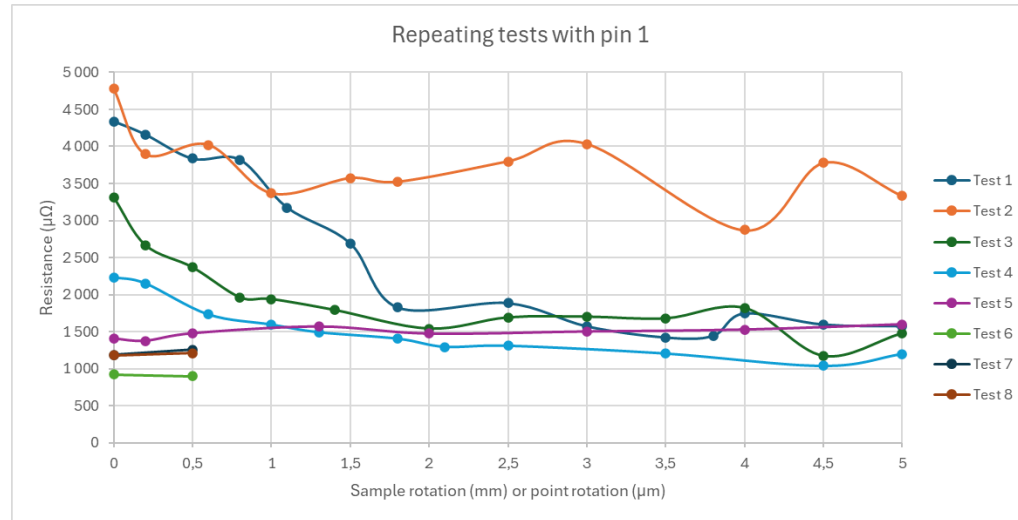
# Resistance under constant force

## Force adjustment to 10 N, measurement current 1 A

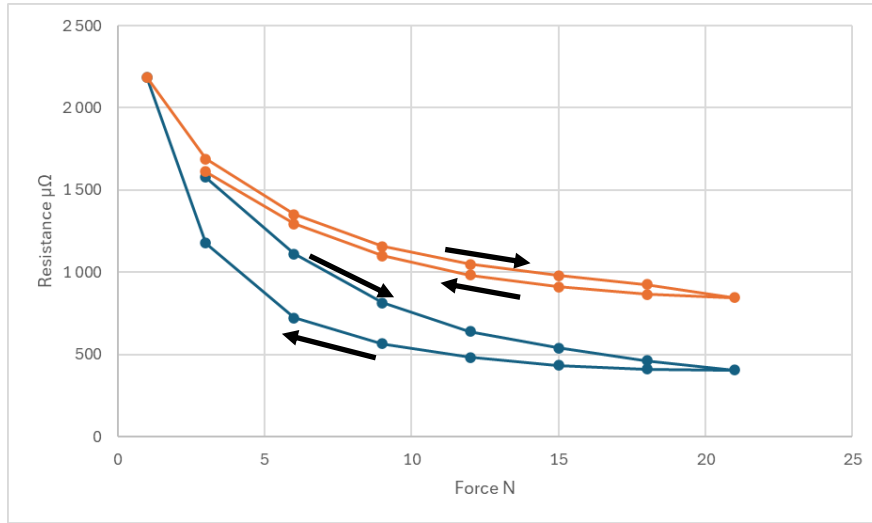


- Continuously measurement, with a few seconds in between, of resistance with a 20 min pause after 31 measurements.
- Then repeating the continuously measurement after 5 mm rotation.
- The current seems to break down or compact the oxide?

# Resistance when rotating the pin



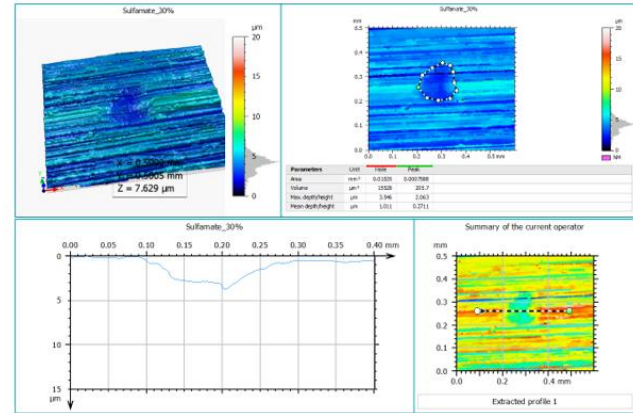
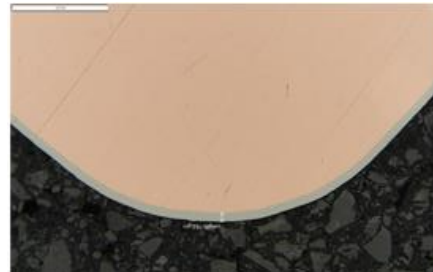
# Oxide removal tests (etching)



The blue curve is the first load cycle.

