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DRESDEN concept

# Influence of Selected Coatings on the Welding Result During Magnetic Pulse Welding (MPW)

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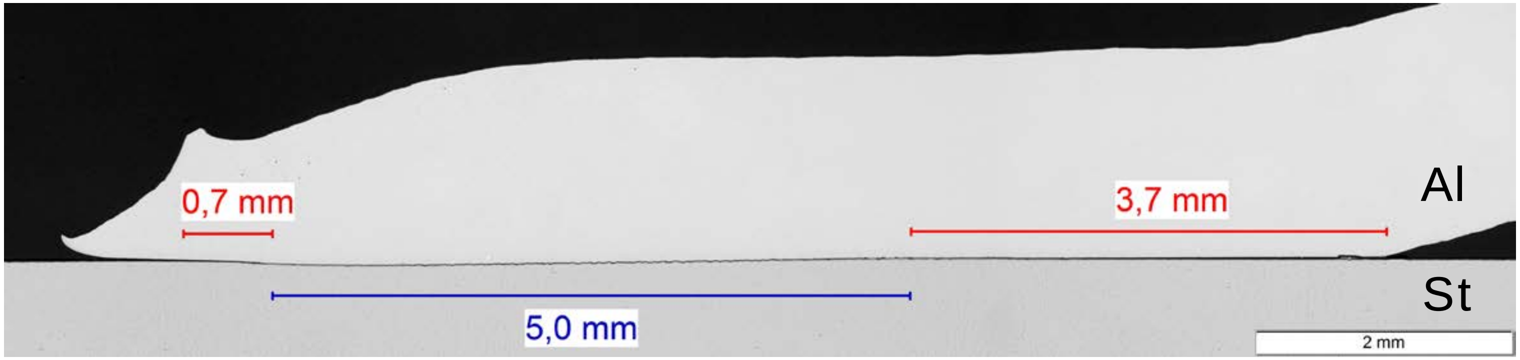
# Agenda

1. Motivation for MPW
2. Experiments with coatings and results
3. Classification of coatings
4. Tailored joining: Outlook



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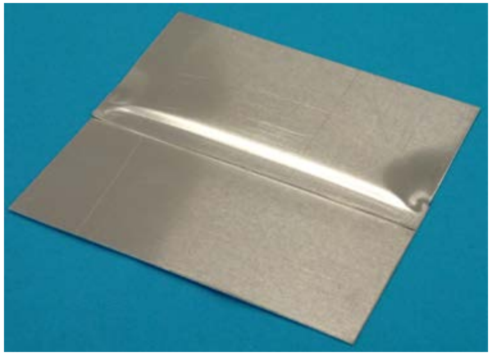
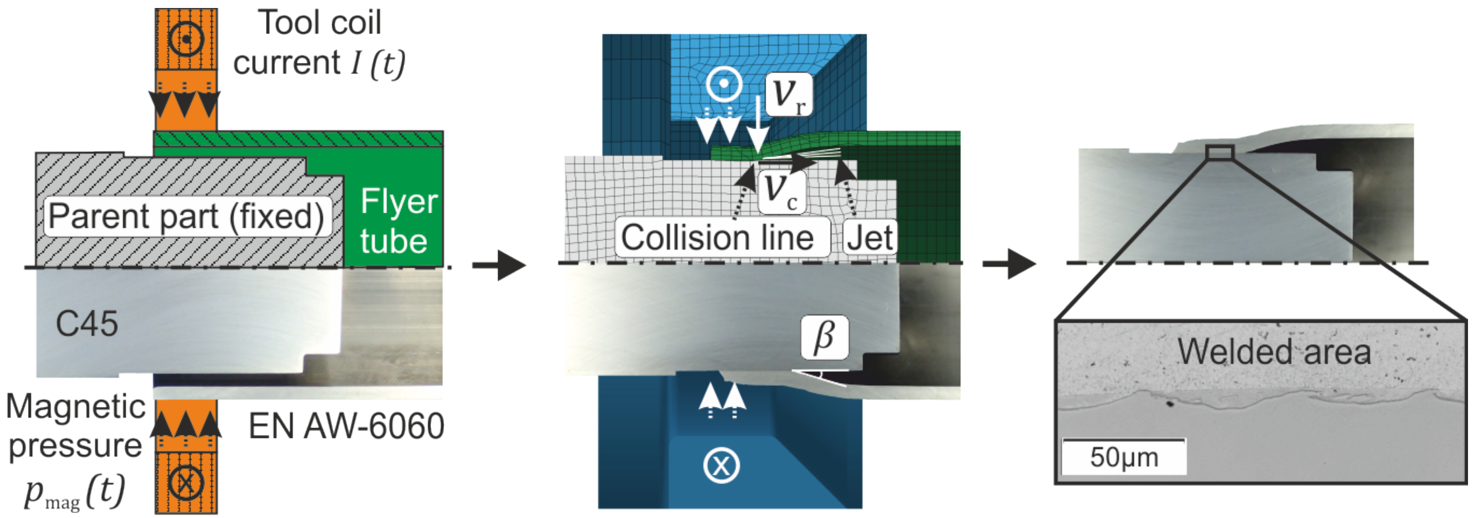
# 1. Motivation for MPW

