Ultrafine Powder Feeding
In Thermal/Cold Spray Application

Alberta Innovates – Technology Futures | Edmonton, Alberta, Canada

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PRESENTATION AGENDA

• Polycontrols: A few words
• Our Powder feeder for Ultra Fine powders
• Example of coatings made of Very Fine Powders
  • Cold spray application (Cu, Ni, Al, AlSi, Zinc, WC-Co)
  • Suspension plasma spray (SPS)-like ZrO2-Y2O3 (YSZ) coatings without the need for suspensions.
• Conclusion
What we are doing in Thermal Spray

N2 & He Pressurization and storage

Gas conditioning, Distribution & Management

INTEGRATION + CALIBRATION

Calibration

Gas Recovery & Recycling

Automatic Switchover for TS Guns and System Integration

Powder Feeding
Powder feeder for Ultra Fine powders

- Based on vibration to fluidize the powder to a certain resonance frequency at which the flowability of the powder is amplified and the powder can be feed easy - Does not use a wheel type principle.

- Mechanism are integrated into the cartridge of the feeder, which operates at high pressure and have been designed for refill within a minute.

- Feed powders as small as 0.5μm reliably and uniformly (no pulsing or unstable rates)
Industrial Characteristics

• Meets all **North American Regulations** (ASME, CRN, NFPA, UL, CSA, ...); Hazardous classification (**Class 1, Div 2 & Class 2, Div 1**) and **EH&S** (Environmental Health & Safety) requirements

• **High feed ratio** (500 g/min +); **Easy to refill**, Real time feedback and diagnostic, **No clogging** (internal mechanism of the cartridge are coated)

• Design to fit with **third party equipment** (Oerlikon, Impact, Plasma Giken, Northwest Mettech, ...)

• **Patent** granted
**INNOVATION for Cold Spray & Thermal Spray processes**

- Example of powder feed with median particle size

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>Median Particle Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Plasma Giken</td>
<td>55 µm</td>
</tr>
<tr>
<td>Nickel</td>
<td>H.C. Starck Amperit</td>
<td>22 µm</td>
</tr>
<tr>
<td>Copper alloys</td>
<td>Custom powder</td>
<td>24 µm</td>
</tr>
<tr>
<td>Alum. alloys</td>
<td>Valimet Al-Si S10</td>
<td>23 µm</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Valimet H30 to H3</td>
<td>31 to 4,5 µm</td>
</tr>
<tr>
<td>Zinc</td>
<td>Alfa-Aesar</td>
<td>9 µm</td>
</tr>
<tr>
<td>WC-Co</td>
<td>Fujimi</td>
<td>6 µm</td>
</tr>
<tr>
<td>Ceramics (YSZ)</td>
<td>Inframat</td>
<td>&lt;1 µm</td>
</tr>
</tbody>
</table>

- Easily feedable

- More challenging to feed
Cold Sprayed COPPER

Giken Plasma Cu powder with a $d_{50}$ of 55 $\mu$m (partially spherical):
The result shows a $>99\%$ density, a good bonding and no sign of delamination.
Low melting point Cu alloy (Custom powder), with median particle size 24 µm: Could not be fed in a conventional volumetric powder feeder (Oerlikon/Impact, Plasma Giken). The powder clogged the volumetric powder feeder in the first few seconds of operation.

Low melting point Cu alloy coating produced via cold spray using our powder feeder.
Cold Sprayed Nickel

Nickel Powders flow easily, can be a challenge when trying to achieve very thin coatings. Dosing typically leads to:
• A very high deposition rate per pass
• Loss of material with low deposition rates
• A possible delamination of the coating

H.C. Starck Amperit powder with a $d_{50}$ of 22 μm (Spherical):
• The result shows a >99% density in the central part; The extremity of the coating shows a high porosity, which is normal in the case of Nickel (the peening effect is important for the densification of this type of coating)
• The result shows a good bonding between the sample and the coating and no sign of delamination
INNOVATION FOR COLD SPRAY PROCESS

Cold Sprayed **Aluminum Alloy (AlSi S10)**

Valimet AlSi S10 powder with a $d_{50}$ of 23 μm (Angular – Sharp edges):
- The result shows a **good bonding** between the sample and the coating, no sign of delamination and homogenous coating thickness compared to other powder feeders.
- **Existing powder feeders in operation for repairs approved by the FAA**

This powder is hard to feed with conventional feeders:
- Typically the sprayed powder has an uneven particle concentration leading to a higher variation in deposition rate per pass compared to other powders such as Ni or Cu.
Valimet Al H30 powder with a $d_{50}$ of 31 μm (Spherical):

- The result shows a **dense coating** and a **low variation in coating thickness**
- Preliminary results show a **smoother surface finish** than other powder feeders and an absence of craters (potential savings of material/post processing)
Cold Sprayed **CP Aluminum (Al-H15)**

- Aluminum powders are generally difficult to feed. Their ability to flow decreases with the average particle size.
- All results shown for CP AL (H30, H15 & H3) have been done with powders ‘as supplied’ by the manufacturer (only dried – no pre-treatment to improve the deposition efficiency and the quality of the coatings have not been used to test the feeder.