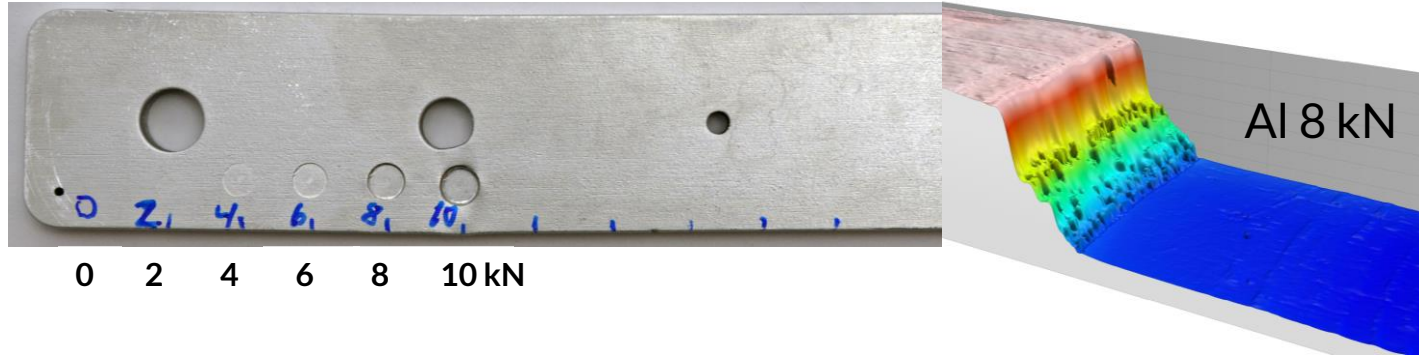
Resistance of HCl-etched (19 µm, 50 N) sulfamate nickel tip into etched sulfamate 5 m busbar at 21 N.

The second load curve has significantly higher resistance. The explanation may be deformation of active metal surface followed by relaxation and oxide growth?