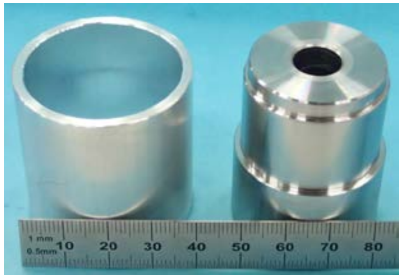
- **Outstanding**: Similar and dissimilar metal joining
- **Wide ranging**: Applicable for tubular and flat parts
- **Nice side effects**: Fast and clean

- **Surface preparation:**
    - Mechanical treating
    - Cleaning
    - Coating



# Process of MPW with tubular parts

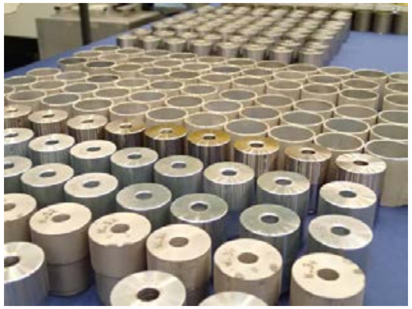


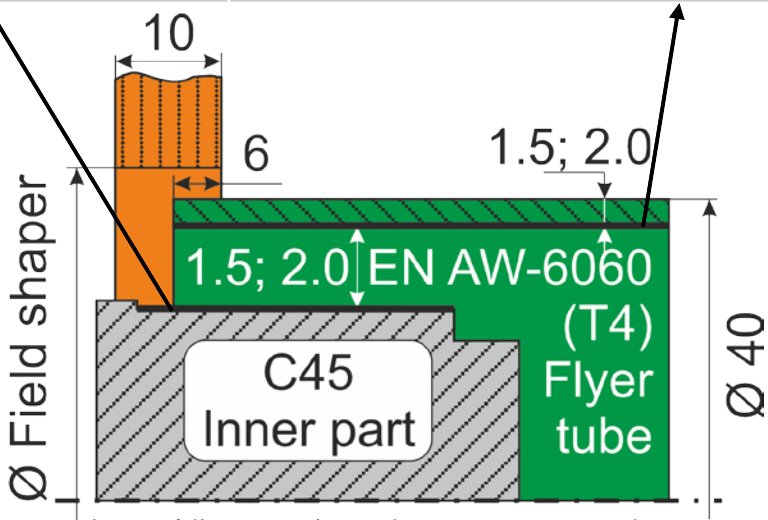



Are typical industrial coatings compatible with magnetic pulse welding?

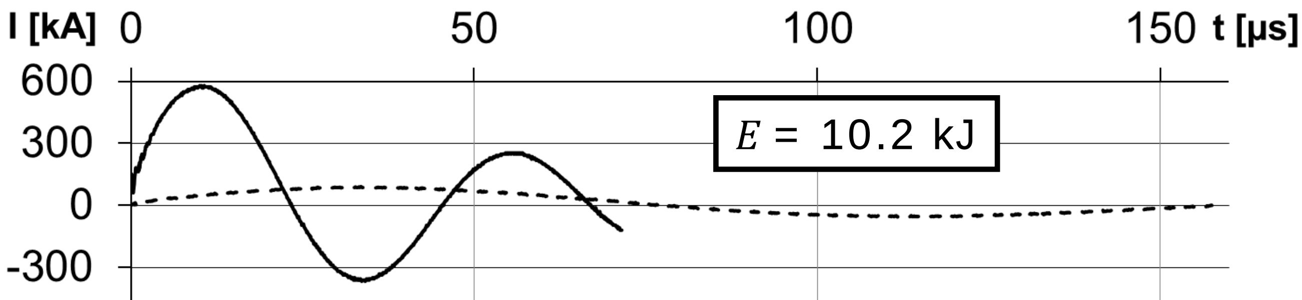
## 2. Experiments with coatings and results

| Inner part | Flyer tube |
|---|---|
| Electroplating nickel 5 µm | Anodized 5 µm, 10 µm |
| Electroplating zinc 5 µm, 10 µm | Hard anodized 15 µm |
| Nitrated | Chromated |
| PVD nickel 2.5 µm | Acid passivated |
| PVD chrome 1.5 µm | |