Valimet Al H15 powder with a $d_{50}$ of 20 μm (Spherical):
- The result shows an even **lower variation in coating thickness** and a **more stable flow** compared to other powder feeders.
INNOVATION FOR COLD SPRAY PROCESS

Cold Sprayed **CP Aluminum (Al-H3)**

**CP-Aluminum (Valimet H-3),** with median particle size 4.5 µm: Could not be fed in a conventional volumetric powder feeder (Oerlikon/Impact, Plasma Giken) nor in the Inovati powder feeder. The powder clogged the powder feeders in the first few seconds of operation.

**Thin CP-Aluminum coating** produced via cold spray using our powder feeder and Plasma Giken gun.
INNOVATION FOR COLD SPRAY PROCESS

Figure 1  **Zinc powder (Alfa-Aesar)** with median particle size of 9 µm: Could not be fed in a conventional volumetric powder feeder (Oerlikon/Impact). The powder does not flow through the wheel.

Figure 2  **Zinc coating** produced via cold spray using our powder feeder.
INNOVATION FOR COLD SPRAY PROCESS

Figure 3  **WC-Co** (Fujimi powder #DTS-W752-7/2), with median particle size 6µm: Could not be fed in a conventional volumetric powder feeder (Plasma Giken, Oerlikon, Impact). The powder does not flow in the feeder.

Figure 4  **Coating produced with the WC-Co powder** using our powder feeder and Plasma Giken gun
Plasma Sprayed ZrO2-Y2O3 (YSZ) powder **without resorting to suspensions**

- This powder cannot be fed using a conventional feeder.
- This powder is typically sprayed by suspending its particles in a slurry and deposited via suspension plasma spray (SPS).
- Typical application for this type of coating: thermal barrier coatings (TBCs) for aerospace and energy production turbine engines.

Inframet 4039R-8601 as received from supplier – No suspension. This powder exhibits a d50 of ~1 μm.
HVOF AND PLASMA INNOVATION

- ZrO2-Y2O3 (YSZ) coating <1μm particle size, produced with plasma spray (Axial III torch) using our powder feeder
- Coating exhibits columnar growth, just like SPS YSZ coatings
INNOVATION FOR THERMAL SPRAY (HVOF, plasma)

Increased Deposition Rate

The deposition rate per pass of an YSZ suspension depends on the spray parameters used, as well as, the amount of the YSZ powder in the slurry.

Based on preliminary results, our depositions are approximately:

- 5 X more material / pass, compared to a 5wt%YSZ suspension.
- 2 X more material / pass, compared to a 25wt%YSZ suspension.
- 60% more material / pass, compared to a traditional suspension spray.
Avenues for future development

Cold Spray process

Document and quantify the observations relating to:
• The improvement of the surface finish
• The uniformity and reproducibility of the coating thickness produced

Complete data collection on the lower and upper feeding limits for some powders.

Thermal Spray process

Continue testing and data collection of SPS-like YSZ TBC coating produced without using suspensions up to a point that we have sufficient data to establish a reliable statistical reference population for:
• Different powders
• Internal & axial powder feeding application
• External & radial powder feeding application

Modify the feeder packaging to remove non-required features for SPS-like applications in order reduce the feeder cost (decrease maximum pressure of operation, optional hazardous classification, ...
CONCLUSION

Benefits for Thermal Spray applications

The projection powder of submicron size (up to 0.5 micron) without resorting to suspensions would enables productivity gains as the preparation of suspension by traditional method to require extensive time, much more control parameters and clogging problem are very common.

In addition, the innovation allows bypassing the buoyancy problems of some powders and reduces the production costs of protective or functional coatings by increasing the deposition rate of these powders to values traditionally obtained with plasma spray.
CONCLUSION

Commercial applications for Cold Spray process

• Use of this fine powder feeder would open the door to different applications requiring thinner coatings than those currently carried out by cold spraying. This would include increasing the number of applications in aerospace and energy sectors but also in other industries such as electronics, automotive & photovoltaics.

• Existing application approved by the FAA for critical components repair for aircraft engines

• Meets all North American regulations
ACKNOWLEDGMENTS

Technical and support staff from NRC-Boucherville
Financial support from NRC-IRAP (Industrial Research Assistance Program)

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NRC/Polycontrols - Suspension feeder for submicron powders