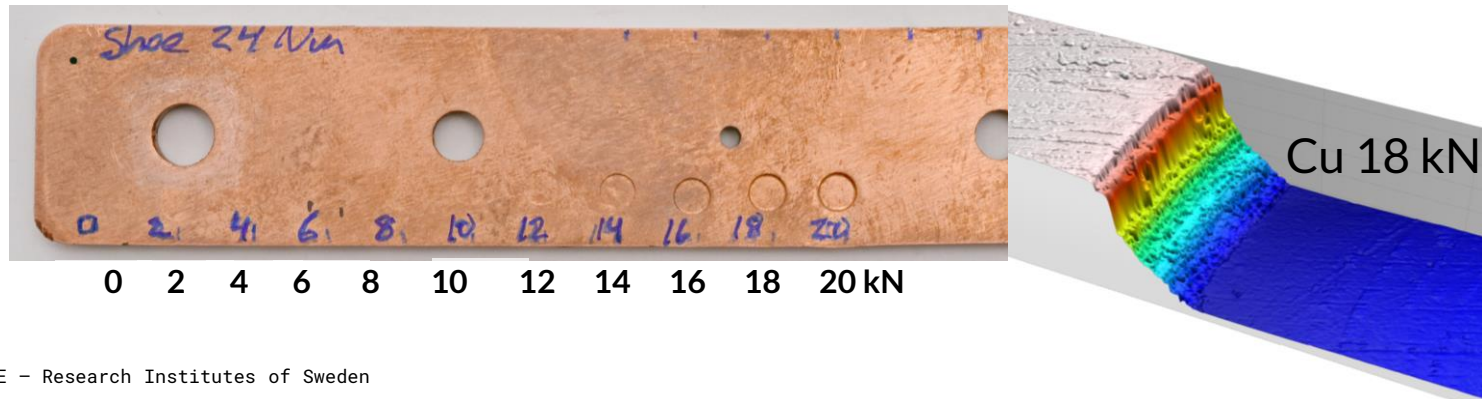


# Deformation of busbars

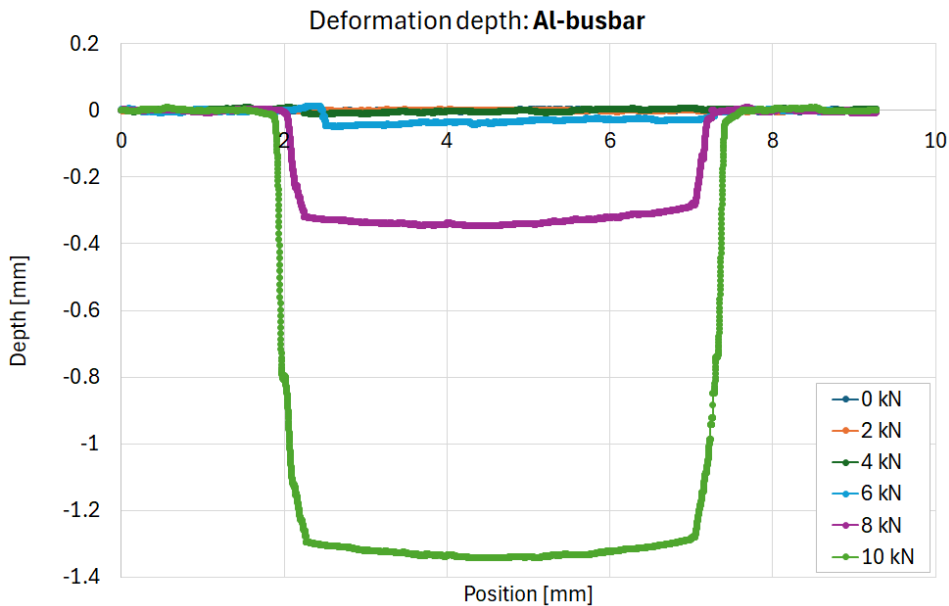
**Al-busbar**      **Material AA 1370-50 Dimension 190 x 30 x 5 mm**



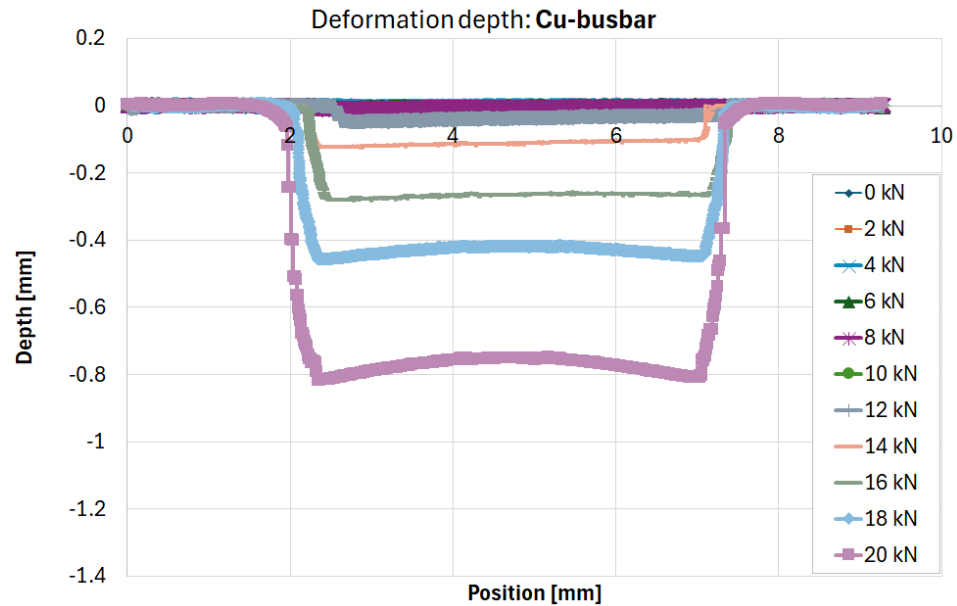
**Cu-busbar**      **Material CW004A Dimension 190 x 30 x 5 mm**