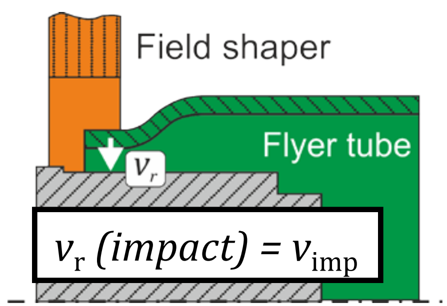


# Parameters of pulse stations: Tool coil current I(t)




$f \approx 20$ kHz
$I_{max} = 580$ kA
**$v_{imp}$ = (380…460) m/s**

$f \approx 7$ kHz
$I_{max} = 86$ kA
**$v_{imp}$ = (240…260) m/s**

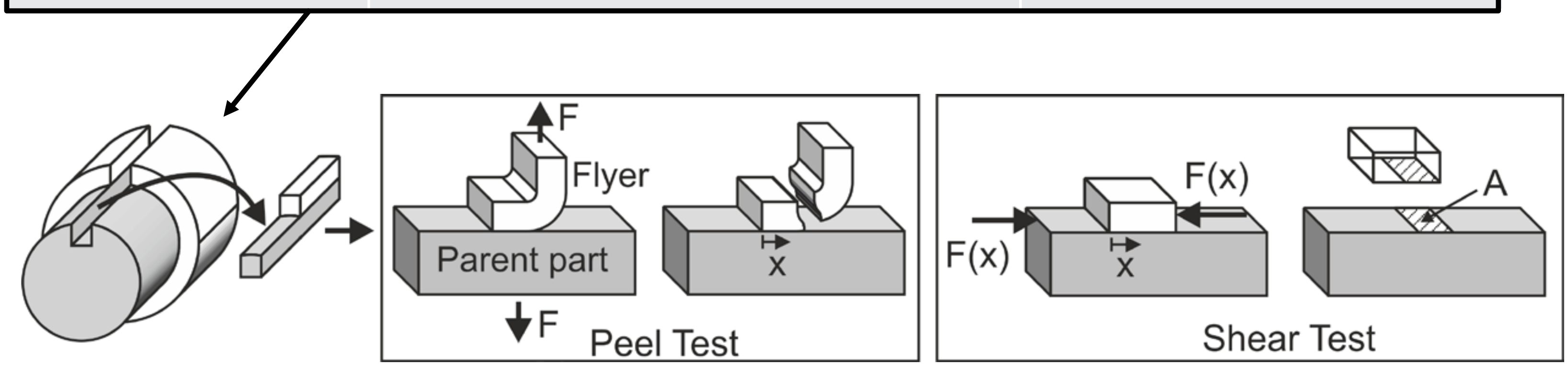



Bmax MPW50/25:
single turn coil, integrated
Ø 42 mm field shaper

Maxwell – Magneform 7000:
8-turn coil with Ø 41 mm
field shaper

# Basic results after cutting the flyer tube

| | Inner part | Flyer tube |
|---|---|---|
| Not welded | Electroplating zinc 5 & 10 µm | Hard anodized 15 µm |
| | Nitrated | Anodized 10 µm |
| Difficult to weld | | Anodized 5 µm |
| Welded | Electroplating nickel 5 µm | Chromated |
| | PVD nickel 2.5 µm | Acid passivated |
| | PVD chrome 1.5 µm | |

