Latest research activities in Coating technologies focusing on thermal spraying

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Coating Technologies – Research Group

Research focuses on coating development with high properties and performances for harsh conditions such as icing, corrosion and wear as well as additive manufacturing. Key coating technologies are thermal spraying and cold spraying.

“We are developing future coatings by starting from material optimization through coating processing to final performance towards more sustainable future.”

Group members:
- Ruqaya Khammas, Reza Jafari, Betul Aktas, Razieh Alikhanifaradonbeh (PhD researchers)
- Niklas Kandelin (Project researcher)
- Eero Helmi, Pentti Kalliotiura, Ahmed Tariq, Kamil Khan (Master’s thesis workers)
- Thermal spray operators: Jarkko Lehti, Anssi Metsähonkala
Project examples:
2023-2027: Refurbishment and additive manufacturing accomplished by kinetic deposition, RE-MAKE, EU/HORIZON/MSCA-DN
2023-2025: Offshore Wind Turbine Farms, OFFwind, EU/Interreg/Aurora
2022-2025: Computationally aided systems engineering for marine advanced technology for the environment, CASEMATE, Business Finland
2020-2025: Sustainable Smart De-Icing by Surface Engineering of Acoustic Waves, SoundOfIce, EU/H2020/FET-OPEN
2019-2020: Cold spraying for harsh material repairs, MATINE, national funding
2018- Service research for companies
Research topics

Coating technologies
- New potential applications
- Functional coatings
- Additive manufacturing
- Repair and restoration
- Thermal spraying
- Cold spraying

Icing research
- Developing research area
- De-icing and anti-icing
- Icephobic coatings and surfaces
- New applications

- Future coating designs
- Sustainable coatings
- Application-related requirements
- Multifunctionality
- Energy and eco efficiency

Collaboration
Industry
Academy
National
International
Networks
Thermal spraying

- Wide range of coating and substrate materials: Metals, alloys, hardmetals, ceramics, plastics and composites
- High deposition rate
- Good coating properties

- Potential of thermally sprayed coatings
  - Large material selection
  - Industrial scale coating manufacturing process for large areas
  - Onsite spraying, manual and automatized processes

![Flame spraying of polymer powder](image1)

**Feedstock materials**
- Powders
- Wires
- Liquids

**Heat source**
- Flame
- Arc
- Kinetic

**Acceleration**
- Thermal energy
- Kinetic energy
- Combination

**Coating formation**
- Impacting
- Adhering
- Building-up

**Structure and surface modifications**

**Color tailoring by feedstock**
Thermal spraying

Key research areas
• Processing and manufacturing of coatings and surfaces by thermal spraying
• Material development and tailoring, novel coatings
• Requirements and performance

Thermal spraying
• Flame spraying, high velocity flame spraying (HVOF, HVAF) and plasma spraying
• Polymers, hardmetals, metals, ceramics and composites
• Functional coatings, corrosion and wear protection
• Coatings for harsh conditions (e.g., icing)

Latest publication:
Cold spraying

HPCS Al on Cu

LPCS - grit blasting

LPCS Cu on Al
Cold spraying

Key research areas
- Processing and manufacturing of coatings and surfaces by thermal spraying
- Multi-material solutions, additive manufacturing
- Requirements and performance

Cold spraying
- High-, medium- and low-pressure cold spray processes
- Laser-assisted cold spraying
- Metals and composites, polymers
- Dense and pure coatings, bulk material properties
- Corrosion, electrical conductivity, repair, AM

Latest publication:
Cold spray - Repair

Zn-based repair materials for LPCS

Needs for high performance surfaces

Functional coating on repaired component

Multifunctional cold spraying for repair

Low-pressure cold spray (LPCS) - Manual

High-pressure cold spray (HPCS) or HVAF - Robot

Defect → Repair → Functional coatings

Corrosion protection
* Metallic materials

Wear protection
* Hardmetals

Valve body (gray cast iron)
LPCS Zn+Al+Al₂O₃

Brake shoe (gray cast iron)
LPCS Zn+Cu+Al₂O₃

Tool holder (tempering steel)
LPCS Zn+Ni+Al₂O₃

Koivuluoto et al., International Thermal Spray Conference 2011, Hamburg, Germany

Koivuluoto et al. THERMEC’2023, Vienna, Austria

Heli Koivuluoto
Coating technologies at Tampere University
Multifunctional cold spraying for repair

HPCS Al
LPCS Zn-Al-Al$_2$O$_3$
Al substrate
HPCS dense and protective coatings

HPCS Aluminium Al6061

HPCS Aluminium Al2024

30bar, 300°C
30bar, 400°C
35bar, 400°C
40bar, 400°C

Koivuluoto et al., Coatings, 10 (4) 2020, 248

Koivuluoto et al., SCANDEM2022
Multifunctional repair (LPCS and HVAF)

- HVAF WC-CoCr
- LPCS Zn-Al-Al$_2$O$_3$

<table>
<thead>
<tr>
<th>Process step</th>
<th>Material</th>
<th>Hardness HV$_{0.3}$</th>
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<tbody>
<tr>
<td>Coating</td>
<td>HVAF WC-CoCr</td>
<td>1312±60</td>
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<tr>
<td>Repair</td>
<td>Zn-Al-Al$_2$O$_3$</td>
<td>80±6</td>
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<tr>
<td>Substrate</td>
<td>Stainless steel</td>
<td>260±8</td>
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</tbody>
</table>

Koivuluoto et al., THERMEC'2023, Vienna, Austria
HVAF WC-CoCr – Wear resistance

Cavitation erosion resistance

Dry erosion resistance

Slurry erosion resistance

V. Matikainen et al., Surface and Coatings Technology, 370, 2019, 196-212
Cold Spray – Additive Manufacturing

Cold spraying of thick aluminum

As-sprayed surfaces

Machined surfaces
Icing research

Key research areas

- Development of icephobic coatings
- Ice laboratory with icing wind tunnel and ice adhesion measurement devices
- De-icing and anti-icing
- Icing behavior of different materials and surfaces
- Application-related development work

Latest publication:

H. Koivuluoto et al., Thermally sprayed coatings: Novel surface engineering strategy towards icephobic solutions, Materials, 13(6) 2020, 1434

Photos: Jonne Renwall/TAU
ICE Laboratory

Icing wind tunnel (IWiT)

Icing parameters:
- Temperature: -40°C – RT
- Wind speed: 0 – 25 m/s
- Droplet size: 25 – 1000 µm
- LWC: 0 – 4.2 g/m³
- Iced area: 0.5 – 50 cm²
- Ice type: rime, mixed glaze, glaze

Development of de-icing:
Sustainable Smart De-Icing by Surface Engineering of Acoustic Waves,
EU/H2020/FETOPEN -project

Centrifugal ice adhesion test (CAT)

Pushing ice adhesion test
Conclusions

- Advanced coatings for harsh conditions
- Sustainable coatings
- Teamwork
- Collaboration
- New collaborators

- Future coating designs
- Novel applications
- Environmentally friendly solutions

- Thermal spraying
- Cold spraying
- Corrosion protection
- Wear protection
- Additive manufacturing
- Repair
- Anti-icing and de-icing coatings
- Functionality
Thank you for your attention!

More information:
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