# Deformation depth

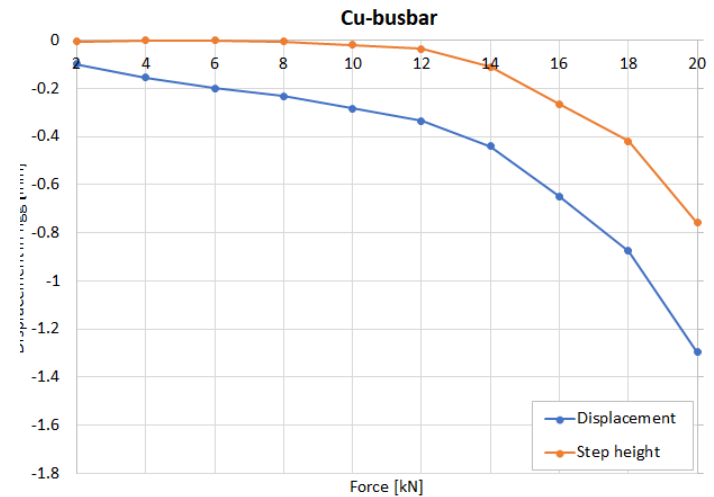
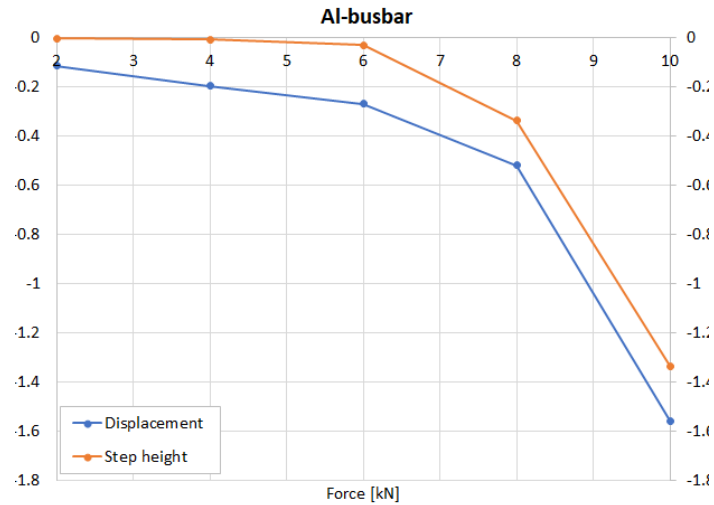