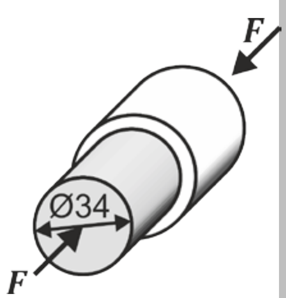


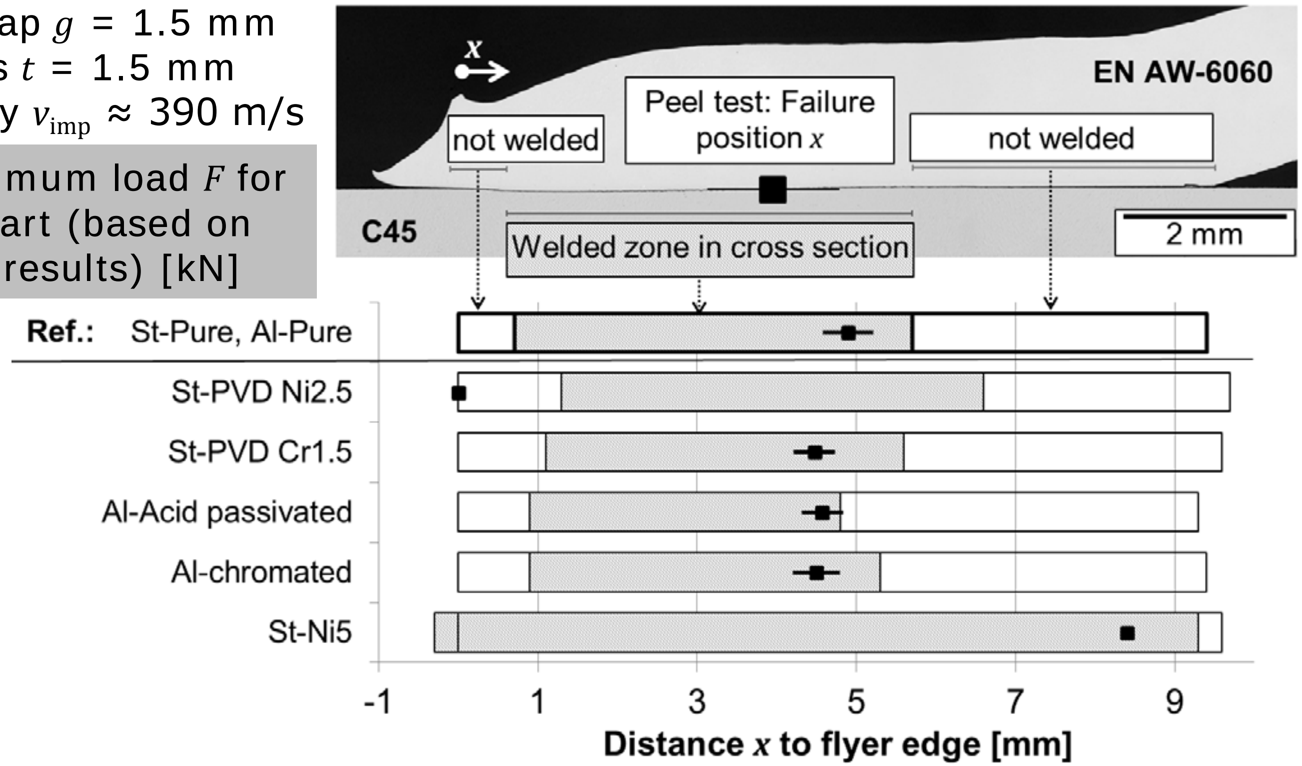
# Welding results: Length and strength

Acceleration gap $g$ = 1.5 mm
Tube thickness $t$ = 1.5 mm
Impact velocity $v_{imp}$ ≈ 390 m/s

Average maximum load $F$ for complete part (based on shear test results) [kN]

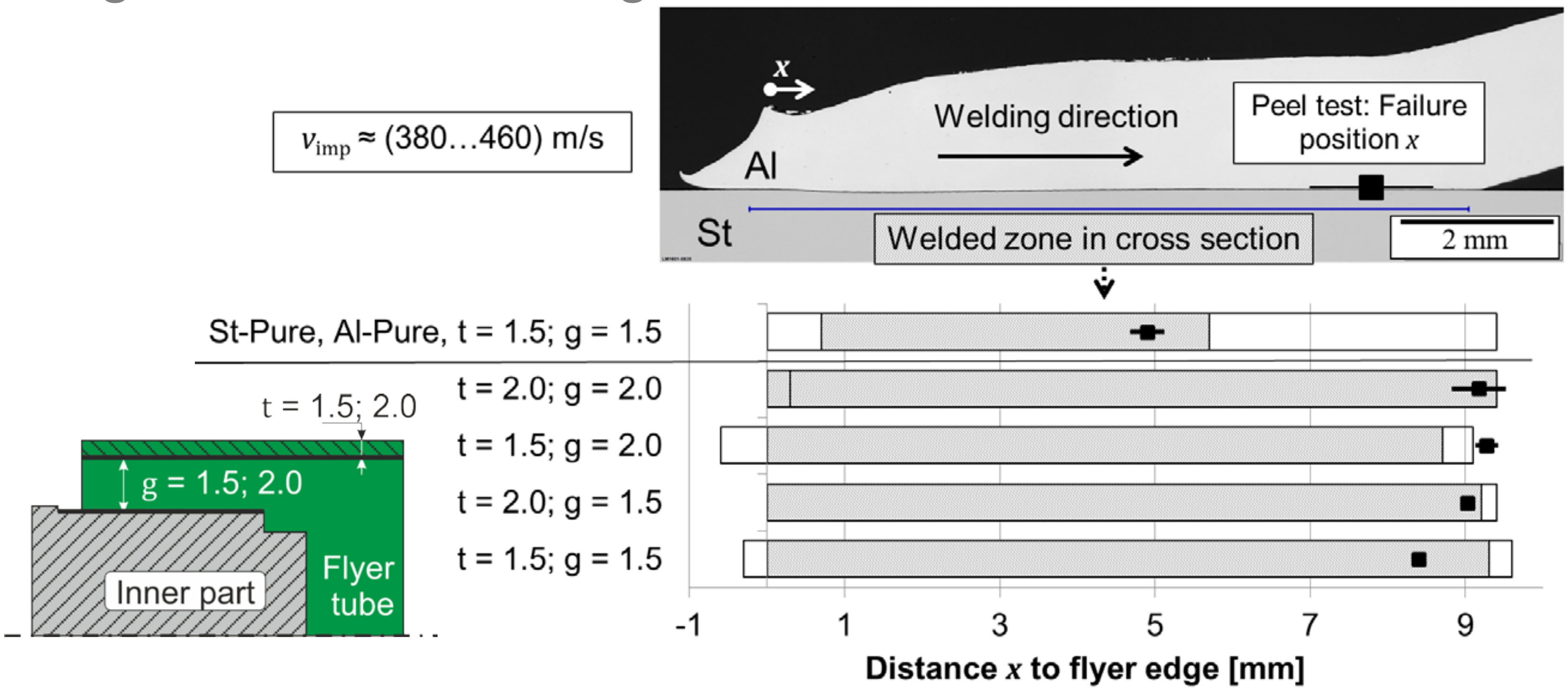
| | |
|---|---|
| Ref.: St-Pure, Al-Pure | 76 |
| St-PVD Ni2.5 | 70 |
| St-PVD Cr1.5 | 81 |
| Al-Acid passivated | 61 |
| Al-chromated | 73 |
| St-Ni5 | 139 |




**Electroplating nickel 5 µm clearly increases the weld length and the maximum load**

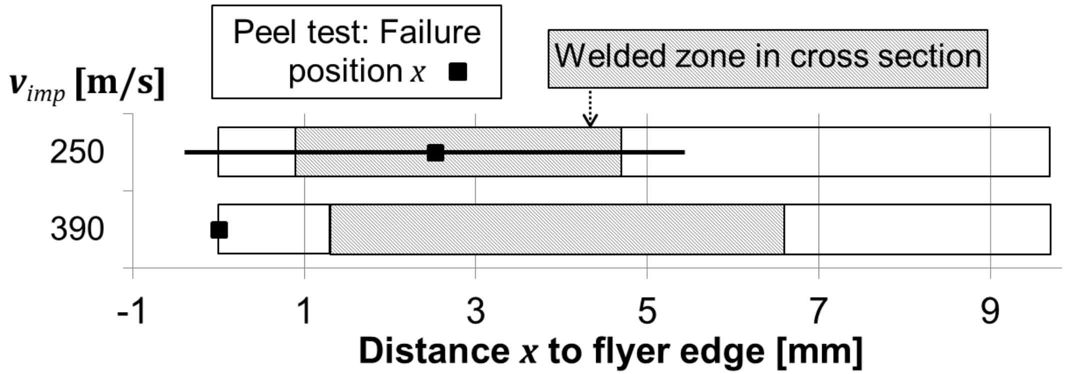
# Focus: Electroplating nickel 5 µm in different geometrical configurations

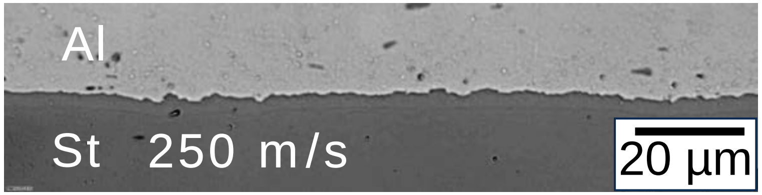


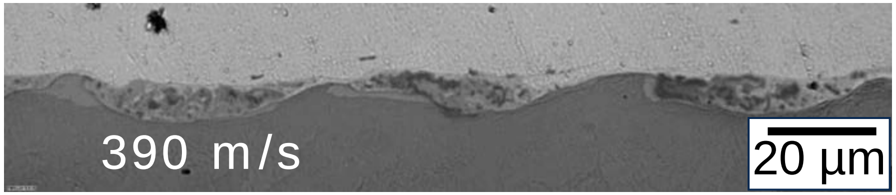

Electroplating Nickel 5 µm increases the weld length during MPW in all tested configurations