10 kN is far too high for the Al material

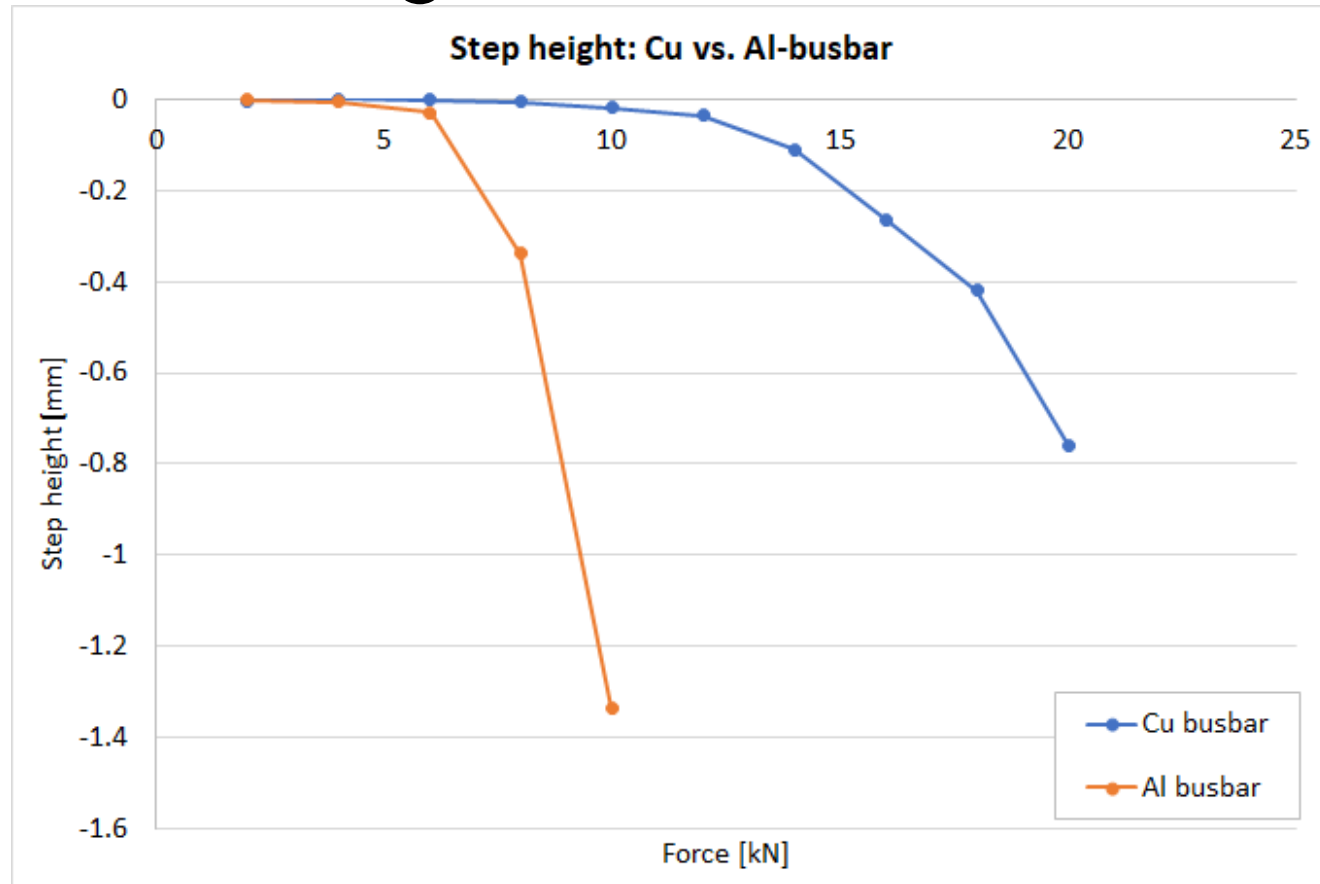


20 kN is slightly too high for the Cu material

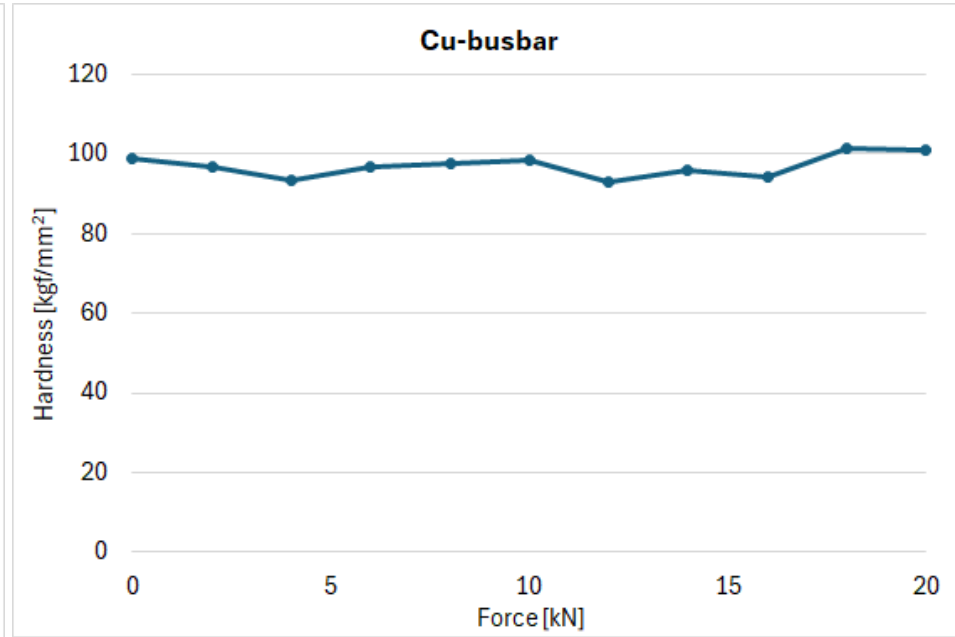
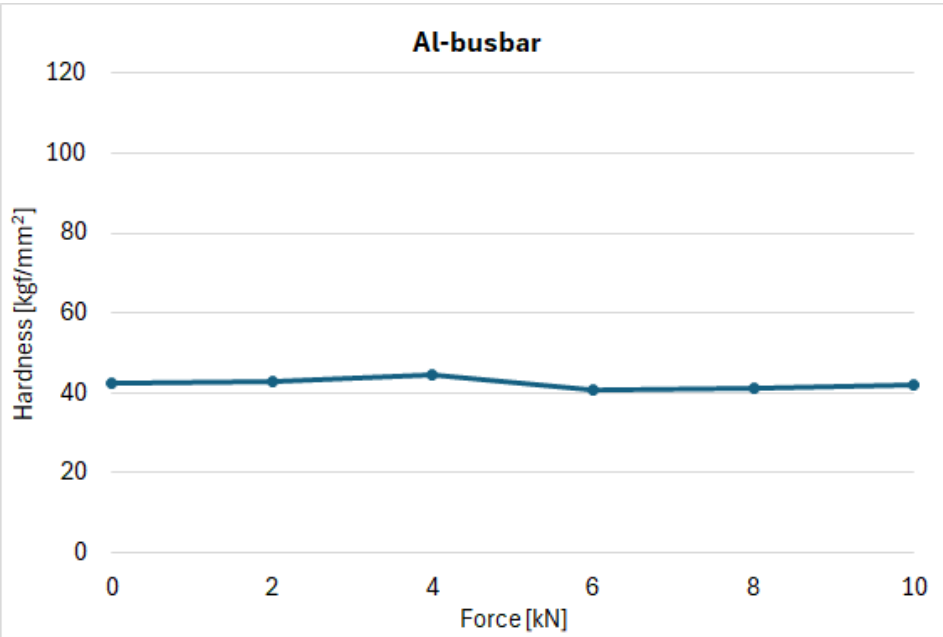
# Step height and displacement in rigg