# Focus: Impact velocity

Parameters: PVD Ni 2.5 µm, $E$ = 10.2 kJ, $t$ = 1.5 mm, $g$ = 1.5 mm

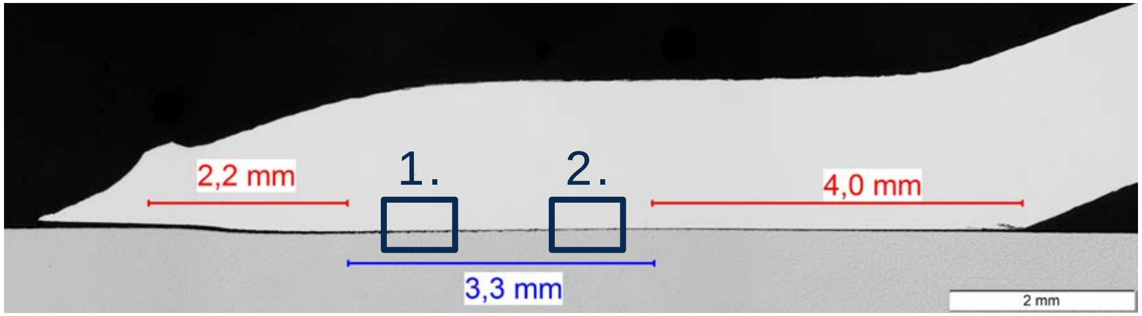


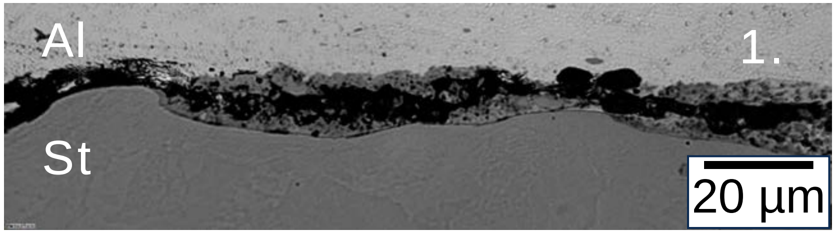



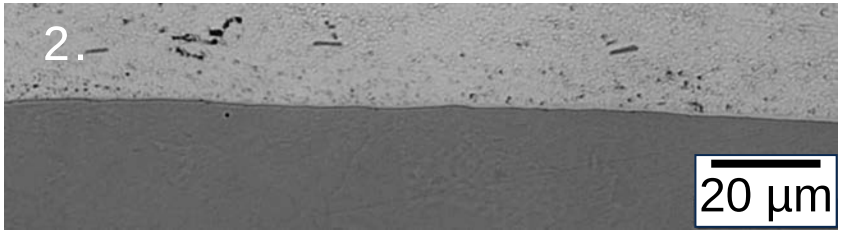




High impact velocity → wavy interface

# Focus: Anodized aluminum




Global deformation of the flyer fractures the anodized layer

1. Before start of jetting: Embedded layer
2. With jetting: Removed layer

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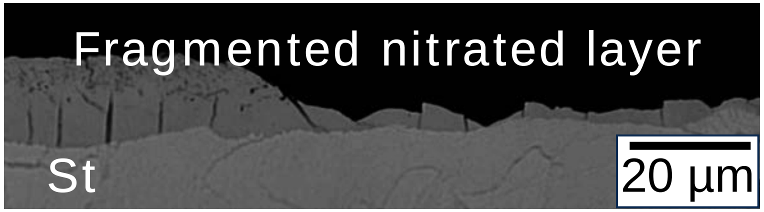
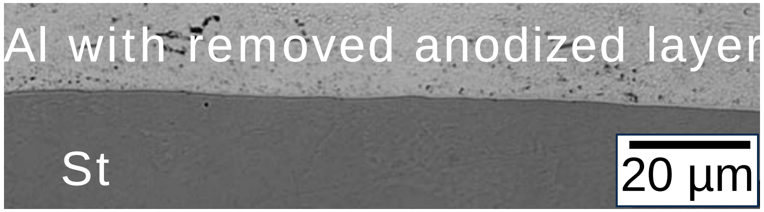
# 3. Classification of coatings
## Type I – Brittle surface coatings

| | Inner part | Flyer tube |
|---|---|---|
| Coatings | Electroplating zinc 5 & 10 µm<br>Nitrated | Hard anodized 15 µm<br>Anodized 5 & 10 µm |
| Fragmentation | Partly (delaminated) | Strongly |
| Removable by the jet | Not completely | Completely (Anodized 5 µm) |

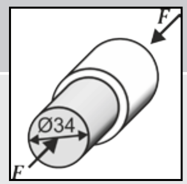


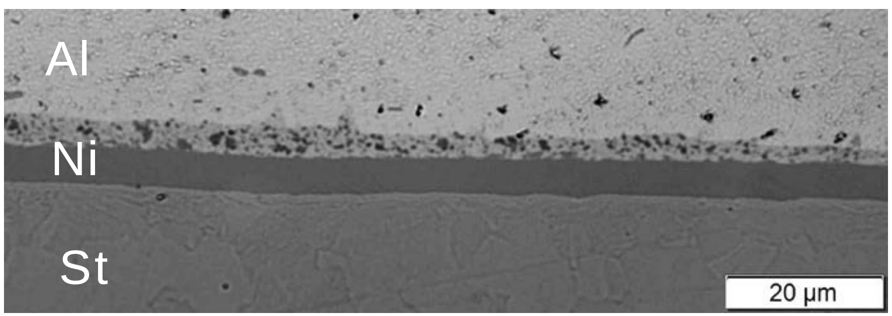




Brittle surface coatings: Weldability depends on the amount of deformation prior jetting

# 3. Classification of coatings
## Type II – Thick and ductile surface coatings

| Coating inner part | Shear strength [MPa] | Average maximum load F for complete part (based on shear test results) [kN] | Weld length [mm] |
|---|---|---|---|
| - | 143±8 | 76 | 5 |
| Electroplating nickel 5 µm | 140±17 | 139 | 9,6 |




Thickness $t$ = 1.5 mm

Gap $g$ = 1.5 mm

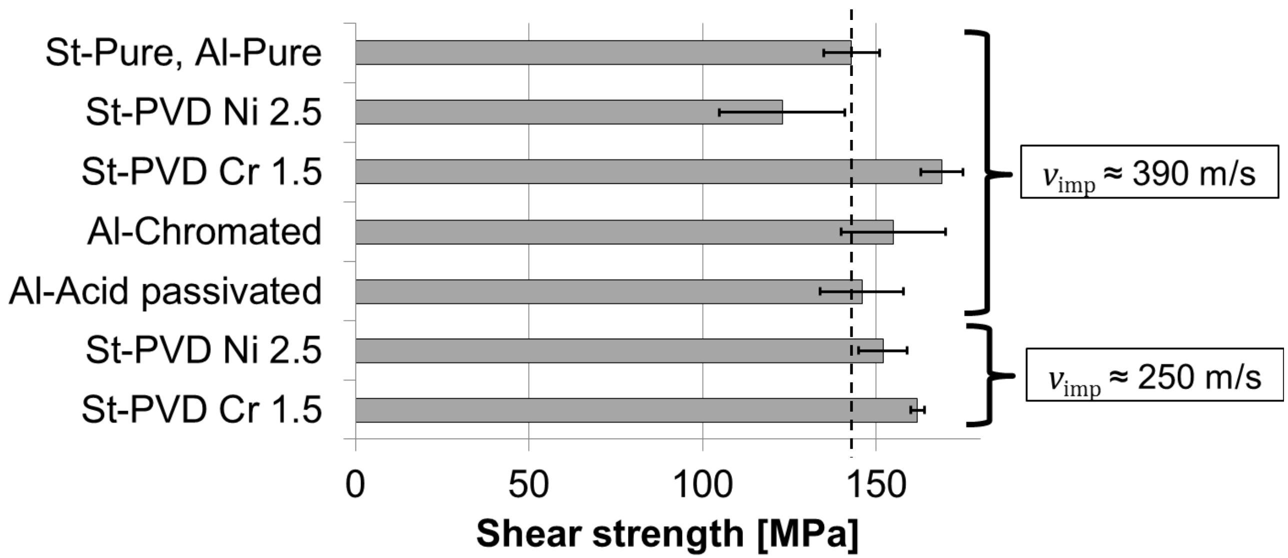
Energy $E$ = 10.2 kJ

Impact velocity $v_{imp} \approx$ 390 m/s

**Thick and ductile layers: Increase of weld length and maximum load**

# 3. Classification of coatings
# Type III – Thin and ductile surface coatings

Tube thickness $t$ = 1.5 mm, gap $g$ = 1.5 mm, energy $E$ = 10.2 kJ




Thin and ductile layers: Embedding in the weld interface is possible with modified strength