# Step height



# Hardness: HV0,5



No deformation hardening observed!

# Combined temperature and vibration



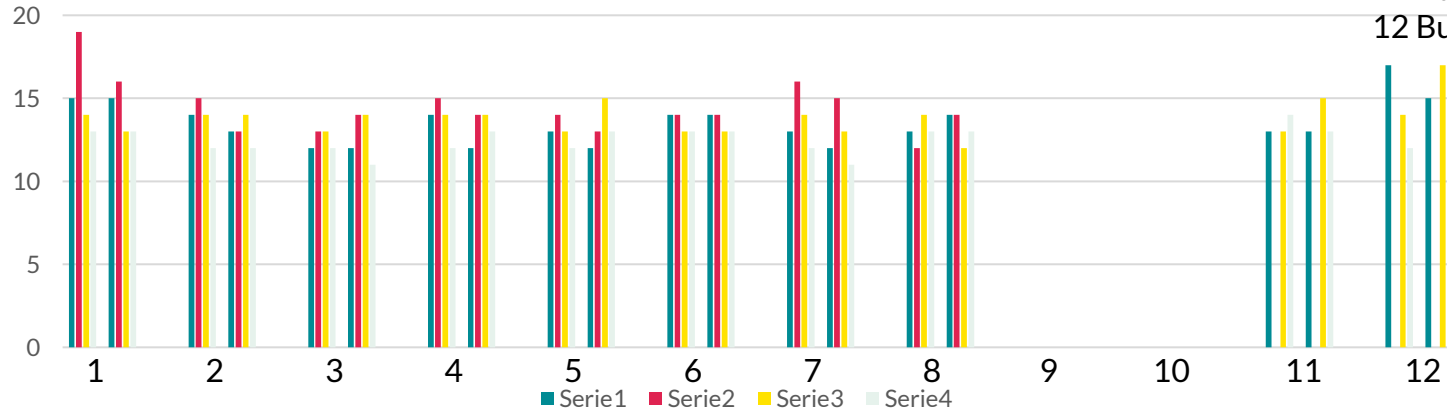
- 200 h with combined vibration and temperature cycling
- Temperature: - 40 °C – + 72 °C, 5 °C/min, stop 20 min at extremes
- Vibrations: random 4 g RMS in x-direction

# Resistance cable shoe - busbar

R1	After assembly			
R2	After vibration test			
R3	After temperature cycling			
R4	After combined vibration and temperature cycling			

- 1 Washer 16 Nm
- 2 Washer 20 Nm
- 3 Washer 24 Nm
- 4 Washer+Belleville 16 Nm
- 5 Washer+Belleville 20 Nm
- 6 Washer+Belleville 24 Nm
- 7 Pressscrew washer 16 Nm
- 8 Pressscrew washer 20 Nm
- 9 -
- 10 -
- 11 Busbolt round
- 12 Busbolt flat

Resistance  $\mu\Omega$



# Assemblies after combined testing