# 3. Classification of coatings – Three types

I. Brittle:
→ unfavorable on the inner part
→ feasible on the flyer tube

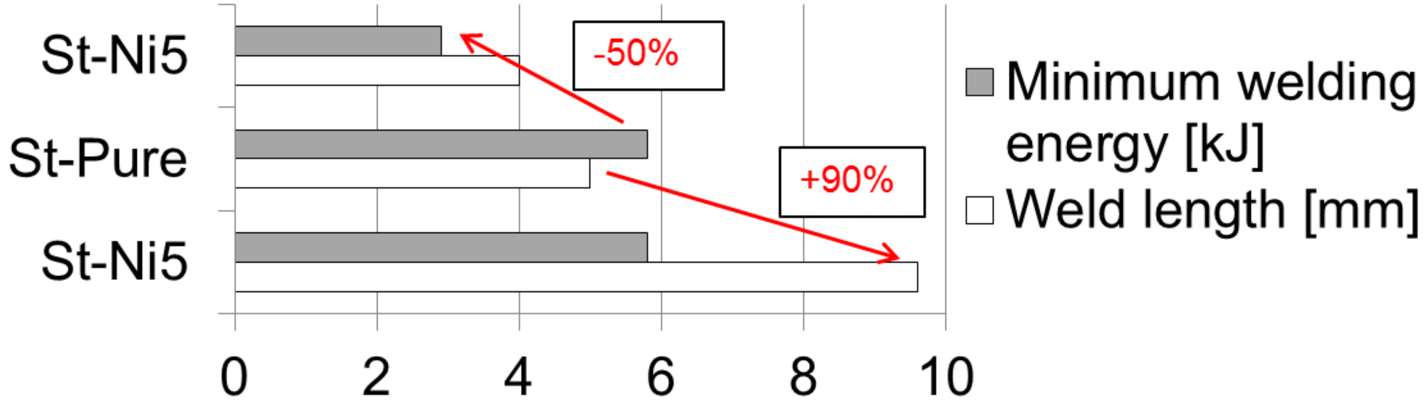
II. Thick and ductile:
→ improved weld length and quality

III. Thin and ductile:
→ uncritical for magnetic pulse welding

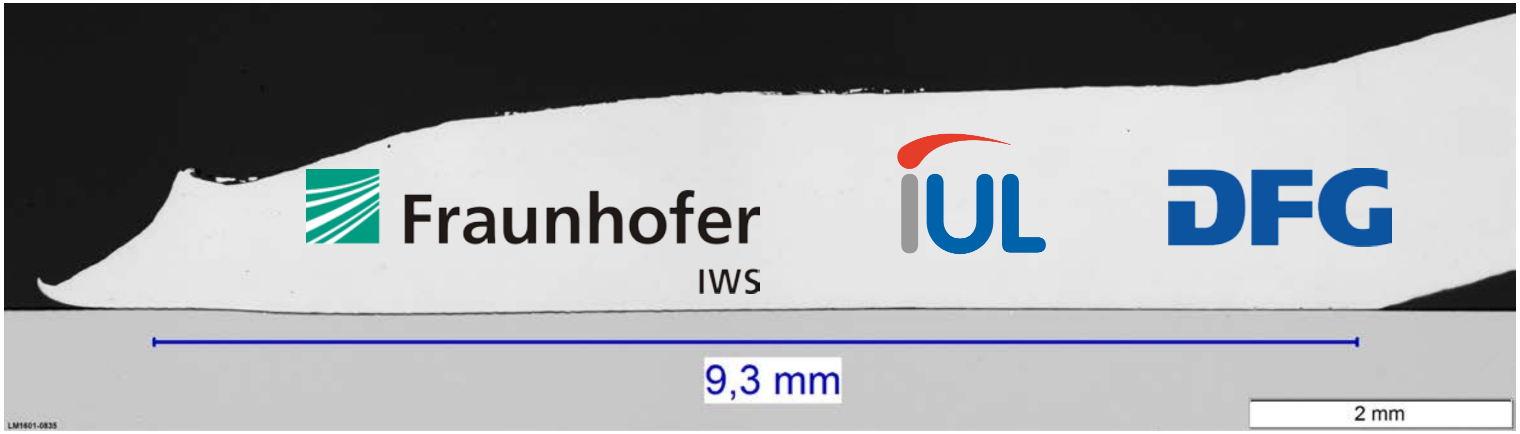
# 4. Tailored joining: Outlook

For welding of EN AW-6060 to C45, electroplating nickel 5 µm (on steel) can:

- Increase the weld length ⬄ decrease the energy




- Lower the necessary impact velocity for welding
- Avoid spallation of already welded areas





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